SNU
SISTER NIVEDITA UNIVERSITY

2022

SYLLABUS

School of Sciences

B.Sc. (H) in Physics under UGC – CBCS

B.Sc Physics (H) Course Structure

Credit Distribution

Name of Department: Physics

Name of the UG program: B.Sc. (Hons.)

Duration of program: 6 Semester (3 years)

Head/ In-Charge of the department: Shrabana Chakraborty Sarkar

Semester	**Credit**						
	CC	**DSE**	**GE**	**AECC**	**SEC**	**USC**	**Total/ Sem**
1st	12	6		2			20
2nd	12	6	4	2	1		25
3rd	12	6	4		1	2	25
4th	18	6	4		1	2	31
5th	18				1	2	21
6th	18					2	20
Total Credit / Course	**90**	**24**	**12**	**4**	**4**	**8**	
Total Credit							**142**

CC: Core Courses; **GE**: General Elective; **AECC**: Ability Enhancement Compulsory Course;

SEC: Skill Enhancement Courses; **DSE**: Discipline Specific Elective; **USC**: University-specified course

B.Sc. Physics (H)

First Year						
Semester – I						
Category	**Course name**	**Code**	**Credit**	**Teaching Scheme**		
				L	**T**	**P**
CC – 1	Mathematical Methods-I		4	4	0	0
	Mathematical Methods-I Lab		2	0	0	4
CC – 2	General Physics		4	4	0	0
	General Physics Lab		2	0	0	4
DSE – 1			6	4	0	4
AECC – 1	Communicative English		2	2	0	0
Total Credit = 20				Teaching Hour = 26		
Semester – II						
CC – 3	Electricity and Magnetism		4	4	0	0
	Electricity and Magnetism Lab		2	0	0	4
CC – 4	Waves and Optics		4	4	0	0
	Waves and Optics Lab		2	0	0	4
DSE – 2			6	4	0	4
GE – 1	Generic Elective		4	3	1	0
AECC – 2	Environmental Science		2	2	0	0
SEC – 1	Mentored Seminar – I		1	1	0	0
Total Credit = 25				Teaching Hour = 31		

Second Year						
Semester – III						
CC – 5	Mathematical Methods- II		4	4	0	0
	Mathematical Methods- II Lab		2	0	0	4
CC – 6	Thermal Physics		4	4	0	0
	Thermal Physics Lab		2	0	0	4
DSE – 3			6	4	0	4
GE – 2	Generic Elective		4	3	1	0
SEC – 2	Mentored Seminar – II		1	1	0	0
USC – 1	Foreign Language – I		2	2	0	0
Total Credit = 25				Teaching Hour = 31		
Semester – IV						
CC – 7	Analog Electronics		4	4	0	0
	Analog Electronics Lab		2	0	0	4
CC – 8	Digital Electronics		4	4	0	0
	Digital Electronics Lab		2	0	0	4
CC – 9	Modern Physics		4	4	0	0
	Modern Physics Lab		2	0	0	4
DSE – 4			6	4	0	4
GE – 3	Generic Elective		4	3	1	0
SEC – 3	Mentored Seminar – III		1	1	0	0
USC – 2	Foreign Language – II		2	2	0	0
Total Credit = 31				Teaching Hour = 39		

Third Year						
Semester –V						
CC – 10	Quantum Mechanics		4	4	0	0
	Quantum Mechanics Lab		2	0	0	4
CC – 11	Electromagnetic Theory		4	4	0	0
	Electromagnetic Theory Lab		2	0	0	4
CC - 12	Statistical Mechanics		6	4	0	4
SEC – 4	Mentored Seminar – IV		1	1	0	0
USC – 3	Foreign Language – III		2	2	0	0
Total Credit = 21				Teaching Hour = 27		
Semester – VI						
CC – 13	Special Theory of Relativity		6	5	1	0
CC – 14	Solid State Physics		4	4	0	0
	Solid State Physics Lab		2	0	0	4
CC – 15	Project		6	0	0	12
USC – 4	Foreign Language – IV		2	2	0	0
Total Credit = 20				Teaching Hour = 28		

Program Outcomes (POs)

- **PO1: Disciplinary knowledge and skills-** The students should be capable of demonstrating
  (i) good knowledge and understanding of major concepts, theoretical principles and experimental findings in Physics and its different subfields like Mathematical Physics, Classical and Quantum mechanics, Thermal and Statistical mechanics, Electricity, Magnetism and Electromagnetic theory, solid state physics, Nuclear and Particle Physics and other related fields of study, including broader interdisciplinary subfields like Chemistry, Mathematics, Life sciences, Environmental sciences, Atmospheric Physics, Computer science, Information Technology etc.
  (ii) ability to use modern instrumentation and laboratory techniques to design and perform experiments is highly desirable in almost all the fields of Physics listed above in (i).
- **PO2: Skilled communicator:-** Ability to transmit complex technical information relating all areas in Physics in a clear and concise manner in writing and oral ability to present complex and technical concepts in a simple language for better understanding.
- **PO3: Critical thinker and problem solver-** Ability to employ critical thinking and efficient problem solving skills in all the basic areas of Physics.
- **PO4: Sense of inquiry-** Capability for asking relevant/appropriate questions relating to the issues and problems in the field of Physics, and planning, executing and reporting the results of a theoretical or experimental investigation.
- **PO5: Team player/worker**- Capable of working effectively in diverse teams in both classroom, laboratory, Physics workshop and in industry and field-based situations.
- **PO6: Skilled project manager-** Capable of identifying/mobilizing appropriate resources required for a project, and manage a project through to completion, while observing responsible and ethical scientific conduct; and safety and laboratory hygiene regulations and practices.
- **PO7: Digitally Efficient-** Capable of using computers for simulation studies in Physics and computation and appropriate software for numerical and statistical analysis of data, and employing modern e-library search tools like Inflibnet, various websites of the renowned Physics labs in countries like the USA, Europe, Japan etc. to locate, retrieve, and evaluate Physics information.
- **PO8: Ethical awareness / reasoning-** The graduate should be capable of demonstrating ability to think and analyze rationally with modern and scientific outlook and identify ethical issues related to one's work, avoid unethical behavior such as fabrication, falsification or misrepresentation of data or committing plagiarism, not adhering to intellectual property rights, and adopting objectives, unbiased and truthful actions in all aspects of work.
- **PO9: National and international perspective-** The graduates should be able to develop a national as well as international perspective for their career in the chosen field of the academic activities. They should prepare themselves during their most formative years for their appropriate role in contributing towards the national development and projecting our national priorities at the international level pertaining to their field of interest and future expertise.
- **PO10: Lifelong learners-** Capable of self-paced and self-directed learning aimed at personal development and for improving knowledge/skill development and reskilling in all areas of Physics.

SEMESTER I

Course CC1: MATHEMATICAL METHODS- I
Credit 6: (4L-0T-2P)

Component: Theory

Unit 1: Calculus
Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). First Order Differential Equations and Integrating Factor.

Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral.

Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.

Unit 2: Vector Calculus
Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Gradient, divergence, curl and Laplacian in spherical and cylindrical coordinates.

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).

Unit 3: Orthogonal Curvilinear Coordinates
Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

Unit 4: Dirac Delta function and its properties
Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

References:

- Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
- Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

Component: Practical

PHYSICS LAB I: PYTHON/OCTAVE/MATLAB

Topics	Description
Introduction and Overview	Computer architecture and organization, memory and Input / output devices

Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow & overflow emphasize the importance of making equations in terms of dimensionless variables, Iterative methods
Errors and error Analysis	Truncation and round off errors, Absolute and relative errors, Floating point computations.
Review of Python Programming fundamentals	Statements and comments, Python variables, python datatypes, Python I/O and import. Python if..else, for loop, while loop, break and continue, Pass statement, Looping technique. Python function, function argument, python recursion, anonymous function, Python global and local variable, Python modules, Python packages. Python numbers, python list, python tuple, string, set, dictionary, arrays, matrix. File operation, python directory
Python packages and applications	Numpy Scipy Sympy Matplotlib

Course learning outcome:

After completing this course, student will be able to,

- **CO1:** Draw and interpret graphs of various elementary functions.
- **CO2:** Solve and apply first and second order differential equations for physics problems. Understand the functions of more than one variable and concept of partial derivatives.
- **CO3:** Understand the vector quantities as entities with Cartesian components. Use index notation to write the product of vectors for easy application in computational work.
- **CO4:** Explain the concept of scalar field, vector field, conservative field, scalar potential, gradient of scalar fields and the divergence and rotation of vector field.
- **CO5:** Elaborate the curvilinear coordinates which have applications in problems with spherical and cylindrical symmetries, Dirac delta function and its properties, which have applications in various branches of Physics, especially quantum mechanics.
- **CO6:** Understand the differential operation of vectors and apply it to the calculation of particle motion.

CO7: Solve practical problems using the integral theorems of vector field. Elucidate and describe the skills that are involved in computational thinking. Build up programming, analytical and logical thinking abilities. The emphasis of laboratory course is to enable the students for preparing algorithms and flowcharts for solving a problem. They will learn to design, code and test programs in Python in the process of solving various problems

Course CC2: General Physics

Credit 6: (4L-0T-2P)

Component: Theory

Unit 1: Fundamentals of Dynamics

Reference frames. Inertial frames; Galilean transformations; Galilean invariance. Review of Newton's Laws of Motion. Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse. Momentum of variable-mass system: motion of rocket.

Unit 2: Collisions
Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.

Unit 3: Rotational Dynamics
Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.

Unit 4: Elasticity
Relation between Elastic constants. Twisting torque on a Cylinder or Wire.

Unit 5: Fluid Motion
Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.

Unit 6: Gravitation and Central Force Motion
Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS). Physiological effects on astronauts.

Unit 7: Non-Inertial Systems
Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems.

Unit 8: Classical Mechanics of Point Particles
Generalised coordinates and velocities. Hamilton's Principle, Lagrangian and Euler-Lagrange equations. Applications to simple systems such as coupled oscillators. Canonical momenta & Hamiltonian. Hamilton's equations of motion. Applications: Hamiltonian for a harmonic oscillator, particle in a central force field. Poisson brackets. Canonical transformations.

References

- Evolution of Physics by Einstein and Infeld
- Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
- An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw- Hill
- Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
- Classical Mechanics and General Properties of Matter. S.N. Maiti and D.P. Raychaudhuri, New Age
- Introduction to Classical Mechanics, R. G. Takwale and P.S.Puranik, Tata McGraw-Hill Publishing Company Ltd.
- Theory and Problems of Theoretical Mechanics, M. R. Spiegel, Mc Grow Hill Education
- Classical Mechanics , R.D. Gregory, 2006, Cambridge University Press
- Introduction to Classical Mechanics With Problems and Solutions , D. Morin, Cambridge University Press

Component: Practical

<u>PHYSICS LAB-II</u>

1. Measurements of length (or diameter) using vernier caliper, screw gauge and travelling microscope.

2. To study the random error in observations.

3. To determine the height of a building using a Sextant.

4. To study the Motion of Spring and calculate (a) Spring constant, (b) g and (c) Modulus of rigidity.

5. To determine the Moment of Inertia.

6. To determine the Young's Modulus of a Wire by Optical Lever Method.

7. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.

8. To determine the elastic Constants of a wire by Searle's method.

9. To determine the value of g using Bar Pendulum.

References

1. B.sc. Practical Physics, C. L. Arora, 2010, S Chand & Company; Classic Edition

Course learning outcome:

Upon completion of this course, students will be able to,

- **CO1:** Demonstrate the Galilean invariance of Newton's laws of motion.
- **CO2**: Understand translational and rotational dynamics of a system of particles.
- **CO3:** Illustrate elasticity and fluid motion
- **CO4**: Apply Kepler's laws to describe the motion of planets and satellite in circular orbit.
- **CO5**: Explain and analyze central force motion and relate with problems
- **CO6**: Elaborate Lagrangian, Hamiltonian and solve equation of motion for various problems
- **CO7**: In the laboratory part of the course, the students will learn to use various instruments, estimate the error for every experiment performed and report the result of experiment along with the uncertainty in the result up to correct significant figures.

Semester II

Course CC3: ELECTRICITY AND MAGNETISM
Credit 6: (4L-0T-2P)

Unit 1: Electric Field and Electric Potential Electric field

Electric field lines. Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry.

Conservative nature of Electrostatic Field. Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole.

Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere.

Unit 2: Dielectric Properties of Matter

Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss' Law in dielectrics.

Unit 3: Magnetic Field

Magnetic force between current elements and definition of Magnetic Field B. Biot-Savart's Law and its simple applications: 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 (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field.

Unit 4: Magnetic Properties of Matter

Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability. Relation between B, H, M. Ferromagnetism. B-H curve and hysteresis.

Unit 5: Electromagnetic Induction

Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge Conservation and Displacement current.

Unit 6: Electrical Circuits

AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit.

Unit 7: Network theorems

Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits.

References

- Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
- Electricity and Magnetism, J.H.Fewkes & J.Yarwood. Vol. I, 1991, Oxford Univ. Press

- Electricity and Magnetism, D.Chattopadhyay and P.C.Rakshit, New Central Book Agency, 2011
- Fundamentals of Electricity and Magnetism, B. Ghosh, Books and Allied (P) Ltd., 4th edition, 2015.

Component: Practical

Physics Lab III

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 B and its variation in a solenoid (determine dB/dx)

7. To verify the Thevenin and Norton theorems.

8. To verify the Superposition, and Maximum power transfer theorems.

9. To determine self inductance of a coil.

10. To study 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) Antiresonant frequency and (b) Quality factor Q.

12. To determine self-inductance of a coil by Rayleigh's method.

13. To determine the mutual inductance of two coils by Absolute method.

Course learning outcome:

After going through the course, the student should be able to

- **CO1:** Demonstrate Gauss law, Coulomb's law for the electric field, and apply it to systems of point charges as well as line, surface, and volume distributions of charges.
- **CO2:** Explain and differentiate the vector (electric fields, Coulomb's law) and scalar (electric potential, electric potential energy) formalisms of electrostatics.
- **CO3:** Apply Gauss's law of electrostatics to solve a variety of problems.
- **CO4:** Articulate knowledge of electric current, resistance and capacitance in terms of electric field and electric potential.
- **CO5:** Demonstrate a working understanding of capacitors.
- **CO6:** Describe the magnetic field produced by magnetic dipoles and electric currents.
- **CO7:** Explain Faraday-Lenz and Maxwell laws to articulate the relationship between electric and magnetic fields.
- **CO8:** Understand the dielectric properties, magnetic properties of materials and the phenomena of electromagnetic induction.
- **CO9:** Elaborate how magnetism is produced and list examples where its effects are observed.
- **CO10:** Apply Kirchhoff's rules to analyze AC circuits consisting of parallel and/or series combinations of voltage sources and resistors and to describe the graphical relationship of resistance, capacitor and inductor.
- **CO11:** Apply various network theorems such as Superposition, Thevenin, Norton, Reciprocity, Maximum Power Transfer, etc. and their applications in electronics, electrical circuit analysis, and electrical machines. In the

laboratory course, the student will be able to verify the various laws in electricity and magnetism, various circuit laws and the network theorems.

Course CC4: WAVES AND OPTICS
Credit 6: (4L-0T-2P)

Unit 1: Simple Harmonic Oscillations
SHM: Simple Harmonic Motion. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor.

Unit 2: Superposition of Collinear Harmonic oscillations
Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences

Unit 3: Superposition of two perpendicular Harmonic Oscillations
Graphical and Analytical Methods. Lissajous Figures (1:1 and 1:2) and their uses.

Unit 4: Wave Motion

Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave. Water Waves: Ripple and Gravity Waves

Unit 5: 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 6: 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. Superposition of N Harmonic Waves.

Unit 7: Wave Optics
Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Temporal and Spatial Coherence.

Unit 8: Interference
Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. 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.

Unit 9: Interferometer
Michelson Interferometer-(1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes. Fabry-Perot interferometer.

Unit 10: Diffraction
Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula and its application to rectangular slit.

Unit 11: Fraunhofer diffraction
Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating.

Resolving power of grating.

Unit 12: 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.

Unit 13: Geometrical Optics
Matrix method in Paraxial optics, Aberrations.

References

- Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
- Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
- Optics, Ajoy Ghatak, 2008, Tata McGraw Hill
- Waves and Oscillations, N. K. Bajaj, Tata McGrow Hill

Component: Practical

Physics Lab IV

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 –T law.

2. To investigate the motion of coupled oscillators.

3. To study Lissajous Figures.

4. Familiarization with: Schuster`s focusing; determination of angle of prism.

5. To determine refractive index of the Material of a prism using sodium source.

6. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.

7. To determine the wavelength of sodium source using Michelson's interferometer.

8. To determine wavelength of sodium light using Fresnel Biprism.

9. To determine wavelength of sodium light using Newton's Rings.

10. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.

11. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.

12. To determine dispersive power and resolving power of a plane diffraction grating.

Course learning outcome:

On successfully completing the requirements of this course, the students will have the skill and knowledge to:

- **CO1:** Understand Simple harmonic oscillation and superposition principle.
- **CO2:** Explain superposition of a range of collinear and mutually perpendicular simple harmonic motions and their applications.
- **CO3:** Elaborate the importance of classical wave equation in transverse and longitudinal waves and solving a range of physical systems on its basis.
- **CO4:** Interpret Concept of normal modes in transverse and longitudinal waves: their frequencies and configurations
- **CO5:** Understand the concept of temporal and spatial coherence.

• **CO6:** Discuss Interference as superposition of waves from coherent sources derived from same parent source
• **CO7:** Demonstrate understanding of Interference experiments: Young's Double Slit, Fresnel's biprism, Llyod's Mirror, Newton's Rings.
• **CO8:** Construction and working of Michelson's Interferometer.
• **CO9:** Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from apertures
• **CO10:** Understand Fraunhoffer Diffraction from a slit.
• **CO11:** Learn about the different types of mirror and lenses and respective ray diagrams for image formation along the mathematical tactics and Analysis. Understand Fermat's Principle and its application. In the laboratory component of the course students will perform experiments that expose them to different aspects of real oscillatory systems. In the laboratory course, student will gain hands-on experience of using various optical instruments

Semester III

Course CC5: MATHEMATICAL METHODS-II
Credit 6: (4L-0T-2P)

Unit 1: Fourier Series
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. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

(Include Linear Vector Spaces)
Vector space: Definition, linear independence , bases, dimensionality, inner product; Gram-Schmidt orthogonalisation ; **Space of Complex numbers as a vector space and the ,triangle and Schwarz inequalities.**
Matrices: Representation of linear transformations and change of base; Eigenvalues and eigenvectors; Functions of a matrix; Cayley-Hamilton theorem; Commuting matrices with degenerate eigenvalues ; Orthonormality of eigenvectors.

Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations.

Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits.

Unit 2: Frobenius Method and Special Functions
Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Basic ideas on Legendre, Bessel, Hermite and Laguerre Differential

Equations.

Unit 3: Some Special Integrals
Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).

Unit 4: Theory of Errors
Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error.

Unit 5: Partial Differential Equations
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 6: Complex Analysis

Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions.

References

• Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
• Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.

Component: Practical

<u>Physics Lab V: Scilab, Matlab, Octave</u>

Topics	Description with Applications
Introduction to Numerical computation software Scilab	Introduction to Scilab, Advantages and disadvantages, Scilab environment, Command window, Figure window, Edit window, Variables and arrays, Initialising variables in Scilab, Multidimensional arrays, Subarray, Special values, Displaying output data, data file, Scalar and array operations, Hierarchy of operations, Built in Scilab

	functions, Introduction to plotting, 2D and 3D plotting (2), Branching Statements and program design, Relational & logical operators, the while loop, for loop, details of loop operations, break & continue statements, nested loops, logical arrays and vectorization (2) User defined functions, Introduction to Scilab functions, Variable passing in Scilab, optional arguments, preserving data between calls to a function, Complex and Character data, string function, Multidimensional arrays (2) an introduction to Scilab file processing, file opening and closing, Binary I/o functions, comparing binary and formatted functions, Numerical methods and developing the skills of writing a program (2).
Curve fitting, Least square fit, Goodness of fit, standard deviation	Ohms law to calculate R, Hooke's law to calculate spring constant
Solution of Linear system of equations by Gauss elimination method and Gauss Seidal method. Diagonalization of matrices, Inverse of a matrix, Eigen vectors, eigen values problems	Solution of mesh equations of electric circuits (3 meshes) Solution of coupled spring mass systems (3 masses)
Solution of ODE First order Differential equation Euler, modified Euler and Runge-Kutta second order methods Second order differential equation Fixed difference method	First order differential equation • Radioactive decay • Current in RC, LC circuits with DC source • Newton's law of cooling • Classical equations of motion Second order Differential Equation • Harmonic oscillator (no friction) • Damped Harmonic oscillator • Over damped • Critical damped • Oscillatory • Forced Harmonic oscillator • Transient and • Steady state solution • Apply above to LCR circuits also
Using Scicos / xcos	• Generating square wave, sine wave, saw tooth wave • Solution to harmonic oscillator • Study of beat phenomenon • Phase space plots

Course learning outcome:

After completing this course, student will be able to,

- **CO1:** Demonstrate a periodic function by a sum of harmonics using Fourier series
- **CO2:** Solve differential equations with initial conditions using Laplace transform.
- **CO3:** Evaluate the Fourier transform of a continuous function and be familiar with its basic properties.
- **CO4:** Determine whether the given function is Continuous / differentiable / analytic, and find the derivative of a function. Solve basic ordinary and partial differential equations using analytical techniques.

- **CO5**: Solve improper integrals using beta, gamma functions. Use computer programming for numerical computation.
- **CO6:** The laboratory course will develop mathematical thinking and problem solving skills, design, implement and derive solutions to significant physical problems by means of computational tools, analyze and compare alternative solutions to physical problems.

Course CC6: THERMAL PHYSICS
Credit 6: (4L-0T-2P)

Unit 1: Zeroth and First Law of Thermodynamics

Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient.

Unit 2: Second Law of Thermodynamics

Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

Unit 3: Entropy

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. 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. Unattainability of Absolute Zero.

Unit 4: Thermodynamic Potentials

Extensive and Intensive Thermodynamic Variables. Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations

Unit 5: Maxwell's Thermodynamic Relations

Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) Tds Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process.

Unit 6: Kinetic Theory of Gases Distribution of Velocities

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases.

Unit 7: Molecular Collisions

Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.

Unit 8: Real Gases

Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour 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. p-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a

Perfect Gas. Joule-Thomson Porous Plug Experiment. JouleThomson Effect for Real and Van der Waal Gases. Temperature of Inversion. JouleThomson Cooling.

References

• Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
• A Treatise on Heat, Meghnad Saha, and B.N.Srivastava, 1958, Indian Press

Component: Practical

Physics Lab VI

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.

2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.

3. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.

4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.

5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).

6. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.

7. To calibrate a thermocouple to measure temperature in a specified Range using (1) Null Method, (2) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.

Course learning outcome:

After completing this course, student will be able to,

- **CO1:** Comprehend the basic concepts of thermodynamics, the first and the second law of thermodynamics.
- **CO2:** Elaborate the concept of entropy and the associated theorems.
- **CO3:** Interpret the thermodynamic potentials and analyze their physical interpretations.
- **CO4:** Learn about Maxwell's thermodynamic relations.
- **CO5:** Understand the basic aspects of kinetic theory of gases, Maxwell-Boltzman distribution law, equitation of energies, mean free path of molecular collisions, viscosity, thermal conductivity, diffusion and Brownian motion.
- **CO6:** Understand the real gas equations, Van der Waal equation of state, the Joule-Thompson effect. In the laboratory course, the students will be able to do some basic experiments in thermal Physics.

Semester IV

Course CC7: ANALOG ELECTRONICS
Credit 6: (4L-0T-2P)

Unit 1: Semiconductor Diodes and application

(a) 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.
(b) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, L and C filter. Circuit and operation of clipping and clamping circuit.
(c) Principle and structure of
• LEDs
• Photodiode

• Solar Cell
• Varactor diode

Unit 2: Bipolar Junction transistors and biasing

(a) n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Physical Mechanism of Current Flow. Current gains α and β, Relations between them. Active, Cut-off and saturation Regions. DC Load line and Q-point.
(b) Transistor Biasing and Stabilization Circuits; Fixed Bias, collector to base bias, emitter or self bias, voltage Divider Bias. Transistor as 2 port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance.

Unit 3: Field Effect transistors

JFET and MOSFET (both depletion and enhancement type) as a part of MISFET. Basic structure & principle of operations and their characteristics. Pinch off, threshold voltage and short channel effect.

Unit 4: Regulated power supply

Load regulation and line regulation. Zener diode as a voltage regulator. The problem with the zener regulator circuit. Requirement of feedback and error amplifier. Study of series regulated power supply using pass and error transistor assisted by zener diode as a reference voltage supplier.

Unit 5: Amplifiers

Transistor amplifier; CB, CE and emitter follower circuit and their uses. Load Line analysis of Transistor amplifier. Classification of Class A, B & C Amplifiers with respect to placement to Q point. Frequency response of a CE amplifier. The role of series and parallel capacitors for cut off frequencies. The idea about the value of coupling and bypass capacitor with respect to lower cut-off frequencies. Miller capacitance and its role in higher cut-off frequency.

Unit 6: Feedback amplifiers and OPAMP

(a) Effects of Positive and Negative Feedback. Voltage series, current series, voltage shunt and current shunt feedback and uses for specific amplifiers. Estimation of Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise for voltage series feedback
(b) Operational Amplifiers (Black Box approach): Characteristics of an Ideal and Practical Op-Amp. (IC 741) Open-loop and Closed-loop voltage Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground.
(c) Application of OPAMP:
D.C. Application:
• Inverting and non-inverting amplifiers
• Inverting and non inverting Adder
• Differentiator as Subtractor
• Logarithmic & anti logarithmic amplifiers
• Error amplifier
– Comparator
– Schmidt Trigger
A.C. Application:
• Differentiator
• Integrator

Unit 7: Oscillators

Sinusoidal Oscillators: Barkhausen’s Criterion for self-sustained oscillations. RC Phase shift oscillator, Wein Bridge oscillator, determination of feedback factor and frequency of oscillation. Reactive network feedback oscillators: Hartley’s & Colpitt’s oscillators. Relaxation oscillator using OPAMP.

Reference Books

1. Circuits and Networks, Analysis and Synthesis, A Sudhakar, Shyammohan S Palli, Tata McGraw Hill Education
Private Ltd.
2. Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI Private Ltd.
3. Fundamental Principles of Electronics, B Ghosh, 2nd ed, 2008, Books & Allied (P) Ltd.
4. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata McGraw Hill Education Private Ltd.
5. Electronics: Fundamentals and Applications, J.D. Ryder,2004, Prentice Hall India Private Ltd.
6. Learning OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition,2000, Prentice Hall India Private Ltd.

Additional Reference Books
1. Electronic Devices and Circuit Theory, R.L. Boylestad, L. Nashelsky, PHI Private Ltd.
2. Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford University Press
3. Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk,2008, Springer
4. Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India
5. Microelectronic Circuits, M.H. Rashid, 2nd Edition, Cengage Learning
6. Electronic Devices, Thomas L. Floyd, 7/e 2008, Pearson India
7. Microelectronics, Jacob Millman, Arvin Grabel, Tata McGRAW Hill
8. Electronic Devices and Circuits, S. Salivahanan, N. Suresh Kumar, McGraw Hill Education Private Ltd.

Component: Practical

Physics Lab VII

1. To study the reverse characteristics of Zener diode and study the load and line regulation.
2. To study the static characteristics of BJT in CE Conguration.
3. To design and study the frequency response of the BJT amplifier in CE mode.
4. Construction of a series regulated power supply from an unregulated power supply.
5. To study OPAMP: inverting amplifer, non inverting amplier, adder, substractor, comparator, Schmitt trigger,
Integrator, differentiator, relaxation oscillator.
6. To design a Wien bridge oscillator for given frequency using an op-amp.

Reference Books
1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill
2. Advanced Practical Physics (volume II), B. Ghosh , Shreedhar Publication
3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Ltd
4. Laboratory Manual for Operational Amplifiers and Linear ICs, David A. Bell, Prentice Hall of India Pvt Ltd.

Course learning outcome:

After completing this course, student will be able to,

- **CO1:** Demonstrate the circuit and network theorems.
- **CO2:** Understand the physics of semiconductor devices such as p-n junction, rectifier diodes and applications.
- **CO3:** Develop understanding of bipolar junction transistors, biasing and field effect transistors; solve related problems
- **CO4:** Describe working of rectifier circuits and quantitatively explain effect of capacitance filter, line and load regulation
- **CO5:** Distinguish different type of amplifiers, OP-AMP. Comprehend multivibrators and oscillators.
- **CO6:** At the successful completion of the laboratory course the student is expected to acquire hands on skills/ knowledge on the following:- I-V characterization of PN, Zener diodes, design and build CE amplifiers, build Weinbridge oscillators and construct series regulated power supply, study OPAMP.

Course CC8: DIGITAL ELECTRONICS
Credit 6: (4L-0T-2P)

Unit 1: Integrated Circuits
Principle of Design of monolithic Chip. Advantages and drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only w.r.t. micron/submicron feature length).
Unit 2: Number System
Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal

numbers. Signed and unsigned number representation of binary system. Representation of negative number. 1's Complement and 2's Complement method of subtraction.

Unit 3: Digital Circuits

(a) Difference between Analog and Digital Circuits. Introduction of switching algebra, Huntington's postulates. Combinational logic, Truth table. Introduction of basic logic functions AND, OR and NOT. Implementation of OR, AND, NOT Gates (realization using Diodes and Transistor). De Morgan's Theorems. NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. Circuit representation of gates (both Usual and IEEE symbols). Introduction to different logics like DTL, TTL, MOS and CMOS. MOS and CMOS inverter circuit. NAND/NOR circuit using MOS logic.

(b) Product term and sum term in logical expression. Sum of Product and Product of Sum and mixed expression. Minterm and Maxterm in the expressions. Conversion between truth table and logical expression. Simplification of logical expression using Karnaugh Map.

Unit 4: Implementation of different circuits

Half and Full Adders. Subtractors, 4-bit binary adder/Subtractor. Combinational logic circuits using PAL/PLA, use of IC 7483 as adder and subtractor.

Unit 5: Data processing circuits

Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders.

Unit 6: Sequential Circuits:

Introduction to Next state present state table, excitation table and truth table for Sequential circuits. SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race condition in SR and Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop, T type FF.

Unit 7: Registers and Counters

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

(b) Counters (4 bits): Asynchronous counters: ripple counter, Decade Counter. Synchronous Counter, Ring counter.

Unit 8: Computer Organization

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

Unit 9: Data Conversion

A/D (Ladder and weighted resistance) and D/A conversion circuit

Reference Books:

1. Digital Circuits, Part I & II, D. Raychaudhuri, Eureka Publisher
2. Digital Logic and Computer Design, M. Morris Mano, Pearson Education
3. Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw Hill
4. Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata Mc-Graw Hill
5. Fundamental of Digital Circuits, A. Anand Kumar, Prentice Hall India Learning Pvt. Ltd.
6. Digital Systems, Principles and Applications, R. Tocci, N. S. Widemer, Prentice Hall India Learning Pvt. Ltd.
7. Modern Digital Electronics, R. P. Jain, Tata McGrow Hill Publishing Company
8. Digital Electronics An Introduction to Theory and Practice, Prentice Hall India Learning Pvt. Ltd.
9. Digital Computer Electronics, A. Malvino & Jerald Brown, Tata McGrow Hill Publishing Company.

Component: Practical

Physics Lab VIII

1. To design OR & AND logic with diode and resistor. Basic logic gates with Transistors. To verify the logics by
any type of universal gate NAND/NOR.
2. Construction of half adder and full adder
3. Construction of SR, D, JK FF circuits using NAND gates.
4. Construction of 4 bit shift registers (serial & parallel) using D type FF IC 7476.
5. Construction of 4×1 Multiplexer using basic gates and IC 74151.

Course learning outcome:

After completing this course, student will be able to,

- **CO1:** Demonstrate the concept of Boolean algebra in detail and arithmetic circuits
- **CO2:** Distinguish between analog and digital systems.
- **CO3:** Explain the basics of digital logic and Boolean algebra and apply it to simplify digital logic.
- **CO4:** Analyze the basics of logic gates, data processing, and sequential circuits. Define and distinguish integrated circuits
- **CO5:**. Understand and summarize the construction and functioning of flip flops, shift register, counter, and microprocessor and make use of this understanding to appreciate their application and also explain the basics of computer organization.
- **CO6:** Develop understanding of data conversion.
- **CO7:** In laboratory, construct all logic gates with diode and transistor; and also using NAND/NOR as a building block, construct adders/subtractors; construct Flip flops using NAND gates, shift registers and multiplexer.

Course CC9: MODERN PHYSICS
Credit 6: (4L-0T-2P)

Unit1:

Planck's quantum, Planck's constant and light as a collection of photons; Blackbody Radiation: Quantum theory of Light; Photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. Group and Phase velocities and relation between them. Two-Slit experiment with electrons. Probability. Wave amplitude and wave functions.

Unit2:

Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables): Derivation from Wave Packets impossibility of a particle following a trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle- application to virtual particles and range of an interaction.

Unit3:

Two slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; Probability and probability current densities in one dimension.

Unit4:

One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; Quantum dot as example; Quantum mechanical scattering and tunnelling in one dimension-across a step potential & rectangular potential barrier.

Unit5:

Atomic Structure- Thomson model of atom; Alpha-particle scattering experiment and Rutherford model; Electron orbit; Atomic spectra-the Bohr atom, Energy levels and spectra; Bohr's Correspondence Principle; Sommerfield's elliptic orbits, relativistic corrections; Atomic Excitation-Frank-Hertz experiment

Unit 6:

Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. Nature of nuclear force, NZ graph, Liquid Drop model: semi-empirical mass formula and binding energy, Nuclear Shell Model and magic numbers.

Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay; Beta decay- energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.

Fission and fusion- mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235; Fusion and thermonuclear reactions driving stellar energy (brief qualitative discussions).

Unit 7:

Application of lasers in spectroscopy, in biological and medical sciences, working principle of a laser, Einstein's A and B coefficients. Metastable states. Spontaneous and Stimulated emissions. Optical Pumping and Population Inversion. Three-Level and Four-Level Lasers. Ruby Laser and He-Ne Laser.

References:

• Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
• Quantum Mechanics: Theory & Applications, A.K.Ghatak & S.Lokanathan, 2004, Macmillan

Component: Practical

Physics Lab IX

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-alpha emission line of Hydrogen atom.

6. To determine the ionization 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 tunneling effect in tunnel diode using I-V characteristics.

11. To determine the wavelength of laser source using diffraction of single slit.

12. To determine the wavelength of laser source using diffraction of double slits.

13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating

Course learning outcome:

After getting exposure to this course, student will be able to,

• **CO1:** Identify the main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics, laying the foundation of modern physics.

• **CO2:** Demonstrate the formulation of Schrodinger equation and explain the idea of probability interpretation associated with wave-functions.
• **CO3:** Classify properties of nuclei like density, size, binding energy, nuclear force and structure of atomic nucleus, liquid drop model and mass formula.
• **CO4:** Understand the concept of radioactive decays like alpha, beta, gamma decay. Neutrino, its properties and its role in theory of beta decay.
• **CO5:** Interpret and distinguish Fission and fusion: Nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.
• **CO6:** Develop understanding of spontaneous and stimulated emission of radiation, optical pumping and population inversion. Basic lasing action. In the laboratory course, the students will get opportunity to measure Planck's constant, verify photoelectric effect, determine e/m of electron and work function of a metal.

Semester V

Course CC10: QUANTUM MECHANICS
Credit 6: (4L-0T-2P)

Unit 1: Time dependent Schrodinger equation:

Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle

Unit 2: Time independent Schrodinger equation

Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle

Unit 3: General discussion of bound states in an arbitrary potential

Continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero point energy & uncertainty principle

Unit 4: Quantum theory of hydrogen-like atoms

Time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers l and m; s, p, d,.. shells

Unit 5: Atoms in Electric & Magnetic Fields:
Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton.

Unit 6: Atoms in External Magnetic Fields
Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only).

Unit 7: EPR Paradox

References

- A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill
- Introduction to Quantum Mechanics, D.J. Griffiths, 2nd Ed. 2005, Pearson Education
- Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
- Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
- Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHI Learning of India.
- Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
- Quantum Mechanics: Foundations & Applications, Arno Bohm, 3rd Edn., 1993, Springer
- Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press

Component: Practical

Physics Lab X

Use Python/ Scilab/Octave for solving the following problems based on Quantum Mechanics like

1. Solve the s-wave Schrodinger equation for the ground state and the first excited

state of the hydrogen atom:

$$\frac{d^2y}{dr^2} = A(r)u(r),\ A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

Where m is the reduced mass of the system (which can be chosen to be the mass of

an electron), for the screened coulomb potential

$$V(r) = -\frac{e^2}{r}e^{-r/a}$$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 $(eVÅ)^{1/2}$, m = 0.511x106 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

3. Solve the s-wave radial Schrodinger equation for a particle of mass m:

$$\frac{d^2y}{dr^2} = A(r)u(r),\ A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

For the anharmonic oscillator potential

$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^2, k = 100 MeV fm^{-2}, b = 0, 10, 30 MeV fm^{-3}. In these units, cħ = 197.3 MeV fm. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

4. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2\mu}{\hbar^2}[V(r) - E]$$

Where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D(e^{-2ar^F} - e^{-ar^F}), r' = \frac{r-r_0}{r}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function. Take: m = 940x10^6eV/C^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å

Course learning outcome:

This paper will expose the students to a number of basic foundational topics of quantum Mechanics. The students will be able to:

• **CO1:** Comprehend time independent and time dependent Schrodinger's equation.

• **CO2:** Understand the time evolution of quantum mechanical systems. Apply time dependent Schrodinger's equation to get an insight into time evolution.

• **CO3:** Grasp over the concept of wavefunctions, their normalization, and properties. Explain momentum and position as operators and their commutation relations. Determine expectation values of operators corresponding to physical quantities.

• **CO4:** Explain Eigenvalues, Eigenvectors, stationary states and linear combination of stationary states to describe the solution of time dependent Schrodinger's equation.

• **CO5:** Solve Schrodinger's equation for physical systems like square well potential with the applications of boundary conditions

• **CO6:** Develop a good understanding of Quantum Mechanical harmonic oscillator and describe the concept

• **CO7:** Find the exact solutions of one particle systems, specifically hydrogen atom.

• **CO8:** Understand and demonstrate angular momentum operator and angular momentum quantum numbers.

• **CO9:** Elaborate the interaction of atomic system with electric and magnetic field.

• **CO10:** Demonstrate electron spin, spin orbit interaction, Larmor precession, and LS coupling, JJ coupling in many electron atoms. In the laboratory course, with the exposure in computational programming in the computer lab, the student will be in a position to solve Schrodinger equation for ground state energy and wave functions of various simple quantum mechanical one-dimensional and three dimensional potentials.

Course CC11: ELECTROMAGNETIC THEORY
Credit 6: (4L-0T-2P)

Unit 1: Maxwell Equations

Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density.

Unit 2: EM Wave Propagation in Unbounded Media
Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere.

Unit 3: EM Wave in Bounded Media
Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence)

Unit 4: Polarization of Electromagnetic Waves:
Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. 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

Rotatory Polarization: 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 5: Wave Guides:
Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission.

Unit 6: Optical Fibres:
Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibres (Concept and Definition Only).

References

• Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
• Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.

Component: Practical

Physics Lab XI

1. To verify the law of Malus for plane polarized light.

2. To determine the specific rotation of sugar solution using Polarimeter.

3. To analyze elliptically polarized Light by using a 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, 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 polarization 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 characteristics of PN junction diode.

Course learning outcome:

- **CO1:** Achieve an understanding of the Maxwell's equations, role of displacement current, gauge transformations, scalar and vector potentials, Coulomb and Lorentz gauge, boundary conditions at the interface between different media. Apply Maxwell's equations to deduce wave equation, electromagnetic field energy, momentum and angular momentum density.
- **CO2:** Analyze the phenomena of wave propagation in the unbounded, bounded media.
- **CO3:** Understand the laws of reflection and refraction and to calculate the reflection and transmission coefficients at plane interface in bounded media.
- **CO4:** Interpret the linear, circular and elliptical polarisations of em waves. Production as well as detection of waves in laboratory.
- **CO5:** Understand the concept of optical rotation, theories of optical rotation and their experimental rotation, calculation of angle rotation and specific rotation.
- **CO6:** Demonstrate the features of planar optical wave guide and obtain the Electric field components, Eigen value equations, phase and group velocities in a dielectric wave guide.
- **CO7:** Explain the fundamentals of propagation of electromagnetic waves through optical fibres and calculate numerical apertures for step and graded indices and transmission losses. In the laboratory course, the student gets an opportunity to perform experiments.

Course CC12: STATISTICAL MECHANICS
Credit 6: (4L-0T-2P)

Unit 1: Classical Statistics

Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal 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.

Unit 2: Classical Theory of Radiation

Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula. Rayleigh-Jean's Law. Ultraviolet Catastrophe.

Unit 3: Quantum Theory of Radiation:

Spectral Distribution of Black Body Radiation. 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 law.

Unit 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.

Unit 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.

References

• Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
• Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill

Component: Practical

Physics Lab XII

Use C/Python/Scilab/Octave for solving the problems based on Statistical Mechanics like

1. Plot Planck's law for Black Body radiation and compare it with Wein's Law and Raleigh Jeans Law at high temperature (room temperature) and low temperature.
2. Plot Specific Heat of Solids by comparing (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature (room temperature) and low temperature and compare them for these two cases
3. Plot Maxwell-Boltzmann distribution function versus temperature.
4. Plot Fermi-Dirac distribution function versus temperature.
5. Plot Bose-Einstein distribution function versus temperature.

Course learning outcome:

- **CO1:** Understand the concepts of microstate, macrostate, ensemble, phase space, thermodynamic probability and partition function.
- **CO2:** Analyze the combinatoric studies of particles with their distinguishably or indistinguishably nature and conditions which lead to the three different distribution laws e.g. Maxwell-Boltzmann distribution, Bose-Einstein distribution and Fermi-Dirac distribution laws of particles and their derivation.
- **CO3:** Understand the Gibbs paradox, equipartition of energy and concept of negative temperature in two level system.
- **CO4:** Learn to develop classical radiation laws of black body radiation. Wiens law, Rayleigh Jeans law, ultraviolet catastrophe. Saha ionization formula.
- **CO5:** Learn to calculate the macroscopic properties of degenerate photon gas using BE distribution law, understand Bose-Einstein condensation law and liquid Helium. Bose derivation of Plank's law
- **CO6:** Understand the concept of Fermi energy and Fermi level, calculate the macroscopic properties of completely and strongly degenerate Fermi gas, electronic contribution to specific heat of metals.
- **CO7:** Utilize the application of F-D statistical distribution law to derive thermodynamic functions of a degenerate Fermi gas, electron gas in metals and their properties.
- **CO8:** Determine electron degeneracy pressure and ability to understand the Chandrasekhar mass limit, stability of white dwarfs against gravitational collapse. In laboratory course, students will be able to solve problems on statistical mechanics by C/Python/Scilab/Octave

Semester VI

Course CC13: SPECIAL THEORY OF RELATIVITY
Credit 6: (5L-1T-0P)

Unit-1:
Newtonian Relativity, Galilean Transformation, Electromagnetism and Newtonian Relativity, Attempts to locate absolute frame, the Michaelson-Morley Experiment, Foundation of special theory of relativity, Postulates of special theory of relativity

Unit-2:
The relativity of simultaneity, Lorentz transformation equations, Derivation and Consequences of Lorentz transformation, Time dilation, Length contraction, Synchronization of clocks, Twin paradox. Lorentz transformation in arbitrary direction. Paradox with muons. Doppler effect

Unit-3:
Relativistic dynamics, Mechanics and Relativity, The need to redefine momentum, Relativistic momentum, Relativistic mass, Relativistic energy, kinetic energy and rest mass energy, relativistic force law and dynamics of a single particle, equivalence of mass and energy. Relativistic collisions

Unit-4:
Geometric representation of space-time, Minkowski space. the invariant interval, light cone and world lines. Space-time diagrams. Four-vectors: space-like, time-like & light-like. Four-velocity and acceleration.
Metric and alternating tensors. Four-momentum and energy-momentum relation. Doppler effect from a four vector perspective. Concept of four-force. Conservation of four-momentum. 4-vectors, Tensors, Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and antisymmetric tensors; 4-dimensional velocity and acceleration; 4-momentum and 4-force

Unit-5:
Relativity and electromagnetism The Electromagnetic field tensor and its transformation under Lorentz transformations: relation to known transformation properties of E and B. Electric and magnetic fields due to a uniformly moving charge. Equation of motion of charged particle & Maxwell's equations in tensor form. Motion of charged particles in external electric and magnetic fields. Invariance of Maxwell’s equations.

References

- Introduction to Special Relativity, R. Resnick, 2010, John Wiley and Sons
- Theoretical Physics 4, Special Theory of Relativity, Wolfgang Nolting, Springer
- The Special Theory of Relativity, Banerji and Banerjee 2nd Ed., PHI Learning Private Ltd.

Course learning outcome

- **CO1:** Understand Einstein’s postulates of special relativity
- **CO2:** Apply Lorentz transformations to describe simultaneity, time dilation and length contraction.
- **CO3:** To be able to understand and demonstrate the basic properties of nuclei as well as knowledge of experimental determination of the same, the concept of binding energy, its various dependent parameters, N-Z curves and their significance
- **CO4:** Knowledge of radioactivity and decay laws. A detailed analysis, comparison and energy kinematics of alpha, beta and gamma decays.

- **CO5:** Explain energy losses due to ionizing radiations, energy losses of electrons, gamma ray interactions through matter and neutron interaction with matter.
- **CO6:** Apply the acquired knowledge 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.

Course CC14: SOLID STATE PHYSICS
Credit 6: (4L-0T-2P)

Unit 1: Crystal Structure: Solids

Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis – Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor. Brief introduction to defects in crystals.

Unit 2: Elementary Lattice Dynamics

Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law

Unit 3: Magnetic Properties of Matter

Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia– and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss.

Unit 4: Dielectric Properties of Materials

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. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes.

Unit 5: Ferroelectric Properties of Materials

Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

Unit 6: Elementary band theory

Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (04 probe method) & Hall coefficient.

Unit 7: Superconductivity

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation)

References

• Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
• Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning

Component: Practical

Physics Lab XIII

Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method)

2. To measure the Magnetic susceptibility of Solids.

3. To determine the Coupling Coefficient of a Piezoelectric crystal.

4. To measure the Dielectric Constant of a dielectric Materials with frequency

5. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)

6. To determine the refractive index of a dielectric layer using SPR

7. To study the PE Hysteresis loop of a Ferroelectric Crystal.

8. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.

9. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 ^{o}C) and to determine its band gap.

10. To determine the Hall coefficient of a semiconductor sample.

Course learning outcome:

On successful completion of the module students should be able to

• **CO1:**Elucidate the concept of lattice, crystals and symmetry operations.

• **CO2:**Explain the concepts such as the reciprocal lattice and the Brillouin zone and the dynamics of atoms and electrons in solids.

• **CO3:**Explain diffraction of X-rays by solids to determine the crystal structure.

• **CO4:**Understand the elementary lattice dynamics and its influence on the properties of materials.

• **CO5:**Interpret lattice vibrations, phonons and Einstein and Debye theory of specific heat of solids

• **CO6:**Describe the main features of the physics of electrons in solids.

• **CO7:**Illustrate of Drude Model, Kronig Penny model.

• **CO8:**Understand the origin of energy bands, and how they influence electronic behavior.

• **CO9:**Explain the origin and distinguish dia-, para-, and ferro-magnetic properties of solids.

• **CO10:**Elaborate the origin of the dielectric properties exhibited by solids and the concept of polarizability: Clausius Mosotti Equation. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant.

• **CO11:** Analyze the basics of phase transitions and the preliminary concept and experiments related to superconductivity in solid. In laboratory course, they will measure the magnetic susceptibility, dielectric constant, trace hysteresis loop. They will also employ to four probe methods to measure electrical conductivity and the hall set up to determine the hall coefficient of a semiconductor

Course CC15: PROJECT
Credit 6: (0L-0T-6P)

Course learning outcome:

The students gain considerable expertise in a particular field and is quite well prepared to carry out future research activities in that particular area.