Four Year Undergraduate Course in Physics
Semester - I
Paper Name: Mathematical Physics & Mechanics
Paper Code= PHY010104
Total number of lectures= 45
Total credits = 4 (Theory 3 +Laboratory 1) (Total Marks Internal-25+External-75)

Part A
Mathematical Physics (Theory)
Credit = 1

Course outcome: *This course introduces vector calculus, curvilinear coordinates and Dirac delta function. On successful completion of the course, students will be able to understand how to compute in the calculus of vectors which plays a central role in laws of physics. They will be able to apply vector calculus in curved spaces which play major role in relativity. They will also be able to learn the powerful method of computation through Dirac delta function which often appears in complex problems of physics. In general, the students will be able to apply the mathematical methods on the problems of physics and engineering.*

Unit - I: Vector calculus (Lectures - 8)

Scalar and vector fields. Derivatives of vector functions (physical examples - velocity, centripetal acceleration of a point in circular motion). Directional derivative. Gradient of a scalar field (example of Newton's gravitational force as gradient of a scalar potential). Gradient as normal vector to a surface. Divergence and curl of a vector field- solenoidal and irrotational vector fields. Laplacian operator (physical problems –Laplacian of gravitational potential, divergence of central force). Vector identities.

Vector integration- Line integral (physical example- work done by a force, path dependence/independence and concept of conservative force). Surface and volume integrals. Concept of vector flux. Gauss's divergence theorem and Stokes's theorem (statement only)

Unit - II: Curvilinear coordinates (Lectures - 5)

Introduction to curvilinear coordinates. Orthogonal curvilinear coordinates. Examples of spherical, cylindrical and plane polar coordinates. Line element- transformation from Cartesian to curvilinear coordinates (spherical and cylindrical). Gradient, divergence and curl in spherical and cylindrical coordinates.

Unit - III: Dirac delta function (Lectures - 2)

Definition and properties of Dirac delta function. Representation of delta function by Gaussian function, rectangular function and Laplacian of 1/r . 3 Dimensional delta function.

Part B

Mechanics (Theory)

Credits = 2

Course outcome: *On successful completion of this course students should be able understand inertial and non-inertial reference frames, Newtonian motion, projectile motion, work and energy, elastic and inelastic collisions, motion under central force, simple harmonic oscillations. They will be able to apply foundational principles of physics in higher studies of physics, technology and engineering.*

Unit – I: Reference frames (Lectures - 4)

Inertial frames. Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications.

Unit – II: Gravitation and central force motion (Lectures - 7)

Motion under central force. Two-body problem and its reduction to one body problem. Kepler's laws, Gravitational potential and fields due to spherical body. Gauss's law and Poisson's equation for gravitational field.

Unit – III: Conservation laws (Lectures - 4)

Dynamics of a system of particles. Centre of mass. Principle of conservation of momentum. Torque. Impulse.

Elastic and inelastic collisions between particles. Centre of mass and laboratory frames.

Unit – IV: Dynamics of rigid bodies (Lectures - 6)

Rigid body motion. Rotational motion. Moment of inertia of rectangular lamina, disc, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.

Unit – V: Work and energy (Lectures - 3)

Work and kinetic energy theorem. Conservative and non-conservative forces. Potential energy. Force as gradient of potential energy. Work and potential energy. Work done by non-conservative forces.

Unit – VI: Oscillations (Lectures - 2)

Oscillation - differential equation of simple harmonic motion and its solution. Total energy of oscillation.

Unit – VII: Properties of matter (Lectures - 4)

Relation between elastic constants. Twisting torque on a cylinder or wire. Beam bending moment, Cantilever. Kinematics of moving fluids: Poiseuille's equation for flow of a liquid through a capillary tube.

Part C
Laboratory
Credit =1

Course outcome: *After the successful completion of this course, students will be able to determine various physical quantities of mechanics that will help them understand important principles related to the subject.*

The students are required to perform at least four experiments from the following list of experiments.

1. Measurements of length (or diameter) using Vernier calliper, screw gauge, spherometer and travelling microscope
2. To study the motion of spring and calculate (a) spring constant and (b) rigidity modulus.
3. To determine the moment of inertia of a cylinder about two different axes of symmetry by torsional oscillation method.
4. To determine coefficient of viscosity of water by capillary flow method (Poiseuille's method).
5. To determine the Young's modulus of the material of a wire by Searle's apparatus.
6. To determine the modulus of rigidity of a wire (static method).
7. To determine the value of g using bar pendulum.
8. To determine the value of g using Kater's pendulum.
9. To determine the height of a building using a sextant.
10. To determine g and velocity for a freely falling body using digital timing technique.

Reference books:

[1] Essential Mathematical Methods for the Physical Sciences; K.F. Riley and M.P. Hobson, Cambridge University Press.

[2] Advanced Engineering Mathematics; E. Kreyszic, John Wiley & Sons (New York).

[3] Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier.

[4] Mathematical Physics-I, K. K Pathak and S. Parasher, Vishal Publication, Jalandhar (Delhi).

[5] Theoretical Mechanics, M. R. Spiegel, Tata McGraw Hill.

[6] Mechanics; D. S. Mathur, S. Chand & Company Limited.

[7] An Introduction to Mechanics, D. Kleppner and R. J. Kolenkow, Tata McGraw-Hill.

[8] Mechanics, Berkeley Physics, vol.1, C. Kittel, W. Knight, et.al., Tata McGraw-Hill.

[9] Physics, R. Resnick, D. Halliday and J. Walker, John Wiley & Sons.

[10] Analytical Mechanics, G. R. Fowles and G. L. Cassiday, Cengage Learning.

[11] Feynman Lectures, Vol. I, R. P. Feynman, R. B. Leighton and M. Sands, Pearson Education. University Physics, F. W. Sears, M. W. Zemansky and H.D Young, Addison Wesley.

[12] Physics for Scientists and Engineers with Modern Phys., J. W. Jewett and R. A. Serway, Cengage Learning.
[13] Mechanics, D. Sarma and K. K Pathak, Vishal Publications, Jalandhar (Delhi).

Four Year Undergraduate Course in Physics
Semester - II
Paper Name: Mathematical Physics & Electricity and Magnetism
Paper Code: PHY020104
Total number of lectures= 45
Total credits = 4 (Theory 3 +Laboratory 1) (Total Marks 100: Internal-25+External-75)

Course objectives:

- *To introduce the methods of solving differential equations.*
- *To introduce various concepts of matrix algebra.*
- *Electric field from vector calculus point of view and use of potential formulation to solve electrostatic problems.*
- *Magnetic fields of current carrying conductors, torus, solenoids etc. Study magnetic properties of matter.*
- *Study and analysis of AC circuits like LCR, and use of network theorems in electrical circuits.*

Course outcome:

After the successful completion of the course, students will be able to understand methods of solving various differential equations appearing in physics. It will give an idea of how to study evolution of a physical system. Through matrix algebra students will be able to compute various matrix operations which are required for solving physical problems. They will be able to understand electric field and magnetic fields in matter, dielectric properties of matter, magnetic properties of matter, application of Kirchhoff's law in different circuits, and application of network theorem in different circuits. The students will also get accustomed to using multimeters and potentiometers, and they will be able to determine some of the important physical quantities related to electricity and magnetism for a better understanding of the topic.

Part A
Mathematical Physics (Theory)
Credit = 1

Unit - I: Differential equations (Lectures - 10)

First and second order ordinary differential equations (ODE). Homogeneous and inhomogeneous differential equations. Solutions of first order ODE – integrating factors (physical examples – radioactive decay, Newton's law of cooling, particle falling under gravity through a resistive medium). Concept of initial/boundary conditions. Solutions of second order ODE with constant coefficients - complementary function and particular integral (physical examples- simple harmonic oscillation, forced vibration). Wronskian- definition and its use to check linear independence of 2^{nd} order homogeneous linear differential equation.

Partial differential equations (PDE) (physical examples – wave equation, diffusion equation, Laplace and Poisson equation – introduction only). Exact and inexact differentials. Concept of variable separation in a PDE.

Unit - II: Matrices (Lectures - 5)

Properties of matrices. Determinant and rank. Transpose and complex conjugate of matrices. Hermitian and anti-Hermitian matrices. Unitary and orthogonal matrices. Representation of linear homogeneous and inhomogeneous equations through matrix equation. Inverse of a matrix. Eigen values and eigen-vectors. Cayley-Hamilton Theorem (statement only), Diagonalisation of simple matrices.

Part B
Electricity and Magnetism (Theory)
Credit = 2

Unit - I: Electric field and electric potential (Lectures - 13)

Electrostatic field, electric flux. Gauss's law. Application of Gauss's law to charge distributions with planar, spherical and cylindrical symmetries. Conservative nature of electrostatic field. Electrostatic potential. Electrostatic energy of a system of charges. Electrostatic boundary conditions. Laplace's and Poisson's equations. Uniqueness theorem. Application of Laplace's equation involving planar, spherical and cylindrical symmetries. Potential and electric field of a dipole. Force and torque on a dipole. Capacitance of a system of charged conductors. Parallel plate capacitor. Capacitance on an isolated conductor.

Unit - II: Dielectric properties of matter (Lectures - 4)

Electric field in matter. Polarisation, polarisation charges. Electrical susceptibility and dielectric constant. Capacitor (parallel plate, spherical and cylindrical) filled with dielectric. Displacement vector, $\vec{D}$. Relation between $\vec{E}$, $\vec{P}$ and $\vec{D}$. Gauss's law in dielectrics.

Unit - III: Magnetic field (Lectures - 6)

Magnetic force on a point charge, definition and properties of magnetic field $\vec{B}$. Curl and divergence. Vector potential, $\vec{A}$. Magnetic scaler potential. Magnetic force on (i) a current carrying wire and (ii) between two elements. Torque on a current loop in a uniform magnetic field. Biot-Savart's law and its simple application: straight wire and circular loop. Current loop as a magnetic dipole and its dipole moment (analogy with electric dipole). Ampere's circuital law and its application to (i) solenoid and (ii) torus.

Unit - IV: Magnetic properties of matter (Lectures - 2)

Magnetization vector, $\vec{M}$. Magnetic intensity, $\vec{H}$. Magnetic susceptibility and permeability. Relation between $\vec{B}$, $\vec{H}$ and $\vec{M}$. Ferromagnetism. B-H curve and hysteresis.

Unit - V: Electrical circuits (Lectures - 5)

AC circuits: Kirchhoff's laws for AC circuits. Complex reactance and inductance. Series LCR circuits and parallel LCR circuits: (i) phasor diagram, (ii) resonance, (iii) power dissipation, (iv) quality factor, and (v) band width. Ideal constant-voltage and constant-current sources. Thevenin theorem and Norton theorem (only statements and solving of related problems).

Part C
Laboratory
Credit = 1

The students are required to perform at least four experiments from the following list.

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2. To study the characteristics of a series RC circuit.
3. To determine an unknown Low Resistance using Potentiometer.
4. To determine an unknown Low Resistance using Carey Foster's Bridge.
5. To compare capacitances using De' Sauty's bridge.
6. Measurement of field strength $\vec{B}$ and its variation in a solenoid (determine $\frac{dB}{dx}$).
7. To verify the Thevenin and Norton Theorems.
8. To verify the superposition and maximum power transfer theorems.
9. To determine the self-inductance of a coil by Anderson's bridge.
10. To study the response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti- resonant frequency and (b) Quality factor Q.
12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
13. Determine a high resistance by leakage method using Ballistic Galvanometer.
14. To determine the self-inductance of a coil by Rayleigh's method.
15. To determine the mutual inductance of two coils by the Absolute method.

Reference books:

[1] Essential Mathematical Methods for the Physical Sciences; K. F. Riley and M. P. Hobson, Cambridge University Press.

[2] Advanced Engineering Mathematics; E. Kreyszic, John Wiley & Sons (New York)

[3] Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier

[4] Mathematical Physics, H. K. Dass and Dr. Rama Verma, S. Chand Publication.

[5] Mathematical Physics-I; Krishna K. Pathak and Sangeeta Prasher, Vishal Publishing Co, Jalalandhar (Delhi).

[6] Introduction to Electrodynamics, D. J. Griffiths.

[7] Electricity and Magnetism [With electromagnetic theory and special theory of relativity], D. Chattopadhyay and P. C. Rakshit, 2013, New Central Book Agency (P) Limited.

[8] Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and S. R. Choudhury, 2012, Tata Mcgraw.

[9] Schaum's outline of Theory and Problems of Electromagnetics, J. A. Edminister.

[10] Electromagnetics, B. B. Laud, New Age International Publishers.

[11] Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.

[12] Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education.

[13] Elements of Electromagnetics, M. N. O. Sadiku, 2008. Pearson Education.

[14] Electricity and Magnetism, J. W. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.

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Four Year Undergraduate Course in Physics

Semester III

Paper Name: Wave and Optics

Paper Code: PHY030104

Total Number of Lectures = 45, Total Credits = 4

(Total Marks 100: Internal-25+External-75)

Course Objective:

- To learn the superposition of harmonic waves and oscillations, different types of wave motions, formation of standing waves and velocity of waves in media.
- To learn optical phenomena such as interference, diffraction and polarization in terms of the wave model
- To learn the principles and applications of optical instruments like biprism, interferometer and diffraction grating etc.
- To learn hand on experiments with prism, biprism, spectrometer, Newton's ring apparatus, grating, CRO, sodium and mercury light sources etc.

Course learning outcomes:

On successful completion of the course students will:

1. understand Simple Harmonic Oscillation and superposition principle.
2. understand the classical wave equation in transvers and longitudinal waves and solutions of few physical systems on its basis.
3. understand the concept of normal modes in transvers and longitudinal waves
4. understand the interference as superposition of waves from coherent sources and also understand the basic principle of Young's double slit experiment, Fresnel's Biprism, Newton's Rings, Michelson interferometer etc.
5. understand the basic concept of diffraction, Fresnel and Fraunhofer diffraction from a slit.
6. understand the concept of polarisation of light, the production and detection of polarized light.
7. understand working principle of prism, biprism, spectrometer, Newton's ring apparatus, grating, CRO, sodium and mercury light sources etc.

Wave and Optics (Theory)

Total Credits = 3

Unit I: Superposition of harmonic oscillations (Lectures 04)

Superposition of waves: Linearity and Superposition principle, Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats), Lissajous figures and their use.

Unit II: Wave motion (Lectures 04)

Waves: Progressive (Travelling) Waves, wave equation, plane wave and spherical wave, Longitudinal and Transverse Waves, dispersion, group velocity, phase velocity, Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave.

Unit III: Velocity of waves (Lectures 04)

Velocity of Waves: Velocity of Transverse Vibrations of Stretched Strings. Velocity of Longitudinal Waves in a Fluid in a Pipe. Newton's Formula for Velocity of Sound. Laplace's Correction.

Unit IV: Superposition of two harmonic waves (Lectures 09)

Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes.

Unit V: Wave optics (Lectures 04)

Wave optics: Electromagnetic nature of light, definition and properties of wave front. Huygens principle. Temporal and Spatial coherence.

Unit VI: Interference (Lectures 08)

Division of wavefront and amplitude, intensity distribution in an interference pattern, Young's double slit experiment, Fresnel's Biprism. Phase change on reflection: Stokes' treatment, Interference in Thin Films: parallel and wedge-shaped films, Newton's Rings: Measurement of wavelength and refractive index, Michelson interferometer.

Unit VII: Diffraction (Lectures 07)

Fresnel and Fraunhofer diffraction. Fresnel's Half-Period Zones for Plane Wave. Fresnel diffraction pattern of a straight edge and at a circular aperture. Fraunhofer diffraction: Single slit. Double slit. Diffraction grating. Resolving power of grating.

Unit VII: Polarization: (Lectures 05)

Polarized light and its mathematical representation, Production of polarized light by reflection, refraction and scattering. Polarization by double refraction and Huygen's theory, Nicol prism, Production and analysis of circularly and elliptically polarized light.

Wave and Optics (Practical)

Total Credits = 1

A minimum of four experiments to be done.

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2-T law.
2. Study of Lissajous Figure of two different waves using CRO and find out the unknown frequency of an electrical signal.
3. Familiarization with: Schuster's focusing, determination of angle of prism.
4. To determine refractive index of the Material of a prism using sodium source.
5. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
6. To determine wavelength of sodium light using Fresnel Biprism.
7. To determine wavelength of sodium light using Newton's Rings.
8. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
9. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
10. To determine dispersive power and resolving power of a plane diffraction grating.

Reference Books

[1] Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.

[2] The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

[3] Vibrations and Waves in Physics, 2nd edition, I. G. Main, 1984, Cambridge University Press.

[4] A Textbook of Sound, 3rd Edition, A. B. Wood, 1955, Bell & Sons.
[5] The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
[6] Fundamentals of Optics, F. A. Jenkins and H.E. White, 1981, McGraw-Hill
[7] Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
[8] Optics, Ajoy Ghatak, 2008, Tata McGraw Hill
[9] Principles of Optics, B. K. Mathur and T. P. Pandya, 1981, Tata McGraw-Hill International.
[10] Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.

Four Year Undergraduate Course
Subject: Physics
Semester-IV
Paper: Classical Mechanics
Paper Code PHY040104
Total Lectures: 60 (45 Theory; 15 tutorials) (Total Marks 100: Internal-40+External-60)

Credits: 4 (Theory -03; Tutorial – 01)

Course objectives: *The basic objectives of the course are*

- *to introduce the laws of classical dynamics*
- *to train students in solving problems of motion of particles, systems of particles and fluids and*
- *to introduce relativity and hence the idea of how space and time play role in dynamics of matter.*

Course outcome: *On successful completion of the course students will be able to apply the laws of classical dynamics to physical problems of motion of particles, systems of particles and fluids in various fields of physics and natural science as a whole. They will also get the exposure of the idea of how space and time play role in dynamics of matter.*

Unit –I: Mechanics of point particles-the Lagrangian approach

(Lectures 14)

Review of Newtonian mechanics; system of particles; constrained motion – types of constraints; concept of degrees of freedom; generalised coordinates and velocities; principle of virtual work and D'Alembert's principle and associated problems; Lagrange's (Euler-Lagrange, EL) equation; physical problems (construction of EL equations only) – simple and compound pendulums, two vibrating particles of equal mass attached to springs, Lagrange's equations for a particle in spherical and cylindrical coordinate systems, falling body in uniform gravitational field.

Unit-II: Mechanics of point particles – the Hamiltonian approach

(Lectures 06)

Generalised momenta; Legendre transformation; Hamilton's canonical equations; Hamiltonian from the Lagrangian; conservation of energy and momentum; physical problems – Hamiltonian for simple pendulum, particle moving in central force field (gravitational potential).

Unit – III: Small oscillation (Lectures 05)

Minimum of potential energy and concept of stable equilibrium; expansion of potential energy around a minimum; kinetic and potential energy matrices; equation of motion of small oscillation.

Unit-IV: Special theory of relativity (Lectures 15)

Inadequacy of Galilean transformation; postulates of special relativity; Lorentz transformation; simultaneity and order of events; length contraction and time dilation; relativistic addition of velocities; variation of mass with velocity and mass-energy equivalence. Lorentz transformation as a rotation in spacetime; relation between proper time and coordinate time; relativistic kinematics:energy-momentum relation.

Unit- V: Fluid dynamics (Lectures 05)

Definition of a fluid; idea fluids; density and pressure of a fluid; velocity of a fluid element and its time derivative; mass conservation and equation of continuity; incompressible fluid; Euler's equation of fluid dynamics; Navier-Stokes equation (introduction only).

Suggested text books:

(1) Classical Mechanics, H. Goldstein, C.P. Poole and J.L. Safko (Pearson Education)
(2) Theoretical Mechanics, M. R. Spiegel (McGraw Hill Book Company)
(3) Classical Mechanics, P.S. Joag and N.C Rana (McGraw Hill Book Company)
(4) Mathematical Physics, B. S. Rajput (Pragati Prakashan)

Suggested reference books:

(1) Classical Mechanics, T.W.B. Kibble and F.H. Berkshire (Imperial College Press)
(2) Mechanics: Courses in Theoretical Physics (Vol. 1), L.D. Landau and E.M. Lifshitz (Butterworth-Heinemann) (3rd Edn.)
(3) Classical Mechanics: With introduction to non-linear oscillations and chaos, V.B. Bhatia (Narosa Publishing House)

Four Year Undergraduate Course in Physics
Semester IV
Paper Name - Quantum mechanics I
Paper Code - PHY040204
Total Lectures: 45, Credits: 4 (Theory: 03, Lab: 01)
(Total Marks 100: Internal 25+External-75)

Course Objectives

- To learn about the inadequacies of classical mechanics, the origin and need of quantum mechanics, historical developments in quantum mechanics.
- Dual nature of radiation & matter, description of matter wave through wave packet.
- Probabilistic nature and wave function, Schrödinger equation, the uncertainty principle, stationary and non-stationary states.
- Applications of Schrödinger equation in different cases like infinite and finite potential well, tunneling effect, linear harmonic oscillator and H-atom.
- Formulation of quantum mechanics in terms of operators.

Course Outcome: On successful completion of the course students will be able to learn physical and mathematical fundamentals of Quantum physics, and various topics in it. These concepts are used in various branches of physics, like condensed matter physics, lasers, quantum statistics, atomic and molecular physics, particle physics, astrophysics and optics etc.

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Theory :

Unit I : Origin of Quantum Theory (Lectures= 3)

Failure of classical theories, Explanation of Black body radiation, Photoelectric effect, Compton effect, different evidences in support of quantum theory, particle nature of radiation, Bohr's correspondence principle.

Unit II: Dynamical Variables as Operators and Uncertainty Principle (Lectures=10)

Dynamical variables as operators, definition of an operator, different types of operators and their properties, position, energy and momentum operator; commutation relations; introduction to Hilbert space, Dirac notation, eigenvalue and eigenfunctions; expectation value of an operator e.g. position, momentum operator etc, orthonormality condition, Ehrenfest's theorem.

Simultaneous measurement and uncertainty principle; general statement of Heisenberg's uncertainty principle(for any two non commutating operators), different uncertainty relations involving canonical pair of variables; particle trajectory and fuzziness, applications of the position momentum uncertainty principle, application of energy time uncertainty principle to virtual particles and range of an interaction.

Unit III : Matter Wave and Wave-Particle Duality (Lectures = 8)
Wave particle duality and de Broglie wavelength, particle as a wave or matter wave, wave description of particles by wave packets; phase and group velocity, wave function, wave amplitude, probability; Experimental verification of matter wave, Davisson and Germer experiment; linearity and superposition principle, two slit experiments with electrons and photons; Uncertainty principle from wave packet description, Gaussian wave packet and its wave function.

Unit IV : Schrödinger Equation and it's applications (Lectures =24)
Time dependent Schrödinger Equation, Time independent Schrödinger Equation; Physical interpretation and properties of wave function, continuity of a wave function, boundary conditions and emergence of discrete and continuous energy levels; probabilities and normalisation in three and one dimension; equation of continuity, current density in both three and one dimension.

Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wave function as a linear combination of energy eigenfunctions; General solution of the time dependent Schrödinger equation in terms of linear combinations of stationary states, discrete and continuous spectrum, wave function of a free particle, spread of Gaussian wave function in one dimension, Fourier transforms and momentum space wave function.

Applications of Time independent Schrödinger Equation in different problems like : (i) particle in a one dimensional infinite potential well (quantum dot as an example) (ii) particle in a one dimensional finite square potential well (iii) barrier penetration problems – potential step and rectangular potential barrier (tunnel effect) (iv) linear harmonic oscillator (v) spherically symmetric potential for hydrogen atom- radial solution, spherical harmonics, angular momentum operator and different quantum numbers, radial distribution function and shapes of the probability densities for ground & first excited states; degeneracy of states : s, p, d states.

Laboratory :

***A minimum of four experiments to be done*.**

1. Measurement of Planck's constant using black body radiation and photo-detector.
2. Photo-electric effect : Photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
3. To determine work function of material of filament of directly heated vacuum diode.
4. To determine the Planck's constant using LEDs of at least 4 different colours.
5. To determine the wavelength of H_α emission line of hydrogen atom.
6. To determine the ionisation potential of mercury.
7. To determine the absorption lines in the rotational spectrum of iodine vapour.
8. To determine the value of e/m by (a) magnetic focusing or (b) bar magnet.
9. To setup the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunnelling effect in tunnel diode using I-V characteristics.
11. To determine the wavelength of laser source using diffraction from single slit.

12. To determine the wavelength of laser source using diffraction from double slits.
13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating.

Suggested Books

1. N. Zettili, Quantum Mechanics, John Wiley & Sons (2001).
2. J. J. Sakurai and J. Napolitano, Modern Quantum Mechanics, Cambridge Univ. Press, 2020.
3. Y. R.Waghmare, Fundamentals of Quantum Mechanics, Wheeler publishing (2014).
4. P. A. M. Dirac, Principles of Quantum Mechanics, Oxford University Press (1981).
5. B. H. Bransden and C. J. Joachain, Quantum Mechanics, Pearson Education 2nd Ed. (2004).
6. K. Gottfried and T-M Yan, Quantum Mechanics: Fundamentals,2nd Ed., Springer (2003).
7. R. Shankar, Principles of Quantum Mechanics, Springer (India) (2008).
8. D. J. Griffiths, Introduction to Quantum Mechanics, Pearson Education (2005).
9. L. Schiff, Quantum Mechanics, Mcgraw-Hill (1968).
10. A. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2002).
11. A. Bieser, Concepts of Modern Physics, McGraw Hill (2002).
12. Arno Bohm, Quantum Mechanics : Foundations and Applications, 3rd Edition, Springer (1993).
13. H. C. Verma, Quantum Mechanics, TBS publications (2019).
14. P. M Mathews and K. Venkatesan, A Text book of Quantum Mechanics, 2nd Edition, McGraw Hill, (2010).

Analog Electronics

(Semester IV)

Credits 4: (Theory: 3 + Practical: 1) **PHY040304**
(Total Marks 100: Internal-25+External-75)

Total Lectures: 45

Course Objectives:

- To introduce students to analog electronics with hands-on practice on implementing some of these in hardware.
- To make the students understand the physics of semiconductor p-n junction and application in devices like diodes, rectifiers, etc.
- To understand the working of bipolar junction transistors, biasing, stabilization circuits, and various applications like amplifiers, oscillators, etc. together with feedback.
- To know the basics of Operational Amplifiers and applications.
- To understand the basics of the use of CRO in measurements with hands-on experience with some applications.

Course Outcome: On successful completion of the course, students will be able to understand the physics of semiconductor p-n junction and devices such as rectifier diodes, zener diode, photodiode, etc.; they will understand the basics of bipolar junction transistors, transistor biasing, and stabilization circuits; the concept of feedback in amplifiers and the oscillator circuits. Students will also have an understanding of operational amplifiers and their applications.

Unit I: Semiconductor Diodes (Lectures 07)

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width, and Current for Step Junction.

Unit II: Two-terminal Devices and their Applications (Lectures 05)

Rectifier Diode: Half- wave Rectifiers. Centre-tapped and Bridge type Full-wave Rectifiers. Calculation of Ripple Factor and Rectification Efficiency. C-filter. Zener Diode and Voltage

Regulation. Power supply without filter circuit and with C-filter circuit. Principle LEDs, Photodiode, and Solar Cell (Basic concept).

Unit III: Bipolar Junction Transistors (Lectures 05)

n-p-n and p-n-p Transistors. Characteristics of CB, CE, and CC Configurations. Current gains α and β. Relations between α and β. Load line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff, and Saturation Regions.

Unit IV: Amplifiers (Lectures 07)

Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as a 2-port Network. h-parameter. Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage, and Power Gains. Classification of Class A, B & C Amplifiers. Differential amplifiers.

Unit V: Coupled Amplifier (Lectures 02)

Two-stage RC-coupled amplifier and its frequency response.

Unit VI: Feedback in Amplifiers (Lectures 04)

Effects of Positive and Negative Feedback on Input Impedance. Output Impedance. Gain. Stability. Distortion and Noise.

Unit VII: Sinusoidal Oscillators (Lectures 05)

Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator. Determination of Frequency. Colpitt's oscillator.

Unit VIII: Operational Amplifiers (Black Box approach) (Lectures 03)

Characteristics of an Ideal and Practical Op-Amp (IC 741). Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and Concept of Virtual Ground.

Unit IX: Applications of Op-Amps (Lectures 04)

Inverting and non-inverting amplifiers. Adder. Subtractor. Differentiator. Integrator. Log and Anti Log amplifier. Zero crossing detector. Wein bridge oscillator. Comparator.

Unit X: Introduction to CRO (Lectures 03)

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.

Laboratory

A minimum of four experiments are to be done.

1. To study V-I characteristics of PN junction diode, and light emitting diode.
2. To study the V-I characteristics of a Zener diode and its use as a voltage regulator.
3. Study of V-I and power curves of solar cells, and find maximum power point and efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. To study the various biasing configurations of BJT for normal Class A operation.
6. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
7. To study the frequency response of voltage gain of an RC-coupled transistor amplifier.
8. Using an Op-amp, design a Wien bridge oscillator for a given frequency.
9. To design a phase shift oscillator of given specifications using BJT.
10. To design and study Colpitt's oscillator.
11. To design an inverting amplifier using Op-amp for the DC voltage of a given gain.
12. To design inverting amplifier using Op-amp and study its frequency response.
13. To design a non-inverting amplifier using Op-amp and study its frequency response.
14. To study the zero-crossing detector and comparator.
15. To add two DC voltages using Op-amp in inverting and non-inverting modes.
16. To design a precision Differential amplifier of given I/O specification using Op-amp.
17. To investigate the use of an Op-amp as an Integrator.
18. To investigate the use of an Op-amp as a Differentiator.
19. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO. Construct a series LR circuit. Display the two waveforms on the CRO and measure the phase differences between the voltages across R and L.
20. To test a Diode and Transistor using a Multimeter. Draw the forward bias characteristic of the diode. Using only the base-emitter junction of the transistor draw a characteristic curve and show that it behaves as a forward-biased diode.

Note: All students will have to do an electronic project on the circuits, for example, the power supply, the AM detector, etc. to get acquainted.

Suggested Books

1. Integrated Electronics, J. Millman and C. C. Halkias, 1991, Tata Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall.
3. Solid State Electronic Devices, B. G. Streetman & S. K. Banerjee, 6th Edn.,2009, PHI Learning
4. Electronic Devices & circuits, S. Salivahanan & N. S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
5. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
6. Microelectronic circuits, A. S. Sedra, K.C. Smith, A. N. Chandorkar, 2014, 6th Edn., Oxford University Press.
7. Electronic circuits: Handbook of design & applications, U. Tietze, C. Schenk,2008, Springer
8. Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd Ed., 2002, Wiley India
9. Microelectronic Circuits, M. H. Rashid, 2nd Edition, Cengage Learning
10. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India
11. Electronics Fundamentals and Applications, D. Chattopadhyay and P. C. Rakshit, 17th Ed, 2023, New Age International Publishers

Four Year Undergraduate Course in Physics
Semester - IV
Paper Name: Mathematical Physics
Paper Code= PHY040404
Total number of lectures= 45
Total credits = 4 (Theory 3 +Laboratory 1) (Total Marks 100: Internal-25+External-75)

Course Objective:

- To solve partial differential equations using separation of variables, including Laplace's equation and the wave equation.
- To apply Fourier series expansion to represent periodic functions using sine and cosine functions.
- To understand complex analysis principles, including analytic functions, integration and residue theorem.
- To develop proficiency in tensor algebra, covering transformations, contravariant and covariant tensors and tensor algebra.
- To gain a preliminary knowledge to probability theory, focusing on independent random variables, probability distributions, and mean and variance calculations.

Course outcome: On successful completion of the course, the students will be equipped with the techniques related to solving partial differential equations using separation of variables method, application of Fourier series analysis, solving complex integrations, dealing with tensors and probability distributions which are relevant while dealing with wave mechanics, electrodynamics, quantum mechanics, theory of relativity and experimental physics.

Theory

Unit I: Partial Differential Equations ***(Lectures 10)***

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

Unit II: Fourier Series ***(Lectures 07)***

Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Application to square and triangular waves.

Unit III: Complex Analysis ***(Lectures 17)***

Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity. Integration of functions with complex variable. Cauchy's Integral theorem and Cauchy's Integral formula. Simply and multiply connected regions. Laurent and Taylor's series expansions. Residue Theorem with application.

Unit IV: Tensor Algebra ***(Lectures 06)***

Introduction to tensor, Transformation of co-ordinates, Einsteins summation convention. Contravariant, covariant and mixed tensors. Symmetric and antisymmetric tensors, Kronecker delta, LeviCivita tensor. Quotient law of tensors. Rules of combination of tensors: addition, subtraction, outer multiplication, contraction and inner multiplication.

Unit V: Introduction to Probability ***(Lectures 05)***

Independent random variables: Probability distribution functions; binomial, Gaussian and Poisson, with examples. Mean and variance.

References

1. Mathematical Physics; H K Dass and R Verma, S Chand and Company limited.
2. Mathematical methods for Physics and Engineering; K. F Riley, M. P Hobson, S.J Bence, Cambridge University Press.
3. Graduate Mathematical Physics (With Mathematica Supplement); J J Kelly, Willey-VCH Verlag GmbH and Co. KGaA.
4. Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier.
5. Ordinary and Partial Differential equations; M. D Raisinghania, S. Chand and Company Ltd.
6. Complex Variables; M R Spiegel,S Lipschutz, J J Schiller and D Spellman, Schaum's Outline Series, McGraw Hill Education.
7. Complex variables Demystified (A self teaching guide); D McMahan, McGraw Hill Education.
8. A Student's Guide to vectors and Tensors; D A Fleisch, Cambridge University Press.
9. Vector analysis and an introduction to Tensor analysis; S Lipschutz, D Spellman, M R Spiegel, Schaum's Outline Series, McGraw Hill Education.
10. Tensors and applications with Scilab Programs; N D Soni, I.K International Publishing House Pvt. Limited.
11. Probability and Statistics; M R Spiegel, J J Schiller and R A Srinivasan, Schaum's Outline Series, McGraw Hill Education.

Laboratory

(Use C/C++/Scilab/FORTRAN/Mathematica/ Matlab/ Python to solve the following problems.)

1. Solve the differential equations

$$\frac{dy}{dx} = e^x \text{ with } y = 0 \text{ for } x = 0$$
$$\frac{dy}{dx} + e^{-x}y = x^2$$
$$\frac{d^2y}{dx^2} + 2\frac{dy}{dx} = -y$$
$$\frac{d^2y}{dx^2} + e^{-x}\frac{dy}{dx} = -y$$

2. Perform the multiplication of two 3×3 matrices.
3. Compute the eigenvalues and eigenvectors of the following matrices.

$$\begin{bmatrix} 4 & 3 & 7 \\ 1 & 2 & 7 \\ 2 & 0 & 4 \end{bmatrix}, \begin{bmatrix} 1 & -i & 3+4i \\ i & 2 & 4 \\ 3-4i & 4 & 3 \end{bmatrix}, \begin{bmatrix} 2 & -i & 2i \\ i & 4 & 3 \\ -2i & 3 & 5 \end{bmatrix}$$

4. Using random number compute the areas of circle, square, volume of sphere and value of pi (π).
5. Evaluate trigonometric functions e.g. *sinθ; cosθ; tanθ* etc. using Interpolation by Newton Gregory Forward and Backward difference formula.
6. Find the solution of Partial Differential Equations: (a) Wave equation (b) Heat equation.
7. Evaluate the integral I,where,

   $I = \frac{1}{\sqrt{2\pi\sigma^2}} \int exp\left[\frac{(x-2)^2}{2\sigma^2}\right](x+3)dx$ for $\sigma = 1.0, 0.1, 0.01$ and show that $I \rightarrow 5$
8. Compute the *n*th roots of unity for *n* = 2, 3, and 4.
9. Find the two square roots of 5 + 12*i*.

Four Year Undergraduate Course in Physics

Semester V

Paper Name: Atomic and Molecular Physics

Paper Code: PHY050104 Total Number of Lectures = 60, Total Credits = 4 (Total Marks 100: Internal-40+External-60)

Course Objective: The basic objectives of the course are,

- To learn the development of atom models.
- To learn the origin of atomic spectra and their modifications under different physical conditions.
- To learn the basics of molecular spectra for diatomic molecule and a few applications.

Course learning outcomes:

Students will be ability to describe the atomic spectra of one and two valance electron atoms and will also understand the change in behavior of atoms and corresponding modification of their spectra in external applied electric and magnetic field. They will understand the basic principle of pure rotational, vibrational, Rotation-Vibration and Raman spectra of molecules and their few applications.

Unit I: Atom Model: **(Lectures 20)**

The Bohr model of the hydrogen-like atom, Sommerfeld Relativistic Atom Model: Elliptical orbits, explanation of fine structure of H alpha line in Balmer series of hydrogen atom. Limitation of Sommerfeld atom model.

Orbital magnetic dipole moment: Bohr Magneton, Gyromagnetic Ratio, Larmor precession, Space Quantization, Electron Spin, quantum numbers associated with vector atom model, spin-orbit interaction, Coupling Schemes: L-S Coupling and j-j Coupling, Spectroscopic term and their notation, Stern-Gerlach experiment and its conclusion.

Normal and Anomalous Zeeman Effect.

Paschen Back and Stark Effect (Qualitative Discussion only).

Unit II: X-rays: **(Lectures 08)**

Ionizing Power, X-ray Diffraction, Bragg's Law, X-ray Spectra: Continuous and characteristic X-rays Mosley's law, Compton effect.

Unit III: Multi electron atoms: **(Lectures 10)**

Hund's rule, Periodic table: Pauli's exclusion principle, explanation of the periodic classification of the elements, Building up or Aufbau Principle, Broad features of Alkali atom (Na etc.) spectra and its explanation

Unit IV: Molecular Spectra: **(Lectures 15)**

Rotational Energy levels, Selection Rules and Pure Rotational Spectra of a diatomic Molecule. Vibrational Energy Levels, Selection Rules and Vibration Spectra of a diatomic Molecule. Rotation-Vibration Energy Levels, Selection Rules and Rotation-Vibration Spectra. Determination of Internuclear Distance.

Unit V: Raman Effect: **(Lectures 07)**

Quantum Theory of Raman Effect. Characteristics of Raman Lines. Stoke's and Anti-Stoke's Lines. Complimentary Character of Raman and infrared Spectra.

Suggested Books:

1. Introduction to Atomic spectra, H. E. White, Tata McGraw Hill (1934)
2. Atomic and Molecular Spectra, Raj Kumar
3. Concepts of Modern Physics, Arthur Beiser (McGraw-Hill Book Company, 1987)
4. Atomic physics, J. B. Rajam & foreword by Louis De Broglie (S. Chand & Co., 2007)
5. Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachein.
6. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash

Semester:V

Course Name: Condensed Matter Physics

Credits: 4 (Theory: 03, Lab: 01) Course Code - PHY050204

Total Lectures: **45 (Theory)** **(Total Marks 100: Internal-25+External-75)**

Course objectives:

- To provide the elementary idea about crystal structure, bonding and lattice dynamics in solids.
- To make the students understand the concepts of transport properties, dielectric properties, ferroelectric properties and magnetic properties in solids.
- To familiarise the students with nanomaterials, thin film, soft matter and superconductivity.

Course Outcome: *On successful completion of the course students will be able to acquire the basic knowledge of crystal structure, bonding in solids and elementary idea lattice dynamics of materials, dielectric, ferroelectric and magnetic properties of solids, the physics of electrons in solids, basic idea about nanomaterials, thin film and soft matter and understand the basic concept in superconductivity.*

Unit I: Crystal Structure and Bonding in solids (Lectures 09)

Amorphous, crystalline and polycrystalline materials, lattice translation vectors, unit cell, types of crystal lattice, Bravais Lattice, Miller Indices, inter planer spacing.

Ionic, covalent, metallic, van-der-waal and hydrogen bondings, cohesive energy of ionic crystal, Madelung constant.

Unit II: Elementary Lattice Dynamics (Lectures: 04)

Basic idea of lattice vibration and phonon. Dulong and Petit's Law. Einstein and Debye theories of specific heat of solids, T^3 law.

Unit III: Dielectric and Ferroelectric Properties of Materials (Lectures 10)

Polarization. local electric field at an Atom, depolarization field, electric susceptibility, polarizability. Clausius Mosotti equation, classical theory of electric polarizability, normal and anomalous dispersion, Cauchy and Sellmeir relations, Langevin-Debye equation.

Piezoelectric effect, pyroelectric effect, ferroelectric effect, electrostrictive effect, Curie-Weiss Law.

Unit IV: Transport properties of materials (Lectures 09)

Free electron theory of metals, electrical and thermal conductivity of metals, Wiedemann-Franz law, drawback of classical theory and modification with quantum theory, preliminary idea of band theory, band gap, conductor, semiconductor (*p* and *n* type) and insulator, conductivity of semiconductor, mobility, measurement of conductivity (2-

probe & 4-probe resistivity measurement method), Hall Effect (Qualitative idea).

Unit V: Nanophysics and soft matter (Lectures 03)

Basic idea about nanomaterials, thin film physics and soft matter.

Unit VI: Magnetic Properties of Matter (Lectures 07)

Dia, para, ferri, ferro and anti ferromagnetic materials, classical Langevin Theory of dia and paramagnetism, Curie's law, Weiss' theory of ferromagnetic domains, discussion of B − H Curve, hysteresis and energy Loss.

Unit VII: Superconductivity (Lectures 03)

Basic idea of superconductivity, critical temperature, critical magnetic field, Meissner effect. Type I and type II Super- conductors, isotope effect.

Lab:

A minimum of four experiments to be done.

1. Indexing of powder X-Ray diffraction data of cubic crystalline materials and determination of lattice parameters including inter planner spacing (XRD data needs to arrange by the department).
2. Measurement of susceptibility of a paramagnetic solution (Quinck's Tube Method).
3. To measure the magnetic susceptibility of solids.
4. To determine the Coupling Coefficient of a piezoelectric crystal.
5. To measure the Dielectric Constant of a dielectric materials with frequency.
6. To study the *P-E* Hysteresis loop of a Ferroelectric Crystal.
7. To draw the B − H curve of Fe using Solenoid & determine energy loss from Hysteresis.
8. To measure the variation of resistivity of a semiconductor with temperature by four-probe method and to determine its band gap.
9. To determine the Hall coefficient of a semiconductor sample.

Suggested Books

1. *Introduction to Solid State Physics*, C Kittel
2. *Lattice Dynamics*, A K Ghatak and L S Kothari
3. *Solid State Physics*, A J Dekker.
4. *Introductory Solid State Physics*, H P Myers.
5. *Solid State Physics*, N W Ashcroft and N D Mermin
6. *Magnetism in solids*, D H Martin
7. *Physics of Magnetism*, S Chikazumi.
8. *Solid State Physics, S O Pillai*
9. *Introduction to Nanotechnology*, C. P. Poole, J. F. J. Owens

Semester-V

Paper Name: Heat & Thermodynamics
Course Code - PHY050304

Total Lectures: 45, Lab: 30 h; Credit: 04 (03+01) (Total Marks 100: Internal-25+External-75)

Course Objective:

- *To understand principles of thermodynamics*
- *To provide concepts of thermodynamic functions*
- *To address the basic framework of kinetic theory of gases*

Course Outcome: *Upon completion of this course, students will be able to learn thermal properties of gas molecules and their collisions. With this course, students will acquire knowledge of thermodynamics with practical insights into thermal physics, which will help them to understand real world situations.*

Theory

Unit I: ***Distribution of Velocities and Molecular Collisions*** **(Lectures 9)**

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required).

Mean Free Path. Collision Probability. Transport Phenomenon in Ideal Gases: (1) Viscosity, and (2) Thermal Conductivity. Brownian Motion (qualitative idea only).

Unit II: ***Real Gases*** **(Lectures 08)**

Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapor and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. Joule- Thomson Porous Plug Experiment. Joule- Thomson Effect, Joule-Kelvin coefficient for Ideal and Van der Waal Gases. Temperature of Inversion.

Unit III: ***Principles of Thermodynamics*** **(Lectures 16)**

Thermodynamic preliminaries: Extensive and intensive properties, Thermodynamic Variables, Thermodynamic Equilibrium, P-V indicator diagram. Work done in terms of P and V, Zeroth Law of Thermodynamics & Concept of Temperature, Internal energy and First Law of Thermodynamics, Applications of First Law: General Relation between C_P and C_V.

Reversible and Irreversible process with examples. Heat & work, state function, Conversion of heat into work and vice versa, Work Done during Isothermal and Adiabatic Processes, Heat Engines, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence, Carnot's Cycle, Carnot engine & efficiency. Refrigerator

& coefficient of performance, Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

Unit IV: ***Entropy*** **(Lectures 06)**

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics.

Unit V: ***Thermodynamic Potentials and Thermodynamic Relations*** **(Lectures 06)**

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, Surface Films and Variation of Surface Tension with Temperature, Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of C_p-C_v, (3) TdS Equations, (4) Energy equations, (5) Change of Temperature during Adiabatic Process.

Lab *(at least four experiments to be performed)*

1. To determine mechanical equivalent of heat, J, by Callender and Barne's constant flow method
2. To determine the mechanical equivalent of heat, J using calorimeter
3. To determine specific heat of a liquid using calorimeter
4. To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
5. To determine the coefficient of thermal conductivity of an insulator by Lee and Charlton's disc method.
6. To determine the temperature coefficient of resistance by Platinum Resistance Thermometer (PRT).
7. To study the variation of thermo-emf of a thermocouple with difference of temperature of its two junctions.
8. To determine the change of entropy of universe for an AC circuit consists of a thermally insulated resistor.
9. To calibrate a thermocouple to measure temperature in a specified range using (1) Null method, (2) Direct measurement using OPAMP and to determine neutral temperature.

Suggested Books

[1] Heat and Thermodynamics, M. Zemansky, R. Dittman, McGraw-Hill Education, 2017.
[2] A Treatise on Heat, Meghnad Saha and B. N. Srivastava, Indian Press, 1973.
[3] Thermal Physics: Kinetic Theory, Thermodynamics and Statistical Mechanics, S. C. Garg, R. M. Bansal and C. K. Ghosh, Tata McGraw Hill Education Pvt Ltd, 2013.
[4] Thermodynamics, Kinetic Theory and Statistical Thermodynamics, F. W. Sears & G. L. Salinger, Narosa Publishing House, 1998.

[5] Thermal and Statistical Physics, R. B. Singh, New Academic Science, 2011.
[6] Theory and Experiment on Thermal physics, P K. Chakrabarti, New Central Book Agency (P) Ltd, 2011.

Four Year Undergraduate Course in Physics
Semester - V
Paper Name: Electromagnetic Theory
Paper Code: PHY050404
Total number of lectures= 45
Total credits = 4 (Theory 3 +Laboratory 1) (Total Marks 100: Internal-25+External-75)

Course objectives:

- To lay the foundation of electromagnetism through Maxwell's equations.
- Behaviour of electromagnetic waves as it propagates through vacuum and other media.
- Various effects that occur as electromagnetic waves propagate from one medium to another medium.
- Basic concepts of waveguides and fibre optics.
- Various aspects of electromagnetic wave polarisation.

Course outcome:

After the successful completion of the course, students will acquire the concepts of Maxwell's equations, propagation of electromagnetic (EM) waves in different homogeneous-isotropic as well as anisotropic unbounded and bounded media, production and detection of different types of polarized EM waves, general information of waveguides and fibre optics.

Theory (Credits=3)

Unit - I: Maxwell's equations (Lectures -09)

Maxwell's equations, Displacement Current, Vector and Scaler Potentials, Gauge Transformations: Coulomb and Lorentz Gauge, Boundary Conditions at Interface between Different Media, Poynting Theorem and Poynting Vector.

Unit - II: EM Wave Propagation in Unbounded Media (Lectures - 09)

Plane EM Waves through Vacuum and Isotropic Dielectric Medium, Transverse Nature of Plane EM Waves, Refractive Index and Dielectric Constant, Propagation though Conducting Media, Relaxation Time, Skin Depth. Wave Propagation through Dilute Plasma (Basic Concepts).

Unit - III: EM wave in Bounded Media (Lectures - 09)

Reflection and Refraction of Plane EM Waves at Plane Interface between two Dielectric Media – Laws of Reflection and Refraction, Fresnels's Formula for Perpendicular Polarization Case, Brewster's Law, Reflection and Transmission Co-efficients, Waveguides: Basic Concepts and Propagation of EM Waves in a Rectangular Waveguide.

Unit - IV: Polarization of Electromagnetic Waves (Lectures - 11)

Description of Linear, Circular and Elliptical Polarization, Propagation of EM Waves in Anisotropic Media, Symmetric Nature of Dielectric Tensor, Fresnel's Formula, Uniaxial and Biaxial Crystals, Light Propagation in Uniaxial Crystal, Double Refraction, Polarization by Double Refraction, Nicol Prism; Ordinary & Extraordinary Refractive Indices, Production & Detection of Plane, Circularly and Elliptically Polarized Light; Phase Retardation Plates: Quarter-Wave and Half-Wave Plates, Babinet Compensator and its Uses, Analysis of Polarized Light.

Unit - V: Rotary Polarization (Lectures - 04)

Optical Rotation. Biot's Laws for Rotatory Polarization, Fresnel's Theory of Optical Rotation, Calculation of Angle of Rotation, Experimental Verification of Fresnel's Theory, Specific rotation, Laurent's Half-shade Polarimeter.

Unit - VI: Optical Fibres (Lectures - 03)

Numerical Aperture, Step and Graded Indices (Definitions Only), Single and Multiple Mode Fibres (Concept and Definition Only).

Laboratory (Credit=1)

The students are required to perform at least four experiments from the following list of experiments.

1. To verify the law of Malus for plane polarised light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarised light by using Babinet's compensator.
4. To study dependence of radiation on angle for a simple Dipole antenna.
5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection and refraction of microwaves.
7. To study polarization and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To study the polarisation of light by reflection and determine the polarizing angle for air-glass interface.
11. To verify the Stefan's law of radiation and to determine Stefan's constant.
12. To determine the Boltzmann constant using V-I characteristic of pn junction diode.

Reference books:

[1] Introduction to Electrodynamics, D. J. Griffiths.

[2] Electromagnetics, B. B. Laud, New Age International Publishers.
[3] Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.
[4] Introduction to Electromagnetic Theory, T. L. Chow, 2006, Jones & Bartlett Learning.
[5] Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
[6] Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill.
[7] Electromagnetic Field Theory, R. S. Kshetrimayun, 2012, McGraw Hill.
[8] Engineering Electromagnetic, Willian H. Hayt, 2012, McGraw Hill.
[9] Electricity and Magnetism [With electromagnetic theory and special theory of relativity], D. Chattopadhyay and P. C. Rakshit, 2013, New Central Book Agency (P) Limited.

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SEMESTER - VI
NUCLEAR & PARTICLE PHYSICS
Course Code - PHY060104
Credit : 04 (Theory-03, Tutorial-01) **(Total Marks 100: Internal-40+External-60)**

Theory : 45 Hours Tutorial : 15 Hour

Course Objective: The objective of this course is to impart –

- basic knowledge about the nucleus and other subatomic particles and their properties.
- knowledge about the radioactive disintegration of a nucleus and the laws of radioactive decays.
- Knowledge on basic nuclear instrumentation and experimental techniques of nuclear physics.
- Basic knowledge of particle physics.

Course Learning Outcomes: On successful completion of the course, the students shall be able to understand the structure and properties of a nucleus. They will also know about the properties of strong nuclear force that keeps the nuclei bound. They will learn about the radioactive decays and various laws of radioactive disintegration. Students will have adequate knowledge on the construction and working principles of particle accelerators and detectors. Moreover, students will be introduced to the world of particle physics – types and interactions. The acquired knowledge can be applied in the areas of nuclear medicine, medical physics, archaeology, geology and other interdisciplinary fields of Physics and Chemistry. It will enhance the special skills required for these fields.

Unit – I: Basic Properties of Nuclei: (No. of lecture = 8)

Constituents of a nucleus: proton-electron hypothesis -Thompson atom model, failure of proton-electron hypothesis, discovery of neutrons, **Rutherford gold foil experiment** (qualitative) and atom model- mass, radius, volume, matter density of nuclei and their units. Binding energy, binding energy per nucleon, stability of a nucleus- neutron to proton ratio, stability line, stability limit against beta decays.

Unit – II: Radioactivity and Radioactive Laws: (No. of lecture = 10)

Types of Radioactivity – alpha, beta, and gamma decay. Laws of radioactive decay, disintegration constant, half-life and mean life. Activity of a radioactive source, units of radioactivity.
Alpha decay: range, ionization and stopping power, range-energy relation, **Geiger-Nuttall law**, Fine structure of alpha energy spectrum.
Beta decays: types of beta decays, essential conditions of beta decays, beta ray spectra, end-point energy, Pauli's neutrino hypothesis.
Gamma decay: origin of gamma radiation, its property, attenuation of gamma radiation in matter.

Unit III: Nuclear Instrumentation **(No. of lecture = 10)**

Detectors: Interaction of Radiation with Matter: Energy loss by a charged particle due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Interaction of photon with matter – Photoelectric effect, Compton effect, and Pair production, .

Gas filled detectors: Ionization chamber, proportional counter, and GM counter – construction and working principle
Charged particle accelerators: Need of charged particle accelerators, Linear accelerator (LINAC) – Construction and working principle.

Unit IV: Fission and Fusion **(No. of lecture = 10)**

Energy consideration in Nuclear Reaction, Mass defect and Q-value of a nuclear reaction, Einstein's mass-energy equivalence principle and generation of nuclear energy. Nuclear Fission: Spontaneous and induced fission – definition and examples, Fission chain reactions and nuclear reactor: peaceful use of fission energy.
Fusion and thermonuclear reactions: Energy production in stars (brief qualitative discussions).

Unit V: Elementary Particles **(No. of lecture = 7)**

Classification of elementary particles and their quantum numbers, conservation laws, Allowed and forbidden reactions, Types of interactions – strong, electro-magnetic and weak interactions.

Reference Books:

1. Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999. 87
2. Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
3. Introductory Nuclear Physics by K S Krane, Wiley-India Publication, 2008.
4. Nuclear Physics: principles and applications by J Lilley, Wiley Publication, 2006.
5. Radiation detection and measurement, G F Knoll, John Wiley & Sons, 2010.
6. Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
7. Concept of Modern Physics by Arthur Beiser, McGraw Hill Education, 2009.
8. Nuclear Radiation Detector by S S Kapoor and V S Ramamurthy , 1st edition, New Age international publisher.

SEMESTER - VI
NUCLEAR & PARTICLE PHYSICS
Course Code - PHY060104
Credit : 04 (Theory-03, Tutorial-01) **(Total Marks 100: Internal-40+External-60)**

Theory : 45 Hours Tutorial : 15 Hour

Course Objective: The objective of this course is to impart –

- basic knowledge about the nucleus and other subatomic particles and their properties.
- knowledge about the radioactive disintegration of a nucleus and the laws of radioactive decays.
- Knowledge on basic nuclear instrumentation and experimental techniques of nuclear physics.
- Basic knowledge of particle physics.

Course Learning Outcomes: On successful completion of the course, the students shall be able to understand the structure and properties of a nucleus. They will also know about the properties of strong nuclear force that keeps the nuclei bound. They will learn about the radioactive decays and various laws of radioactive disintegration. Students will have adequate knowledge on the construction and working principles of particle accelerators and detectors. Moreover, students will be introduced to the world of particle physics – types and interactions. The acquired knowledge can be applied in the areas of nuclear medicine, medical physics, archaeology, geology and other interdisciplinary fields of Physics and Chemistry. It will enhance the special skills required for these fields.

Unit – I: Basic Properties of Nuclei: (No. of lecture = 8)

Constituents of a nucleus: proton-electron hypothesis -Thompson atom model, failure of proton-electron hypothesis, discovery of neutrons, **Rutherford gold foil experiment** (qualitative) and atom model- mass, radius, volume, matter density of nuclei and their units. Binding energy, binding energy per nucleon, stability of a nucleus- neutron to proton ratio, stability line, stability limit against beta decays.

Unit – II: Radioactivity and Radioactive Laws: (No. of lecture = 10)

Types of Radioactivity – alpha, beta, and gamma decay. Laws of radioactive decay, disintegration constant, half-life and mean life. Activity of a radioactive source, units of radioactivity.
Alpha decay: range, ionization and stopping power, range-energy relation, **Geiger-Nuttall law**, Fine structure of alpha energy spectrum.
Beta decays: types of beta decays, essential conditions of beta decays, beta ray spectra, end-point energy, Pauli's neutrino hypothesis.
Gamma decay: origin of gamma radiation, its property, attenuation of gamma radiation in matter.

Unit III: Nuclear Instrumentation **(No. of lecture = 10)**

Detectors: Interaction of Radiation with Matter: Energy loss by a charged particle due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Interaction of photon with matter – Photoelectric effect, Compton effect, and Pair production, .

Gas filled detectors: Ionization chamber, proportional counter, and GM counter – construction and working principle
Charged particle accelerators: Need of charged particle accelerators, Linear accelerator (LINAC) – Construction and working principle.

Unit IV: Fission and Fusion **(No. of lecture = 10)**

Energy consideration in Nuclear Reaction, Mass defect and Q-value of a nuclear reaction, Einstein's mass-energy equivalence principle and generation of nuclear energy. Nuclear Fission: Spontaneous and induced fission – definition and examples, Fission chain reactions and nuclear reactor: peaceful use of fission energy.
Fusion and thermonuclear reactions: Energy production in stars (brief qualitative discussions).

Unit V: Elementary Particles **(No. of lecture = 7)**

Classification of elementary particles and their quantum numbers, conservation laws, Allowed and forbidden reactions, Types of interactions – strong, electro-magnetic and weak interactions.

Reference Books:

1. Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999. 87
2. Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
3. Introductory Nuclear Physics by K S Krane, Wiley-India Publication, 2008.
4. Nuclear Physics: principles and applications by J Lilley, Wiley Publication, 2006.
5. Radiation detection and measurement, G F Knoll, John Wiley & Sons, 2010.
6. Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
7. Concept of Modern Physics by Arthur Beiser, McGraw Hill Education, 2009.
8. Nuclear Radiation Detector by S S Kapoor and V S Ramamurthy , 1st edition, New Age international publisher.

Digital Electronics

(Semester VI)

Course Code - PHY060204

Credits 4: (Theory: 3 + Practical: 1) **(Total Marks 100: Internal-25+External-75)**

Total Lectures: 45

Course Objectives:

1. To introduce the students to the basics of digital electronics and applications with hands-on experience in implementing some hardware.
2. To help students develop a digital logic and apply it to solve real-life problems
3. To analyze, design and implement various combinational and sequential logic circuits
4. To classify different semiconductor memories.

Course Outcome: After successful completion of the course student will be able to develop, implement and analyze digital logic circuits and apply them to solve real-life problems and classify different semiconductor memories.

Unit I: Integrated Circuits (qualitative treatment only) (Lectures 03)

Active & Passive Components. Discrete components. Wafer. Chip. Advantages and drawbacks of ICs. The scale of integration: SSI, MSI, LSI, and VLSI (basic idea and definitions only). Classification of ICs. Examples of Linear and Digital ICs.

Unit II: Digital Circuits (Lectures 10)

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.

Unit III: Boolean Algebra (Lectures 10)

De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. The idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

Unit IV: Arithmetic Circuits (Lectures 05)

Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor.

Unit V: Timers: IC 555 (Lectures 03)

Block diagram and applications: Astable multivibrator and Monostable multivibrator.

Unit VI: Sequential Circuits (Lectures 04)

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.

Unit VII: Shift Registers (Lectures 04)

Serial-in-Serial-out. Serial-in-Parallel-out. Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).

Unit VIII: Computer Organization (Lectures 06)

Input/Output Devices. Data storage (the idea of RAM and ROM). Computer memory. Memory organization & addressing.

Laboratory

A minimum of four experiments are to be done.

1. To design a switch (NOT gate) using (i) a PNP transistor and (ii) an NPN transistor.
2. To verify and design AND, OR, NOT, and XOR gates using NAND gates.
3. To design a combinational logic system for a specified Truth Table.
4. To convert a Boolean expression into a logic circuit and design it using logic gate ICs.
5. To design a Half Adder and Full Adder
6. To design a 4-bit binary Adder.
7. To design Half Subtractor and Full Subtractor
8. To design Adder-Subtractor using Full Adder IC.

9. To design an astable multivibrator of given specifications using 555 Timer.
10. To design a monostable multivibrator of given specifications using 555 Timer.
11. To build a D flip-flop circuit using NAND gates.
12. To build a JK flip-flop circuit using NAND gates.
13. To build JK Master-slave flip-flop using flip-flop ICs.
14. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.
15. To build SR flip-flop circuit using NAND gates

Suggested Books

1. Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, Tata McGraw
2. Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Digital Electronics G. K. Kharate ,2010, Oxford University Press
5. Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer, 2001, PHI Learning
6. Logic circuit design, Shimon P. Vingron, 2012, Springer.
7. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
8. Digital Electronics, S. K. Mandal, 2010, 1st edition, McGraw Hill
9. Electronics Fundamentals and Applications, D. Chattopadhyay and P. C. Rakshit, 17th Ed, 2023, New Age International Publishers

Four Year Undergraduate Course
Subject: Physics
Semester-VI
Paper: Astronomy & Astrophysics
Paper Code- PHY060304
Total Lectures: 60 (Theory 45; Tutorial 15)
Credits: 4 (Theory -03; Tutorial – 01) (Total Marks 100: Internal-40+External-60)

Course objectives: *The basic objectives of this course are*

- *to introduce the students with fundamental concepts and observational techniques in astronomy including virtual observatory tools,*
- *to introduce them with physical processes occurring inside the celestial objects and*
- *to introduce the physical concepts required for the study of recent frontiers in astrophysics.*

Course outcome: *On successful completion of this course students will be able to understand the fundamental concepts in astronomy. They will be able to apply physics of celestial objects in understanding the universe. They will be equipped with the skills required for (i) observational astronomy (ii) virtual observatory tools and (iii) physical concepts of recent frontiers in astrophysics.*

Unit –I: Fundamentals of astronomy **(Lectures 8)**

Basic components of the universe – stars, planets and galaxies; celestial sphere and celestial coordinates system - altitude-azimuth (Alt-Az) and right ascension-declination (RA-DEC); Introduction to constellations through sky observation and Stellarium; concept of time – universal time, solar and mean solar time, sidereal time, local sidereal time, Julian day; flux and luminosity of celestial objects; stellar magnitude scale – apparent and absolute magnitude; measurement of stellar distances – trigonometric parallax; introduction to HIPPARCOS and GAIA.

Unit- II : Astronomical techniques (Lectures 7)

Telescopes –size and light gathering power; resolving power; different types of optical telescopes (reflecting and refracting); space telescopes; concept of virtual observatory; virtual observatory tools in astronomy – SIMBAD, Aladin; SDSS, AAVSO, Sky-View; introduction to photometry; CCD –an introduction; spectroscopy and polarimetry.

Unit – III: Stellar astrophysics (Lectures 13)

Star formation from interstellar medium (introduction only); properties of stars – mass, luminosity, radius and effective surface temperature; mass-luminosity, mass-radius and luminosity-radius-temperature relation; variable stars- cepheids; star clusters – open and globular, their ages (introduction only).

Gravity and thermodynamics – hydrostatic equilibrium of stars; virial theorem; internal temperature and pressure of stars; spectral classification – HR diagram; stellar evolution- idea of nucleosynthesis in main sequence phase- pp and CNO cycle; evolution of Sun-like stars off the main sequence -red giants and white dwarfs- Chandrasekhar mass limit (introduction only); evolution of massive stars – neutron stars and black holes (introduction only).

Unit-IV: The solar system (Lectures 5)

The Sun; properties of photosphere, chromospheres and corona; Formation of the solar system – Kant-Laplace nebular hypothesis; asteroid belt and meteorites; Distances and atmospheres of planets; Pluto and dwarf planets; comets – Kuiper belt and Oort cloud; extra-solar planets – transit method of detection (introduction only).

Unit- V : Galaxies and cosmology (Lectures 12)

The Milky Way-shape, size and its components; classification of galaxies –Hubble's tuning fork diagram; types – spirals, elliptical and lenticular; difference between spirals and ellipticals.

Large scale structure of the universe – galaxies, clusters, superclusters, filaments, walls and voids; Cosmological Principle; Hubble's law; Newtonian cosmology and derivation of Friedman equation; closed and oscillating universe, flat and open universe; the Hot Big Bang model; Cosmic Microwave Background (CMB); steady state universe (introduction only); flat rotation curves in galaxies and evidence of dark matter; dark energy (introduction only).

Suggested text books:

(1) Astrophysics for physicists, A. Rai Choudhuri, Cambridge University Press.
(2) An introduction to the theory of stellar structure and evolution, D. Prialnik, Cambridge University Press.

(3) Astrophysics- Stars and galaxies, K. D. Abhyankar, Tata McGraw Hill Pub.
(4) Textbook of astronomy and astrophysics with elements of cosmology, V. B. Bhatia, Narosa Pub.
(5) Astronomy Methods - A Physical Approach to Astronomical Observations, Hale Bradt, Cambridge University Press.
(6) Introduction to astrophysics, H.L. Duorah and K. Duorah, Mani Manik Prakash (Guwahati).

Suggested reference books

(1) The physical universe – An introduction to astronomy, F. H. Shu, University of Science Books.
(2) The structure of the universe, J.V. Narlikar, Oxford University Press.
(3) Introduction to cosmology, B. Ryden, Cambridge University Press.

Semester-VI

Paper Name: Statistical Mechanics

Course Code - PHY060404

Total Lectures: 60 (45 L + 15 T); Credit: 04 (Total Marks 100: Internal-40+External-60)

Course objective:

- *To provide basic concepts of statistical mechanics*
- *Describing various thermodynamical phenomena using probability theory*
- *To learn classical and quantum statistics*

Course outcome: Upon completion of the course, students will get accustomed to the microscopic origin of thermodynamic processes. After successful completion of the course, students will be able to perceive classical and quantum pictures of physical and chemical events.

Unit I: Classical Statistics (Lectures 15)

Microstate and macrostate, distributions of particles in compartments, principle of equal a priori probability. Phase space, volume of phase space. Elementary concept of ensembles, Types of ensembles. Ergodic hypothesis. Entropy and thermodynamic probability, Stirling's approximation, Maxwell-Boltzmann distribution function, Partition functions. Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to specific heat and its limitations. Thermodynamic parameters (internal energy, entropy, free energy, enthalpy) using partition functions.

Unit II: Classical and Quantum Theory of Radiation (Lectures 12)

Properties of thermal radiation. Blackbody radiation. Spectral distribution of Blackbody radiation, Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation pressure (for Normal and diffused case). Wien's Displacement law. Wien's Distribution Law. Saha's ionization formula. Rayleigh-Jean's Law (with proof). Ultraviolet catastrophe.

Need of quantum statistics. Planck's quantum postulates. Planck's law of blackbody radiation: Experimental verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan- Boltzmann Law, (4) Wien's Displacement law from Planck's blackbody radiation formula.

Unit III: Bose-Einstein Statistics (Lectures 8)

Bose-Einstein (BE) distribution, Pressure of a Bose gas, Bose Einstein Condensation (qualitative description only), Properties of liquid Helium (qualitative discussion only), Radiation as a photon gas and Bose's derivation of Planck's blackbody radiation formula, Thermodynamic functions of photon gas – energy, entropy, and free energy.

Unit IV: Fermi-Dirac Statistics (Lectures 10)

Fermi-Dirac (FD) distribution, FD function and Fermi Energy, Degenerate Fermi gas, strongly degenerate case (qualitative discussion only), Thermodynamic functions - energy and pressure of a completely degenerate Fermi gas, Heat capacity at low temperature, Free electron gas in metals and electronic specific heat, Relativistic Fermi gas, thermodynamics of white dwarf star (qualitative discussion only).

Suggested books

[1] Statistical Mechanics, R K Pathria and P D Beale, Elsevier Science, 2021.

[2] Statistical Physics, F. Reif, McGraw-Hill Education India, 2008.

[3] Statistical and Thermal Physics, S. Lokanathan and R. S. Gambhir, PHI Learning, 1991.

[4] Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, Springer, 2009.

[5] An Introduction to Statistical Mechanics & Thermodynamics, R. H. Swendsen, Oxford University Press, 2012.

[6] A Primer of Statistical Mechanics, R. B. Singh, New Age International Publishers, 2006.