CO-PO attainment
in
Outcome Based Education
Honours Programme
in
Outcome Based Education

Department of Physics

Government General Degree College, Kalna-I

Program Outcome (PO)

- ❖PO1: Disciplinary knowledge
- ❖PO2: Communication Skills
- ❖PO3: Critical thinking
- ❖PO4 : Problem solving
- ❖PO5: Self directed learning
- ❖PO6: Research-related skills
- ❖PO7: Scientific reasoning
- ❖PO8: Information/digital literacy
- ❖PO9: Lifelong learning

Program Specific Outcome (PSO): UG Physics

❖PSO1: **Foundation for Theoretical Concepts of Physics:** To use theoretical methodologies to explain physical laws around us.

❖PSO2: **Foundation for Experimental/Numerical tools of Physics :** The ability to implement/visualize the theoretical knowledge through laboratory based experimental /numerical techniques.

❖PSO3: **Foundation for possible further developments** : The ability to grasp the scientific ideas behind different physical laws and connecting them to broad area of real life applications and provide new ideas and innovations towards research.

Course Content

Semester: I **Course name: Mathematical Physics-I** **Course Code: CC-I**
(Credits: Theory-04, Practicals-02)

CC –I: Mathematical Physics-I
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)
Theory:

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). (2 Lectures)

First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. (13 Lectures)

Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers. (6 Lectures)

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. (5 Lectures)

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. (8 Lectures)

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). (14 Lectures)

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. (6 Lectures)

Introduction to probability: Independent random variables: Probability distribution functions; binomial, Gaussian, and Poisson, with examples. Mean and variance. Dependent events: Conditional Probability. Bayes' Theorem and the idea of hypothesis testing. (4 Lectures)

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. (2 Lectures)

Practicals:

Review of C & C++ Programming fundamentals	Introduction to Programming, constants, variables and data types, operators and Expressions, I/O statements, scanf and printf, cin and cout, Manipulators for data formatting, Control statements (decision making and looping statements) (If statement. If else Statement. Nested if Structure. Else if Statement. Ternary Operator. Goto Statement. Switch Statement. Unconditional and Conditional Looping. While Loop. Do-While Loop. For Loop. Break and Continue Statements. Nested Loops), Arrays (1D & 2D) and strings, user defined functions, Structures and Unions, Idea of classes and objects
Programs:	Sum & average of a list of numbers, largest of a givenlist of numbers and its location in the list, sorting of numbers in ascending descending order, Binary search
Random number generation	Area of circle, area of square, volume of sphere, value of pi (π)
Solution of Algebraic and Transcendental equations by Bisection, Newton Raphson and Secant methods	Solution of linear and quadratic equation, solving $\alpha = \tan\alpha$; $I = I_0\left\{\frac{\sin\alpha}{\alpha}\right\}^2$ in optics.
Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation	Evaluation of trigonometric functions e.g. sin θ, cos θ, tan θ, etc
Numerical differentiation (Forward and Backward difference formula) and Integration (Trapezoidal and Simpson rules), Monte Carlo method	Given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop
Solution of Ordinary Differential Equations (ODE) First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods	First order differential equation • Radioactive decay • Current in RC, LC circuits with DC source • Newton's law of cooling • Classical equations of motion Attempt following problems using RK4 order method: • Solve the coupled differential equations $\frac{dx}{dt} = y + x - \frac{x^3}{3}$; $\frac{dy}{dx} = -x$ For four initial conditions x(0) = 0, y(0) = -1, -2, -3, -4. Plot x vs y for each of the four initial conditions on the same screen for $0 \le t \le 15$. The differential equation describing the motion of a pendulum is $\frac{d^2\theta}{dt^2} = -\sin\theta$. The pendulum is released from rest at an angular displacement α, i. e. $\theta(0) = \alpha$ and $\theta'(0) = 0$. Solve the equation for α = 0.1, 0.5 and 1.0 and plot θ as a function of time in the range $0 \le t \le 8\pi$.

Course Outcome (CO)	Paper: CC-I

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Discussion** of the fundamental concepts of calculus, graphical representation, and approximation techniques. **Identification** and classification of different types of differential equations.	**L1: Remembering**	**1,2,3,7,8,9**	**1,2,3**
2	**Computation** of the First Order and Second Order Differential Equations, and solution of Particular Integral of a non-homogeneous linear differential equation. **Demonstration** of the concept of Partial derivatives.	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
3	**Discussion** of the fundamental properties of vector algebra.	**L1: Remembering**	**1,2,3,4,5,7,9**	**1,2,3**
4	**Computation** of the differentiation and integration of vector fields and application of the techniques to solve problems in electromagnetism, fluid dynamics, and other fields.	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
5	**Development** of a deeper understanding of orthogonal curvilinear coordinate systems of vector calculus and its geometric underpinnings.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
Practical				
1	**Outline** of the C Programming fundamentals	**L1: Remembering**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Computation** of basic mathematical operation using C programinning	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
		Program Outcome (PO) & Program Specific Outcome (PSO)											
Theory	1	3	3	2	-	-	-	2	3	3	3	2	2
	2	3	3	2	2	2	2	2	2	2	2	2	2
	3	2	2	3	3	3	-	3	-	3	3	3	3
	4	3	3	3	3	3	3	3	2	2	2	3	3
	5	3	2	3	3	2	3	3	2	2	2	3	3
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	2.9	2.7	2.7	2.8	2.7	2.8	2.7	2.8	2.6	2.6	2.7	2.7

Course Content

Semester: I | **Course Code: CC-II**
Course name: Mechanics | **(Credits: Theory-04, Practicals-02)**

CC-II: F.M.=75 (Theory-40, Practical–20, Internal Assessment–15)

COURSE OBJECTIVE: The objectives of this course is to provide an in-depth understanding of the principles of Newtonian mechanics and apply them to solve problems involving the dynamics of classical mechanical systems.

Fundamentals of Dynamics: Reference frames; Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable- mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse. (6 Lectures)

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non- conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy. (4 Lectures)
Collisions: Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames. (3 Lectures)

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 pherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation. (12 Lectures)

Elasticity: Relation between Elastic constants. Twisting torque on a Cylinder or Wire. (3 Lectures)

Fluid Motion: Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube. (2 Lectures)

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. (3 Lectures)

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). (6 Lectures)

Oscillations: SHM: Simple Harmonic Oscillations. 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. (7 Lectures)

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. (4 Lectures)

Special Theory of Relativity: Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity, frequency and wave number. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum. (10 Lectures)

Practical Paper:

1. To study the Motion of Spring and calculate (a) Spring constant,(b)gand (c)Modulus of rigidity.
2. To determine the Moment of Inertia of a Flywheel/regular shaped body.
3. To determine g and velocity for a freely falling body using Digital Timing Technique.
4. To determine the Young's Modulus of a Wire by Optical Lever Method.
5. To determine the Modulus of Rigidity of a Wire by Maxwell's needle/dynamical method.
6. To determine the elastic Constants of a wire by Searle's method.
7. To determine the value of g using Bar pendulum/Kater's Pendulum.
8. To determine the value of Young's Modulus by Flexure method.

Course Outcome (CO) **Paper: CC-II**

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Outline** the laws of Newtonian Mechanics leading to the ideas behind inertial reference frame and free body diagram. **Discussing** Simple Harmonic Oscillation as an generic platform to study bound systems in perturbative regime and analyze free and forced oscillators.	L1: Remembering	1,2,3,4,5,6,7,9	1,2,3
2	**Distinguish** different kind of conservative and non-conservative systems and **illustrate** the concept of energy diagram.	L4: Analyzing	1,2,3,4,5,6,7,9	1,2,3
3	**Demonstrate** the ideas behind rotational motion and moment of inertia in this aspect.	L3: Applying	1,2,3,4,5,6,7,8,9	1,2,3
4	**Illustrate** the central force and outline Gravitational field as an example of the same.	L4: Analyzing	1,2,3,4,5,6,7,8,9	1,2,3
5	**Formulate** different ideas of non-inertial reference frame along with practical examples like Coriolis force, Centrifugal force etc.	L6: Creating	1,2,3,4,5,6,7,8,9	1,2,3
Practical				
1	**Demonstrate** experimental verifications of different Mechanical properties like Spring constant, Young's Modulus, Modulus of Rigidity etc. of material of a wire.	L3: Applying	1,2,3,4,5,6,7,8,9	1,2,3
2	**Measure** gravitational acceleration due to Earth using Kater's pendulum method.	L5: Evaluating	1,2,3,4,5,6,7,8,9	1,2,3

Programme Articulation Matrix (CO-PO Matrix)

Program Outcome (PO) & Program Specific Outcome (PSO)

	CO	PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	2	3	3	2	3	-	3	3	2	3
	2	3	3	2	3	2	2	2	-	3	2	2	3
	3	3	2	2	3	2	3	2	3	3	2	2	2
	4	3	2	3	3	3	3	3	2	3	3	3	2
	5	3	2	3	3	3	3	3	2	3	3	3	2
Practical	1	3	3	3	3	2	2	3	3	3	3	3	3
	2	3	3	3	3	2	2	3	3	3	3	3	3
	Average	3	2.6	2.6	3	2.4	2.4	2.7	2.6	3	2.7	2.6	2.6

Course Content

Semester: II **Course name: ELECTRICITY AND MAGNETISM** **Course Code: CC-III**
(Credits: Theory-04, Practicals-02)

CC – III: ELECTRICITY AND MAGNETISM
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:
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. (6 Lectures)
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. (6 Lectures)
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. (10 Lectures)
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. (8 Lectures)
Magnetic Field: Magnetic force between current elements and definition of Magnetic Field B. BiotSavart'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. (9 Lectures)
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. (4 Lectures)
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. (6 Lectures)
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. (4 Lectures)
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. (4 Lectures)
Ballistic Galvanometer: Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR. (3 Lectures)

Practicals:
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 with distance using search coil.
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 by Anderson's bridge.
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) 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 mutual inductance of two coils by Carey-Foster's method.
15. Construction of one ohm coil.

Course Outcome (CO)	Paper: CC-III

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Explain** Electric Field and Electric Potential	L2: Understanding	1, 3, 5,8, 9	1, 2, 3
2	**demonstrate** Dielectric Properties of Matter: .	L3: Applying	1, 2, 3, 5, 4, 6, 9	1, 2, 3
3	**Illustrate** Magnetic fields and magnetic properties of matter	L4: Analyzing	1, 2, 3, 4, 6, 7, 9	1, 2, 3
4	**Assess** Electromagnetic Induction	L5: Evaluating	1, 3, 4, 6, 7, 8, 9	1, 2, 3
5	**Differentiating** electric circuits and network theorems	L4: Analyzing	1, 3, 4, 5, 6, 9	1, 2, 3
Practical				
1	**Determination** of low and high resistance, capacitance, self and mutual inductance	L5: Evaluating	1,2,3,4,5,6,7,8,9	1,2,3
2	**Explain** the characteristics of RC , Series and Parallel LCR circuits	L2: Understanding	1,2,3,4,5,6,7,8,9	1,2,3

Programme Articulation Matrix (CO-PO Matrix)

	CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	-	3	-	3	-	-	3	3	3	3	3
	2	3	2	3	2	2	3	-	-	2	3	3	3
	3	2	2	3	3	-	3	3	-	2	2	3	3
	4	3	-	3	3	-	3	2	2	3	3	3	3
	5	2	-	2	2	2	2	-	-	3	2	2	2
Practical	1	3	3	3	3	3	3	3	3	3	3	3	2
	2	3	3	3	3	3	3	3	3	3	3	3	2
	Average	2.7	2.5	2.9	2.7	2.6	2.8	2.7	2.7	2.7	2.7	2.9	2.8

Course Content

Semester: II
Course name : Waves and Optics

Course Code: CC-IV
(Credits: Theory-04, Practicals-02)

F.M.=75 (Theory-40, Practical–20, Internal Assessment–15)
Theory
COURSE OBJECTIVE: The objectives of this course is to provide an in-depth understanding of the principles of wave mechanics and optics and apply them to solve problems involving the dynamics of oscillations and optical properties.

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. (5 Lectures)
Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses. (2 Lectures)
Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Wave. Plane Progressive (Travelling) Wave. Wave Equation. Particle and Wave Velocities. Differential Equations. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave. Water Waves: Ripple and Gravity Waves. (4 Lectures)
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. (6 Lectures)
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. (7 Lectures)
Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Temporal and Spatial Coherence. (3 Lectures)
Interference: Division of amplitude and wave front. 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. (9 Lectures)
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. (4 Lectures)
Diffraction: Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only). (2 Lectures)
Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating. (8 Lectures)
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. (7 Lectures)
Holography: Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves. Point source holograms. (3 Lectures)

Practical Paper:
1. To investigate the motion of coupled oscillators.
2. To study Lissajous Figures.
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 Bi-prism.
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.

Course Outcome (CO) Paper: CC-IV

Sl. No.	Course Outcome (CO)	Knowledge Level (Bloom's Level)	POs	PSOs
Theory				
1	**Outline** the Superposition of two collinear and perpendicular Harmonic Oscillations	**L1: Remembering**	**1,2,3,5,9**	**1,2,3**
2	**Distinguish** Plane and Spherical Waves; Longitudinal and Transverse Wave; Plane Progressive (Travelling) Wave with setting up the wave equation	**L2: Understanding**	**1,2,3,4,5,7,9**	**1,2,3**
3	**Demonstrating** the fundamental ideas of interference and its applications in design and working of interferometers.	**L3: Applying**	**1,2,3,4,5,7,9**	**1,2,3**
4	**Illustrate** the fundamental theory of diffraction and its applications	**L4: Analyzing**	**1,2,3,4,5,7,8,9**	**1,2,3**
5	**Outline** ideas on working of holography their applications in various fields.	**L4: Analyzing**	**1,2,3,4,6,7,8,9**	**1,2,3**
Practical				
1	**Demonstrate** the Lissajous Figures using CRO and the motion of coupled oscillators.	**L3: Applying**	**1,2,3,4,5,6,7,9**	**1,2,3**
2	**Measure** angle of prism, refractive index of a prism, the dispersive power and Cauchy constants of the material of a prism and determination of wavelength of sodium light by Fresnel Bi-prism, Newton's Rings, diffraction grating. **Determination** of dispersive power and resolving power of a plane diffraction grating	**L5: Evaluating**	**1,2,3,4,5,6,7,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	2	-	2	-	-	-	2	2	2	3
	2	3	3	2	2	2	-	2	-	2	2	2	2
	3	2	2	3	3	3	-	3	-	3	3	3	3
	4	3	3	3	3	3	-	3	2	3	3	3	3
	5	3	3	2	2	-	2	2	2	2	2	3	2
Practical	1	3	3	3	3	2	2	3	-	3	3	3	3
	2	3	3	3	3	2	2	3	-	3	3	3	3
	Average	2.8	2.8	2.6	2.7	2.3	2.0	2.7	2.0	2.6	2.6	2.7	2.7

Course Content

Semester: III	Course name: Mathematical Physics-II Course Code: CC-V (Credits: Theory-04, Practicals-02)

CC- V: MATHEMATICAL PHYSICS-II
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:
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. (10 Lectures)

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions ($J_0(x)$ and $J_1(x)$) and Orthogonality. (24 Lectures)

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral). (4 Lectures)

Theory of Errors: Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error. Least-squares fit. Error on the slope and intercept of a fitted line. (6 Lectures)

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. Diffusion Equation. (14 Lectures)

Practical Paper:

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

Topics	Description with Applications
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)
Generation of Special functions using User defined functions in Scilab	Generating and plotting Legendre polynomials. Generating and plotting Bessel function
Solution of ODE First order Differential equation Euler, modified Euler and Runge-Kutta second order methods Second order differential equation Fixed difference method Partial differential equations	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 • Partial Differential Equation: Wave equation, Heat equation, Poisson equation, Laplace equation
Using Scicos / xcos	• Generating square wave, sine wave, saw tooth wave • Solution to harmonic oscillator • Study of beat phenomenon • Phase space plots

Course Outcome (CO) Paper: CC-V

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Outline** the concept of Fourier decomposition for periodic functions and apply them to physical problems.	**L1: Remembering**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Distinguish** between singular and non-singlar 2nd order ODE and solve them using series solution/Frobenius method. Also, analyze different aspects of Legendre and Bessel functions.	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
3	**Illustrate** the application of Beta, Gamma and Error functions to solve physical problems.	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
4	**Demonstrate** ideas behind theory of error and propagation of error as applicable to different laboratory experiments.	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
5	**Formulate** different types of PDEs appearing in various physical problems and develop the process of solving them.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
Practical				
1	**Design** the algorithm for numerical solutions to problems associated with Linear Algebra, Special functions, ODE and PDEs.	**L6: Creating**	**1,2,3,4,5,7,8,9**	**1,2,3**
2	**Compute** numerical solutions to problems associated with Linear Algebra, Special functions, ODE and PDEs.	**L3: Applying**	**1,2,3,4,5,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	2	2	3	2	3	3	3	3	3	2	2
	2	3	2	3	3	3	3	3	2	3	3	2	3
	3	3	2	2	3	2	3	2	-	3	2	2	2
	4	3	2	3	3	3	3	3	3	3	3	2	3
	5	3	2	3	3	3	3	3	-	3	3	2	3
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	3	2.3	2.7	3	2.7	3	2.9	2.8	3	2.9	2.3	2.7

Course Content

Semester: III **Course name: Thermal Physics** **Course Code: CC-VI**
(Credits: Theory-04, Practicals-02)

CC - VI: Thermal Physics
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:

Introduction to Thermodynamics:

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. (8 Lectures)

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. (10 Lectures)

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. (7 Lectures)

Thermodynamic Potentials: 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 (7 Lectures)

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. (7 Lectures)

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. (7 Lectures)

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. (4 Lectures)

Real Gases: Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO2Gas. 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. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule- Thomson Cooling. (10 Lectures)

Practicals:

1. To determine Stefan's constant.

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

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

4. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) and determine the boiling point of a liquid.

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

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

Course Outcome (CO) Paper: CC-VI

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Description** of the fundamental concepts of Thermodynamics equilibrium and Principle of Conservation of Energy, and **identification** of the work-energy transfer mechanisms.	**L1: Remembering**	**1,2,4,7,8,9**	**1,2,3**
2	**Explanation** of the Carnot engine and its efficiency. Extension of the Second Law of Thermodynamics and its application, and **estimation** of the entropy in different thermodynamics processes.	**L2: Understanding**	**1,2,3,4,6,7,8,9**	**1,2,3**
3	**Illustration** of Maxwell's Thermodynamic relations and its applications. Identification of different kinds of Thermodynamic Potentials and **distinction** of two kinds of phase transitions.	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
4	**Computation** of Maxwell-Boltzmann velocity distribution law and calculation of velocity of gas. **Demonstration** of Transport Phenomenon of gas.	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
5	**Explanation** of behavior of Real Gases and modification of the gas equation.	**L2: Understanding**	**1,2,3,4,5,7,8,9**	**1,2,3**
Practical				
1	**Demonstrate** experimental verifications of different thermodynamical properties of matter	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Measure** different thermodynamical constant	**L5: Evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO		Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	-	2	-	-	2	3	3	2	3	3
	2	3	3	2	2	-	2	2	2	2	2	2	3
	3	2	2	3	3	3	3	3	3	3	3	3	3
	4	3	3	3	3	3	3	3	2	2	3	2	2
	5	3	2	3	3	2	-	3	2	2	3	2	2
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	2.9	2.7	2.8	2.7	2.8	2.8	2.7	2.6	2.6	2.7	2.6	2.7

Course Content

Semester: III **Course name: Digital System and Applications** **Course Code: CC-VII**
(Credits: Theory-04, Practicals-02)

CC - VII: Digital System and Applications
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:

Introduction to CRO: Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. (3 Lectures)

Integrated Circuits (Qualitative treatment only): Active & Passive components. Discrete components. Wafer. Chip. Advantages and drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification of ICs. Examples of Linear and Digital lCs. (3 Lectures)

Digital Circuits: Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. (6 Lectures)

Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map. (6 Lectures)

Data processing circuits: Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders. (4 Lectures)

Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor. (5 Lectures)

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

Timers: IC 555: block diagram and applications: Astable multivibrator and Monostable multivibrator. (3 Lectures)

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). (2 Lectures)

Counters(4 bits): Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter. (4 Lectures)

Computer Organization: Input/Output Devices. Data storage (idea of RAM and ROM).Computer memory. Memory organization & addressing. Memory Interfacing. Memory Map. (6 Lectures)

Intel 8085 Microprocessor Architecture: Main features of 8085. Block diagram. Components. Pin-out diagram. Buses. Registers. ALU. Memory. Stack memory. Timing & Control circuitry. Timing states. Instruction cycle, Timing diagram of MOV and MVI. (8 Lectures)

Introduction to Assembly Language: 1 byte, 2 byte & 3 byte instructions. (4 Lectures)

Practicals:

1. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO.
2. To test a Diode and Transistor using a Multimeter.
3. To design a switch (NOT gate) using a transistor.
4. To verify and design AND, OR, NOT and XOR gates using NAND gates.
5. To design a combinational logic system for a specified Truth Table.
6. To convert a Boolean expression into logic circuit and design it using logic gate ICs.
7. To minimize a given logic circuit.
8. Half Adder, Full Adder and 4-bit binary Adder.
9. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.
10. To build JK Master-slave flip-flop using Flip-Flop ICs
11. To design an astable multivibrator of given specifications using 555 Timer.
12. To design a monostable multivibrator of given specifications using 555 Timer.
13. Write the following programs using 8085 Microprocessor

a) Addition and subtraction of numbers using direct addressing mode
b) Addition and subtraction of numbers using indirect addressing mode
c) Multiplication by repeated addition.
d) Division by repeated subtraction.

Course Outcome (CO) Paper: CC-VII

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Description** of the fundamental properties of CRO, IC's and Digital Circuits.	**L1: Remembering**	**1,2,3,4,7,8,9**	**1,2,3**
2	**Solution** of the Boolean algebra problem and preparation for different Arithmetic Circuits.	**L3: Applying**	**1,2,3,4,6,7,8,9**	**1,2,3**
3	**Illustration** of Sequential Circuits and IC 555 Timer and its relation to Shift registers.	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
4	**Illustration** of 4-bits Counter and identification of the basic structure of Computer.	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
5	**Design** of Intel 8085 Microprocessor and formulation of Assembly Language.	**L6: Creating**	**1,2,3,4,5,7,8,9**	**1,2,3**
Practical				
1	**Illustration** of different gate and Boolean algebra, and identification of adder, subtractor using ICs.	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Design** different kind of multivibrator and formulation of assembly Language.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	2	2	-	-	2	3	3	2	2	3
	2	3	3	2	2	-	2	2	2	2	2	2	3
	3	2	2	3	3	3	3	3	3	3	3	3	2
	4	3	3	3	3	3	3	3	2	2	3	3	3
	5	3	2	3	3	2	-	3	3	3	3	3	2
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	2	3
	Average	2.9	2.7	2.7	2.7	2.8	2.8	2.7	2.7	2.7	2.7	2.6	2.7

Course Content

Semester: III

Course name: **RENEWABLE ENERGY AND ENERGY HARVESTING**

Course Code: SEC-1
(Credits: Theory-02)

SEC-1: F.M.=50 (Theory-40, Internal Assessment–10)

Theory

COURSE OBJECTIVE: The aim of this course is to impart knowledge about Renewable energy and energy harvesting in context of energy crisis and provide them with exposure and hands-on learning wherever possible.

Fossil fuels and Alternate Sources of energy: Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity.
(3 Lectures)

Solar energy: Solar energy, its importance, storage of solar energy, solar pond, non convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems.
(6 Lectures)

Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies.
(3 Lectures)

Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices. (3 Lectures)
Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass. (2 Lectures)

Geothermal Energy: Geothermal Resources, Geothermal Technologies. (2 Lectures)

Hydro Energy: Hydropower resources, hydropower technologies, environmental impact of hydro power sources. (2 Lectures)

Piezoelectric Energy harvesting: Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric energy harvesting applications, Human power. (4 Lectures)
Electromagnetic Energy Harvesting: Linear generators, physics mathematical models, recent applications.
(2 Lectures)
Carbon captured technologies, cell, batteries, power consumption. (2 Lectures)
Environmental issues and Renewable sources of energy, sustainability. (1 Lecture)

Course Outcome (CO) Paper: SEC-1

Sl. No.	Course Outcome (CO)	Knowledge Level (Bloom's Level)	POs	PSOs
1	**Identify** renewable and non-renewable energy sources in the context of energy crisis	**L1: Remembering**	**1,2,3,5,9**	**1,2,3**
2	**Give example** of Solar, Wind, Geothermal, Ocean, Hydro energy sources	**L2: Understanding**	**1,2,3,4,5,7,9**	**1,2,3**
3	**Demonstrating** the fundamental ideas of Piezoelectric and Electromagnetic Energy harvesting	**L3: Applying**	**1,2,3,5,6,7,9**	**1,2,3**
4	**Illustrate** the basic concepts of Carbon capture technologies and Environmental issues along with sustainability of Renewable sources of energy	**L4: Analyzing**	**1,2,3,5,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
	PO 1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO 1	PSO 2	PSO 3
1	3	3	2	-	2	-	-	-	2	3	3	2
2	3	3	2	2	2	-	2	-	2	3	3	3
3	2	2	3	-	3	2	3	-	3	2	2	3
4	3	3	3	-	3	-	3	2	3	2	3	3
Average	2.8	2.8	2.5	2.0	2.5	2.0	2.6	2.0	2.5	2.7	2.8	2.5

Course Content

Semester: IV **Course name: Mathematical Physics-III** **Course Code: CC-VIII**
(Credits: Theory-04, Practicals-02)

CC - VIII: Mathematical Physics-III
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:

Course Objective: The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

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. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy’s Integral formula. Simply and multiply connected region. Laurent and Taylor’s expansion. Residues and Residue Theorem. Application in solving Definite Integrals. (30 Lectures)

Integrals Transforms:

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. (15 Lectures)

Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order 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 2nd order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1st order. Solution of heat flow along infinite bar using Laplace transform.
(15 Lectures)

Practicals:

Scilab/C++ based simulations experiments based on Mathematical Physics problems like

1. Solve differential equations
2. Dirac Delta Function
3. Fourier Series
4. Frobenius method and Special functions
5. Calculation of error for each data point of observations recorded in experiments done in previous semesters
6. Calculation of least square fitting manually without giving weightage to error. Confirmation of least square fitting of data through computer program.
7. Evaluation of trigonometric functions e.g. sin θ, Given Bessel’s function at N points find its value at an intermediate point. Complex analysis: Integrate 1/(x2+2) numerically and check with computer integration.
8. Compute the nth roots of unity for n = 2, 3, and 4.
9. Find the two square roots of −5+12j.
10. Integral transform: FFT of
11. Solve Kirchoff’s Current law for any node of an arbitrary circuit using Laplace’s transform.
12. Solve Kirchoff’s Voltage law for any loop of an arbitrary circuit using Laplace’s transform.
13. Perform circuit analysis of a general LCR circuit using Laplace’s transform.

Course Outcome (CO) **Paper: CC-VIII**

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Definition** and representation of Complex Numbers.	**L1: Remembering**	**1,2,4,7,8,9**	**1,2,3**
2	**Explanation** of Analyticity and Cauchy-Riemann Conditions and **estimation** of different kind of Singularity.	**L2: Understanding**	**1,2,3,4,6,7,8,9**	**1,2,3**
3	**Computation** of Cauchy's Integral formula, Residues and Residue Theorem and solution of Definite Integrals.	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
4	**Evaluation** of Fourier Transform of different function and **assessment** of the 1-D Wave and Diffusion/Heat Flow Equations.	**L5: Evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
5	**Evaluation** of Laplace Transform (LT) of Elementary functions and **assessment** of Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations, heat flow along infinite bar using Laplace transform.	**L5: Evaluating**	**1,2,3,4,5,7,8,9**	**1,2,3**
Practical				
1	**Computation** of differential equation, Dirac Delta Function, Fourier series and **find** the root of an equation	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Evaluation** of Fourier Transform and Laplace transform of different function	**L5: Evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
		Program Outcome (PO) & Program Specific Outcome (PSO)											
Theory	1	3	3	-	2	-	-	2	3	3	2	3	3
	2	3	3	2	2	-	2	2	2	2	2	3	3
	3	2	2	3	3	3	3	3	3	3	3	2	2
	4	3	3	3	3	3	3	3	2	2	3	3	3
	5	3	2	3	3	2	-	3	2	2	3	2	2
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	2
	Average	2.9	2.7	2.8	2.7	2.8	2.8	2.7	2.6	2.6	2.7	2.7	2.8

Course Content

Semester: IV | **Course name: Elements of modern physics** | **Course Code: CC-IX**

(Credits: Theory-04, Practicals-02)

CC - IX: ELEMENTS OF MODERN PHYSICS
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:
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. (14 Lectures)

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. (5 Lectures)

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. (10 Lectures)

One dimensional infinitely rigid box- energy eigenvalues and eigen functions, normalization; Quantum dot as example; Quantum mechanical scattering and tunnelling in one dimension across a step potential & rectangular potential barrier. (10 Lectures)
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. (6 Lectures)

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. (8 Lectures)

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). (3 Lectures)

Lasers: 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. Basic lasing. (4 Lectures)

Practicals
1. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
2. To determine work function of material of filament of directly heated vacuum diode.
3. To determine the Planck‟s constant using LEDs of at least 4 different colours.
4. To determine the wavelength of H-alpha emission line of Hydrogen atom.
5. To determine the excitation potential of mercury/Argon by Franck-Hertz experiment.
6. To determine the absorption lines in the rotational spectrum of Iodine vapour.
7. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
8. To setup the Millikan oil drop apparatus and determine the charge of an electron.
9. To show the tunnelling effect in tunnel diode using I-V characteristics.
10. To determine the wavelength of laser source using diffraction of single slit.

Course Outcome (CO) Paper: CC-IX

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	Starting from Double Slit Experiment **formulate** mathematical structure of Quantum theory.	**L6: Creating**	**1,2,3,4,5,6,7,9**	**1,2,3**
2	**Outline** the Uncertainty Principal in Quantum theory and apply the same for physical systems.	**L4: Analyzing**	**1,2,3,4,5,6,7,9**	**1,2,3**
3	**Illustrate** different aspects of wave function and derive the same for one dimensional infinite potential well problem.	**L4: Analyzing**	**1,2,3,4,5,6,7,9**	**1,2,3**
4	**Outline** Nuclear Physics based on Liquid drop model and discuss the theory of radioactivity.	**L1: Remembering**	**1,2,3,4,5,6,7,9**	**1,2,3**
5	**Demonstrate** theory of Fission and Fusion in light of Nuclear Energy.	**L3: Applying**	**1,2,3,4,5,6,7,9**	**1,2,3**
Practical				
1	**Evaluate** of plank constant, wavelength of H-alpha emission line of Hydrogen atom	**L5: evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Design** setup for the Millikan oil drop experiment, tunnelling effect in tunnel diode using I-V characteristics.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	2	3	3	3	3	3	-	3	2	3	3
	2	3	2	3	3	3	2	3	-	3	2	3	3
	3	3	2	3	3	3	2	3	-	3	2	3	3
	4	3	2	2	2	2	2	3	-	3	2	2	2
	5	3	3	2	2	2	2	3	-	3	3	2	2
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	2
	Average	3	2.4	2.7	2.7	2.7	2.4	3	3	3	2.4	2.7	2.6

Course Content

Semester: IV
Course name : ANALOG SYSTEMS AND APPLICATIONS

Course Code: CC-X

(Credits: Theory-04, Practicals-02)

F.M.=75 (Theory-40, Practical–20, Internal Assessment–15)
Theory

COURSE OBJECTIVE: The objectives of this course is to deliver an in-depth understanding of the principles of Analog Electronics and apply them to solve problems involving such systems.

Semiconductor Diodes: 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. Current Flow Mechanism in Forward and Reverse Biased Diode. (10 Lectures)

Two-terminal Devices and their Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter (2) Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell. (6 Lectures)

Bipolar Junction transistors: 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. (6 Lectures)

Amplifiers: Transistor Biasing and Stabilization Circuits. Fixed Bias and 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. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers. (10 Lectures)

Coupled Amplifier: Two stage RC-coupled amplifier and its frequency response. (4 Lectures)

Feedback in Amplifiers: Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. (4 Lectures)

Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators. (4 Lectures)

Operational Amplifiers (Black Box approach): 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. (4 Lectures)

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator. (9 Lectures)

Conversion: Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion (successive approximation) (3 Lectures)

Practical :
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 voltage regulator.
3. Study of V-I & power curves of solar cells, and find maximum power point & efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. To study the frequency response of voltage gain of a RC-coupled transistor amplifier.
6. To study a Wien bridge oscillator for given frequency using an op-amp.
7. To design an inverting / non-inverting amplifier using Op-amp (741) for dc voltage of given gain.
8. To add two dc voltages using Op-amp in inverting and non-inverting mode.
9. To investigate the use of an op-amp as an Integrator / Differentiator.

Course Outcome (CO) **Paper: CC-X**

Sl. No.	Course Outcome (CO)	Knowledge Level (Bloom's Level)	POs	PSOs
Theory				
1	**Describe** the formation of P-N junction diode and barrier potential across the junction along with mechanism of current flow in forward and reverse bias.	**L1: Remembering**	**1,2,3,8,9**	**1,2,3**
2	**Explain** Ripple and Regulation characteristics of full wave rectifier with and without capacitor filter and Study of Zener diode as voltage regulator	**L2: Understanding**	**1,2,3,4,5,9**	**1,2,3**
3	**Demonstrate** the concept of transistor with the basic techniques of biasing the transistor	**L3: Applying**	**1,2,3,4,5,7,9**	**1,2,3**
4	**Outline** h-parameter equivalent circuit for the analysis of a single-stage and two-stage R-C coupled amplifier using hybrid model	**L4: Analyzing**	**1,2,3,4,5,7,8,9**	**1,2,3**
5	**Illustrate** the concept of OP-AMP and its uses as Inverting and non-inverting amplifiers, Adder, Subtractor, Differentiator, Integrator, Log amplifier, Zero crossing detector, Wein bridge oscillator.	**L4: Analyzing**	**1,2,3,4,6,7,8,9**	**1,2,3**
Practical				
1	**Demonstrate** V-I characteristics of PN junction diode, and LED, Zener diode as voltage regulator, Study the characteristics of a BJT in CE mode frequency response of RC-coupled amplifier	**L3: Applying**	**1,2,3,4,5,6,7,9**	**1,2,3**
2	**Design** an inverting / non-inverting amplifier using Op-amp (741) for dc voltage of given gain, add two dc voltages using Op-amp in inverting and non-inverting mode	**L6: Creating**	**1,2,3,4,5,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	2	-	-	-	-	2	2	3	2	3
	2	3	3	2	2	2	-	-	-	3	3	2	3
	3	3	2	3	3	3	-	3	-	2	2	3	3
	4	2	2	3	3	3	-	3	2	3	2	3	2
	5	3	3	2	2	-	2	2	2	2	3	2	3
Practical	1	3	3	3	3	3	3	3	-	3	3	3	3
	2	3	3	3	3	3	-	3	3	3	3	3	3
	Average	2.8	2.7	2.6	2.7	2.8	2.5	2.8	2.3	2.6	2.7	2.6	2.8

Course Content

Semester: IV

Course Code: SEC-2

(Credits: Theory-02)

Course name: ELECTRICAL CIRCUITS AND NETWORK SKILLS

SEC-2: F.M.=50 (Theory-40, Internal Assessment–10)

Theory

COURSE OBJECTIVE: The aim of this course is to enable the students to design the electrical circuits, networks and appliances through hands-on mode.

Basic Electricity Principles: Voltage, Current, Resistance, and Power. Ohm's law. Series, parallel, and series-parallel combinations. AC Electricity and DC Electricity. Familiarization with multimeter, voltmeter and ammeter. (3 Lectures)

Understanding Electrical Circuits: Main electric circuit elements and their combination. Rules to analyse DC sourced electrical circuits. Current and voltage drop across the DC circuit elements. Single-phase and three-phase alternating current sources. Rules to analyse AC sourced electrical circuits. Real, imaginary and complex power components of AC source. Power factor. Saving energy and money. (4 Lectures)

Electrical Drawing and Symbols: Drawing symbols. Blueprints. Reading Schematics. Ladder diagrams. Electrical Schematics. Power circuits. Control circuits. Reading of circuit schematics. Tracking the connections of elements and identify current flow and voltage drop. (4 Lectures)

Generators and Transformers: DC Power sources. AC/DC generators. Inductance, capacitance, and impedance. Operation of transformers. (3 Lectures)

Electric Motors: Single-phase, three-phase & DC motors. Basic design. Interfacing DC or AC sources to control heaters & motors. Speed & power of ac motor. (4 Lectures)

Solid-State Devices: Resistors, inductors and capacitors. Diode and rectifiers. Components in Series or in shunt. Response of inductors and capacitors with DC or AC sources. (3 Lectures)

Electrical Protection: Relays. Fuses and disconnect switches. Circuit breakers. Overload devices. Ground-fault protection. Grounding and isolating. Phase reversal. Surge protection. Interfacing DC or AC sources to control elements (relay protection device). (4 Lectures)

Electrical Wiring: Different types of conductors and cables. Basics of wiring-Star and delta connection. Voltage drop and losses across cables and conductors. Instruments to measure current, voltage, power in DC and AC circuits. Insulation. Solid and stranded cable. Cable trays. Splices: wirenuts, crimps, terminal blocks, split bolts, and solder. Preparation of extension board. (5 Lectures)

Course Outcome (CO) **Paper: SEC-2**

Sl. No.	Course Outcome (CO)	Knowledge Level (Bloom's Level)	POs	PSOs
1	**Identify** Basic Electricity Principles and Understanding Electrical Circuits	**L1: Remembering**	**1,2,3,5,9**	**1,2,3**
2	**Explain** the principle of operation of Electric Generator, Transformer and Electric Motors	**L2: Understanding**	**1,2,3,4,5,7,9**	**1,2,3**
3	**Demonstrating** the fundamental ideas of Solid State Devices such as Resistors, inductors and capacitors. Diode and rectifiers	**L3: Applying**	**1,2,3,4,5,6,7,9**	**1,2,3**
4	**Outline** the fundamental ideas of Electrical Protection and Electrical Wiring.	**L4: Analyzing**	**1,2,3,4,5,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO 1	PSO 2	PSO 3
1	3	3	2	-	2	-	-	-	2	3	2	2
2	3	3	2	2	2	-	2	-	2	3	2	2
3	2	2	3	3	3	2	3	-	3	2	3	3
4	3	3	3	3	3	-	3	2	3	3	3	3
Average	2.8	2.8	2.5	2.6	2.5	2.0	2.6	2.0	2.5	2.8	2.5	2.5

Course Content

Semester: V | **Course name: Quantum Mechanics & Applications** | **Course Code: CC-XI**
(Credits: Theory-04, Practicals-02)

CC – XI: Quantum Mechanics & Applications
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:

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. (6 Lectures)

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. (10 Lectures)

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. (12 Lectures)

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. (10 Lectures)

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. (8 Lectures)

Atoms in External Magnetic Fields: Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only). (4 Lectures)

Many electron atoms: Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms- L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.). (10 Lectures)

Practicals:

1. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

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

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

Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 $(eVÅ)^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511×10^6 eV/c^2.

2. Solve the s-wave radial Schrodinger equation for an atom:

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

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

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

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 = 0.511×10^6 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:

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

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 hydrogenmolecule:

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

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

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

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 = 940×10^6 eV/C^2, D = 0.755501 eV, α = 1.44, r_0 = 0.131349 Å

Course Outcome (CO)	Paper: CC-XI

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Definition** of quantum states, wave functions, and probability amplitudes and solution of the time-dependent and time-independent Schrödinger equations for simple systems.	**L1: Remembering**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Computation** of bound states of particle-wave function in an arbitrary potential.	**L3: Applying**	**1,2,3,4,6,7,8,9**	**1,2,3**
3	**Illustration** of Quantum theory of Hydrogen-like atoms.	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
4	**Estimation** of the quantum state of Atoms in presence of Electric and Magnetic Fields.	**L5: Evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
5	**Design** of different types of coupling in Many electron atoms.	**L6: Creating**	**1,2,3,4,5,7,8,9**	**1,2,3**
Practical				
1	**Estimation** of particle wave function for different kind of boundary conditions.	**L5: Evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Computation** of energy eigenvalues for different potential system	**L5: Evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	-	2	-	-	2	3	3	3	3	3
	2	3	3	2	2	-	2	2	2	2	2	3	3
	3	2	2	3	3	3	3	3	3	3	3	2	2
	4	3	3	3	3	3	3	3	2	2	2	3	3
	5	3	2	3	3	2	-	3	2	2	2	3	2
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	2.9	2.7	2.8	2.7	2.8	2.8	2.7	2.6	2.6	2.6	2.9	2.7

Course Content

Semester: V
Course name : SOLID STATE PHYSICS

Course Code: CC-XII
(Credits: Theory-04, Practicals-02)

F.M.=75 (Theory-40, Practical–20, Internal Assessment–15)

Theory

COURSE OBJECTIVE: The objectives of this course is to deliver an in-depth understanding of the principles of Solid state physics and its applications in the field of modern physics aspect.

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. (12 Lectures)

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. T3 law. (10 Lectures)

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. (8 Lectures)

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. (8 Lectures)

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. (6 lectures)

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. (10 Lectures)

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) (6 Lectures)

Practical :

1. To measure the Dielectric Constant of a dielectric Materials with frequency.
2. To determine the band gap using a thermistor.
3. To study the PE Hysteresis loop of a Ferroelectric Crystal.
4. To draw the BH curve of Ferromagnetic material using Solenoid & determine energy loss from Hysteresis.
5. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 0C) and to determine its band gap.
6. To determine the Hall coefficient of a semiconductor sample

Course Outcome (CO) **Paper: CC-XII**

Sl. No.	Course Outcome (CO)	Knowledge Level (Bloom's Level)	POs	PSOs
Theory				
1	**Describe** the basic concept of Crystal Structure and Elementary Lattice Dynamics	**L1: Remembering**	**1,2,3,4,5,9**	**1,2,3**
2	**understand** the Magnetic Properties of Matter; distinguish Dia-, Para-, Ferri- and Ferromagnetic Materials and theory to explain such magnetisms.	**L2: Understanding**	**1,2,3,5,9**	**1,2,3**
3	**Illustrate** the Dielectric Properties of Materials: concept of polarization and optical phenomena	**L4: Analyzing**	**1,2,3,4,7,9**	**1,2,3**
4	**Summarize** Elementary band theory of conductors, insulators and semiconductors and measure conductivity and Hall coefficient	**L5: Evaluating**	**1,2,3,4,6,7,8,9**	**1,2,3**
5	**Demonstrate** the phenomenon of Superconductivity along with qualitative theoretical explanation.	**L3: Applying**	**1,2,3,4,5,7,8,9**	**1,2,3**
Practical				
1	**Measure** different parameter such as the Dielectric Constant of a dielectric Materials with frequency, band gap using a thermistor, the resistivity of a semiconductor by four-probe method, Hall coefficient of a semiconductor.	**L5: Evaluating**	**1,2,3,4,5,6,7,9**	**1,2,3**
2	**Demonstrate** the PE Hysteresis loop of a Ferroelectric Crystal and BH curve of Ferromagnetic material using Solenoid	**L3: Applying**	**1,2,3,4,5,6,7,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	2	2	2	-	-	-	3	2	2	3
	2	3	3	2	-	2	-	-	-	2	2	2	3
	3	3	2	3	3	-	-	3	-	3	3	3	2
	4	3	2	3	3	-	2	3	2	3	3	3	2
	5	3	3	2	2	2	-	2	2	2	2	2	3
Practical	1	3	3	3	3	2	2	3	-	3	3	3	3
	2	3	3	3	3	2	2	3	-	3	3	3	3
	Average	3	2.7	2.6	2.7	2.0	2.0	2.8	2.0	2.7	2.6	2.8	2.7

Program Outcome (PO) & Program Specific Outcome (PSO)

Course Content

Semester: V **Course name: Advanced mathematical physics** **Course Code: DSE-1**
(Credits: Theory-04, Practicals-02)

DSE-1: ADVANCED MATHEMATICAL PHYSICS
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:

Linear Vector Spaces: Abstract Systems. Binary Operations and Relations. Introduction to Groups and Fields. Vector Spaces and Subspaces. Linear Independence and Dependence of Vectors. Basis and Dimensions of a Vector Space. Change of basis. Homomorphism and Isomorphism of Vector Spaces. Linear Transformation. Algebra of Linear Transformations. Non-singular Transformations. Representation of Linear Transformations by Matrices.

Matrices: Addition and Multiplication of Matrices. Null Matrices. Diagonal, Scalar and Unit Matrices. Upper Triangular and Lower-Triangular Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix. Hermitian and Skew- Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrices. Trace of a Matrix. Inner Product.

Eigen-values and Eigenvectors. Cayley- Hamiliton Theorem. Diagonalization of Coupled Linear Ordinary Differential Equations. Functions of a Matrix.

Cartesian Tensors: Transformation of Co-ordinates. Einstein's Summation Convention. Relation between Direction Cosines. Tensors. Algebra of Tensors.Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti- symmetric Tensors. Invariant Tensors: Kronecker and Alternating Tensors. Association of Antisymmetric Tensor of Order Two and Vectors. Vector Algebra and Calculus using Cartesian Tensors : Scalar and Vector Products, Scalar and Vector Triple Products. Differentiation. Gradient, Divergence and Curl of Tensor Fields. Vector Identities. Tensorial Formulation of Analytical Solid Geometry : Equation of a Line. Angle Between Lines. Projection of a Line on another Line. Condition for Two Lines to be Coplanar. Foot of the Perpendicular from a Point on a Line.Rotation Tensor (No Derivation).Isotropic Tensors. Tensorial Character of Physical Quantities. Moment of Inertia Tensor. Stress and Strain Tensors : Symmetric Nature. Elasticity Tensor. Generalized Hooke's Law.

General Tensors: Transformation of Co-ordinates. Minkowski Space. Contravariant & Covariant Vectors. Contravariant, Covariant and Mixed Tensors. Kronecker Delta and Permutation Tensors. Algebra of Tensors. Sum, Difference & Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Metric Tensor.

Practicals

Scilab/ C++ based simulations experiments based on Mathematical Physics problems like
1. Linear algebra:
• Multiplication of two 3 x 3 matrices.
• Eigenvalue and eigenvectors of a given matrix. Orthogonal polynomials as eigenfunctions of Hermitian differential operators.
2. Determination of the principal axes of moment of inertia through diagonalization.
3. Vector space of wave functions in Quantum Mechanics: Position and momentum differential operators and their commutator, wave functions for stationary states as eigenfunctions of Hermitian differential operator.
4. Lagrangian formulation in Classical Mechanics with constraints.
5. Study of geodesics in Euclidean and other spaces (surface of a sphere, etc).
6. Estimation of ground state energy and wave function of a quantum system.

Course Outcome (CO) **Paper: DSE-1**

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Develop** the theory of abstract Linear Vector Space and linear transformation in Linear Vector Spaces.	**L6: Creating**	**1,2,3,4,5,6,7,9**	**1,2,3**
2	**Illustrate** the idea of matrices as representation of Linear transformation and develop different properties of the same.	**L4: Analyzing**	**1,2,3,4,5,6,7,9**	**1,2,3**
3	**Formulate** the Eigen value problem and apply the same for solving physical systems.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
4	**Define** General Tensors and correlate them with physical quantities.	**L2: Understanding**	**1,2,3,4,5,7,8,9**	**1,2,3**
5	**Apply** the understanding of General Tensors to Cartesian Tensors and demonstrate the utility of the same for different physical problems.	**L3: Applying**	**1,2,3,4,6,7,8,9**	**1,2,3**
Practical				
1	**Design** the algorithm for numerical solutions to problems associated with Linear Algebra, Quantum and Classical Mechanics.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Compute** numerical solutions to problems associated with Linear Algebra, Quantum and Classical Mechanics.	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	2	3	1	3	3	3	-	3	2	3	2
	2	3	2	3	3	3	3	3	-	3	2	3	2
	3	3	3	3	3	3	3	3	2	3	3	3	3
	4	3	3	3	3	3	3	3	2	3	3	3	3
	5	3	3	2	2	3	3	3	2	3	3	2	3
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	3	2.7	2.9	2.6	3	3	3	2.4	3	2.7	2.9	2.7

Course Content

Semester: V **Course Code: DSE-2**

Course Name: Classical Dynamics **(Credits: Theory-06)**

F.M.=75 (Theory-60, Internal Assessment–15)

Theory: 75 Lectures

Course Object: The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

Classical Mechanics of Point Particles: Review of Newtonian Mechanics; Application to the motion of a charge particle in external electric and magnetic fields- motion in uniform electric field, magnetic field-gyroradius and gyrofrequency, motion in crossed electric and magnetic fields. Generalized coordinates and velocities, Hamilton's principle, Lagrangian and the Euler-Lagrange equations, one-dimensional examples of the Euler-Lagrange equations- one-dimensional Simple Harmonic Oscillations and falling body in uniform gravity; applications to simple systems such as coupled oscillators Canonical momenta & Hamiltonian. Hamilton's equations of motion. Applications: Hamiltonian for a harmonic oscillator, solution of Hamilton's equation for Simple Harmonic Oscillations; particle in a central force field-conservation of angular momentum and energy.

(22 Lectures)

Small Amplitude Oscillations: Minima of potential energy and points of stable equilibrium, expansion of the potential energy around a minimum, small amplitude oscillations about the minimum, normal modes of oscillations example of N identical masses connected in a linear fashion to (N -1) - identical springs.

(10 Lectures)

Special Theory of Relativity: Postulates of Special Theory of Relativity. Lorentz Transformations. Minkowski space. The invariant interval, light cone and world lines. Space-time diagrams. Time-dilation, length contraction and twin paradox. Four-vectors: space-like, time-like and 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. Relativistic kinematics. Application to two-body decay of an unstable particle.

(33 Lectures)

Fluid Dynamics: Density ρ and pressure P in a fluid, an element of fluid and its velocity, continuity equation and mass conservation, stream-lined motion, laminar flow, Poiseuille's equation for flow of a liquid through a pipe, Navier-Stokes equation, qualitative description of turbulence, Reynolds number.

(10 Lectures)

Course Outcome (CO) Paper: DSE-2

Sl. No.	Course Outcome (CO)	Knowledge Level (Bloom's Level)	POs	PSOs
1	**Explanation** of Euler-Lagrange equations and Hamilton's equations of motion for different physical systems.	**L2: Understanding**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Illustration** of Small Amplitude Oscillations**.**	**L4: Analyzing**	**1,2,3,4,6,7,8,9**	**1,2,3**
3	**Comprehension** of Einstein's postulate of Special Theory of Relativity **and derivation** of the Lorentz transformations for time and space coordinates.	**L2: Understanding**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
4	**Formulation** of Relativistic Mass and Energy relation and development of Relativistic Dynamics, Electrodynamics and Doppler Effect.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
5	**Estimation** of Fluid Dynamics Equations	**L5: Evaluating**	**1,2,3,4,5,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO 1	PSO 2	PSO 3
1	3	3	-	2	-	-	2	3	3	3	2	2
2	3	3	2	2	-	2	2	2	2	2	2	2
3	2	2	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	2	2	2	3	3
5	3	2	3	3	2	-	3	2	2	2	3	3
Average	2.8	2.6	2.8	2.6	2.7	2.7	2.6	2.4	2.4	2.4	2.6	2.6

Course Content

Semester: VI **Course name: Electromagnetic Theory** **Course Code: CC-XIII**
(Credits: Theory-04, Practicals-02)

CC – XIII: Electromagnetic Theory
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:

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. (12 Lectures)

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. (10 Lectures)

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) (10 Lectures)

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 (12 Lectures)

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. (5 Lectures)

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. (8 Lectures)

Optical Fibres: Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibres (Concept and Definition Only). (3 Lectures)

Practicals:

1. To determine the specific rotation of sugar solution using Polarimeter.
2. To analyze elliptically polarized Light by using a Babinet's compensator.
3. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
4. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
5. To verify the law of Malus for plane polarized light.
6. To determine the Boltzmann constant using V-I characteristics of PN junction diode.

Course Outcome (CO) Paper: CC-XIII

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Review** of Maxwell's equations**. Explaining** the same which represents the state of electromagnetic theory.	**L2: Understanding**	**1, 3, 5,8, 9**	**1, 2, 3**
2	**Employing** and **demonstrating** electromagnetic wave propagation in unbounded medium – isotropic, dielectric medium, dilute plasma, and ionosphere.	**L3: Applying**	**1, 2, 3, 5, 4, 6, 9**	**1, 2, 3**
3	**Illustrating** electromagnetic waves in bounded media and relating the laws of reflection and refraction.	**L4: Analyzing**	**1, 2, 3, 4, 6, 7, 9**	**1, 2, 3**
4	**Assessing** the different kinds of polarization electromagnetic waves and **evaluation** of the characteristic of the electromagnetic wave through different media.	**L5: Evaluating**	**1, 3, 4, 6, 7, 8, 9**	**1, 2, 3**
5	**Differentiating** transverse electric waves and transverse magnetic waves and **illustrating** the rectangular waveguides for the two types of mode**s.**	**L4: Analyzing**	**1, 3, 4, 5, 6, 9**	**1, 2, 3**
Practical				
1	**Assessing** the nature of polarization of light	**L5: Evaluating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Estimate** the wavelength and velocity of ultrasonic waves in a liquid and predict the refractive Index of gas and liquid	**L2: Understanding**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO		Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	-	3	-	3	-	-	3	3	3	3	3
	2	3	2	3	2	2	3	-	-	2	3	3	2
	3	2	2	3	3	-	3	3	-	2	3	2	2
	4	3	-	3	3	-	3	2	2	3	3	3	3
	5	2	-	2	2	2	2	-	-	3	2	2	3
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	2.7	2.5	2.9	2.7	2.6	2.8	2.7	2.7	2.7	2.9	2.7	2.7

Course Content

Semester: VI **Course name: Statistical Mechanics** **Course Code: CC-XIV**
(Credits: Theory-04, Practicals-02)

CC – XIV: Statistical Mechanics
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:
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. (18 Lectures)

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. (9 Lectures)

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. (5 Lectures)

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. (13 Lectures)

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. (15 Lectures)

Practicals:

Use C/C++/Scilab/other numerical simulations for solving the problems based on Statistical Mechanics like
1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:
a)Study of local number density in the equilibrium state (i) average; (ii)fluctuations
b) Study of transient behavior of the system (approach to equilibrium)
c) Relationship of large N and the arrow of time
d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution
e)Computation and study of mean molecular speed and its dependence on particle mass
f) Computation of fraction of molecules in an ideal gas having speed near the most probable speed
2. Computation of the partition function $Z(\beta)$ for examples of systems with a finite number of single particle levels (e.g., 2 level, 3 level, etc.) and a finite number of non-interacting particles N under Maxwell-Boltzmann, Fermi-Dirac and Bose- Einstein statistics:
a) Study of how $Z(\beta)$, average energy $\langle E \rangle$, energy fluctuation ΔE, specific heat at constant volume Cv, depend upon the temperature, total number of particles N and the spectrum of single particle states.
b) Ratios of occupation numbers of various states for the systems considered above
c) Computation of physical quantities at large and small temperature T and comparison of various statistics at large and small temperature T.
3. Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at high temperature and low temperature.
4. Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature and low temperature and compare them for these two cases.
5. Plot the following functions with energy at different temperatures
a) Maxwell-Boltzmann distribution b) Fermi-Dirac distribution c) Bose-Einstein distribution

Course Outcome (CO) **Paper: CC- XIV**

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Outline** the importance of Statistical ideas for describing systems with large number of constituents.	**L1: Remembering**	**1,2,3,7,9**	**1,2,3**
2	**Distinguish** different kind of ensembles in Statistical mechanics and **identify** essential results from Microcanonical ensemble.	**L4: Analyzing**	**1,2,3,4,5,7,9**	**1,2,3**
3	**Demonstrate** the ideas behind Classical formulation of theory of radiation and **compute** macroscopic results starting from microscopic descriptions.	**L3: Applying**	**1,2,3,4,5,7,8,9**	**1,2,3**
4	**Discriminate** Quantum theory of radiation from Classical theory and **illustrate** their experimental justifications.	**L4: Analyzing**	**1,2,3,4,5,7,8,9**	**1,2,3**
5	**Formulate** the B-E statistics and the F-D statistics and **construct** the ideas of B-E condensate and applying F-D statistics in semiconductor physics	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
Practical				
1	**Computational** analysis of the behavior of a collection of particles in a box	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Illustrating** a) Maxwell-Boltzmann distribution b) Fermi-Dirac distribution c) Bose-Einstein distribution	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
		Program Outcome (PO) & Program Specific Outcome (PSO)											
Theory	1	3	3	2	-	-	-	2	-	2	2	2	3
	2	3	3	2	2	2	-	2	-	3	2	2	2
	3	2	2	3	3	3	-	3	3	3	3	3	3
	4	2	3	3	3	3	-	2	3	3	3	2	2
	5	3	3	3	3	3	2	3	2	3	3	3	3
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	2.7	2.9	2.7	2.8	2.8	2.7	2.6	2.8	2.9	2.7	2.6	2.7

Course Content

Semester: VI | **Course name: Nuclear and Particle Physics** | **Course Code: DSE-3**
(Credits: Theory-06)

DSE-3: Nuclear and Particle Physics
(Credits: Theory-06)
F.M. = 75 (Theory - 60, Internal Assessment – 15)

Theory:

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. (10 Lectures)

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force. (12 Lectures)

Radioactivity decay: (a) Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion. (10 Lectures)

Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering). (8 Lectures)

Interaction of Nuclear Radiation with matter: Energy loss due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter. (8 Lectures)

Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT).Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector. (8 Lectures)

Particle Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons. (5 Lectures)

Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons. (14 Lectures)

Course Outcome (CO)	Paper: DSE-3

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Define** properties of atomic nuclei	**L1: Remembering**	**1,2,6,7,8,9**	**1,2,3**
2	**Outline** radioactive decay and nuclear reactions	**L4: Analyzing**	**1,2,3,4,7,8,9**	**1,2,3**
3	**Analyze** interaction of nuclear radiation with matter	**L4: Analyzing**	**1,2,3,4,5,7,8,9**	**1,2,3**
4	**Explain** the operation of nuclear detectors	**L2: Understanding**	**1,2,3,4,5,8,9**	**1,2,3**
5	**Outline** the fundamental characteristics of particle physics	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

CO		Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	3	-	-	1	2	-	3	3	3	3
		3	3	3	3	3	3	3	3	3	3	3	3
	2	3	2	2	2	3	-	2	-	2	2	2	3
	3	2	3	3	3	3	3	3	3	3	3	3	2
	4	2	-	2	2	2	3	-	-	3	2	2	2
	5	3	3	2	-	-	3	-	2	3	3	2	3
	Average	2.7	2.8	2.5	2.5	2.8	2.6	2.5	2.7	2.8	2.9	2.5	2.7

Course Content

Semester: VI **Course name: Applied Dynamics** **Course Code: DSE-4**
(Credits: Theory-04, Practicals-02)

DSE-4: Applied Dynamics
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Theory:

Introduction to Dynamical systems: Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. Simple mechanical systems as first order dynamical systems : the free particle, particle under uniform gravity, simple and damped harmonic oscillator. Sketching flows and trajectories in phase space; sketching variables as functions of time, relating the equations and pictures to the underlying physical intuition. Other examples of dynamical systems – In Biology: Population models e.g. exponential growth and decay, logistic growth, species competition, predator-prey dynamics, simple genetic circuits In Chemistry: Rate equations for chemical reactions e.g. auto catalysis, bistability In Economics: Examples from game theory. Illustrative examples from other disciplines. Fixed points, attractors, stability of fixed points, basin of attraction, notion of qualitative analysis of dynamical systems, with applications to the above examples. Computing and visualizing trajectories on the computer using software packages. Discrete dynamical systems. The logistic map as an example.
(26 Lectures)

Introduction to Chaos and Fractals: Examples of 2-dimensional billiard, Projection of the trajectory on momentum space. Sinai Billiard and its variants. Computational visualization of trajectories in the Sinai Billiard. Randomization and ergodicity in the divergence of nearby phase space trajectories, and dependence of time scale of divergence on the size of obstacle. Electron motion in mesoscopic conductors as a chaotic billiard problem. Other examples of chaotic systems; visualization of their trajectories on the computer. Self similarity and fractal geometry: Fractals in nature – trees, coastlines, earthquakes, etc. Need for fractal dimension to describe self-similar structure. Deterministic fractal vs. self-similar fractal structure. Fractals in dynamics – Serpinski gasket and DLA. Chaos in nonlinear finite-difference equations- Logistic map: Dynamics from time series. Parameter dependence- steady, periodic and chaos states. Cobweb iteration. Fixed points. Defining chaos- aperiodic, bounded, deterministic and sensitive dependence on initial conditions. Period- Doubling route to chaos. Nonlinear time series analysis and chaos characterization: Detecting chaos from return map. Power spectrum, autocorrelation, Lyapunov exponent, correlation dimension. (20 Lectures)

Elementary Fluid Dynamics: Importance of fluids: Fluids in the pure sciences, fluids in technology. Study of fluids: Theoretical approach, experimental fluid dynamics, computational fluid dynamics. Basic physics of fluids: The continuum hypothesis- concept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties- viscosity, thermal conductivity, mass diffusivity, other fluid properties and equation of state; Flow phenomena- flow dimensionality, steady and unsteady flows, uniform & non-uniform flows, viscous & inviscid flows, incompressible & compressible flows, laminar and turbulent flows, rotational and irrotational flows, separated& unseparated flows. Flow visualization -streamlines, pathlines, Streaklines.
(14 Lectures)

Practicals:

Laboratory/Computing and visualizing trajectories using software such as Scilab, Maple, Octave, XPPAUT based on Applied Dynamics problems like

1. To determine the coupling coefficient of coupled pendulums.
2. To determine the coupling coefficient of coupled oscillators.
3. To determine the coupling and damping coefficient of damped coupled oscillator.
4. To study population models e.g. exponential growth and decay, logistic growth, species competition, predator-prey dynamics, simple genetic circuits.
5. To study rate equations for chemical reactions e.g. auto catalysis, bistability.
6. To study examples from game theory.
7. Computational visualization of trajectories in the Sinai Billiard.
8. Computational visualization of trajectories Electron motion in mesoscopic conductors as a chaotic billiard problem.
9. Computational visualization of fractal formations of Deterministic fractal.
10. Computational visualization of fractal formations of self-similar fractal.
11. Computational visualization of fractal formations of Fractals in nature – trees, coastlines, earthquakes.
12. Computational Flow visualization - streamlines, pathlines, Streaklines.

Course Outcome (CO)	Paper: DSE-4

Sl. No.	Course Outcome (CO)	Knowledge Level	POs	PSOs
Theory				
1	**Define** the dynamical systems with examples form different physical phenomena.	**L1: Remembering**	**1,2,6,7,8,9**	**1,2,3**
2	**Outline** the solution of 1D continuous time dynamical system by both graphical and analytical methodologies.	**L4: Analyzing**	**1,2,3,4,7,8,9**	**1,2,3**
3	**Analyze** two dimensional phase-space by breaking down different possibilities based on domains of trace-determinant space of Jacobian matrix.	**L4: Analyzing**	**1,2,3,4,5,7,8,9**	**1,2,3**
4	**Explain** different types of motion for discrete dynamical systems.	**L2: Understanding**	**1,2,3,4,5,8,9**	**1,2,3**
5	**Formulate** qualitative behavior of continuous time dynamical systems in light of different techniques like Poincare map, Numerical simulation, Lyapunov exponents etc.	**L6: Creating**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
Practical				
1	**Computational analysis** of the behavior of different dynamical systems	**L3: Applying**	**1,2,3,4,5,6,7,8,9**	**1,2,3**
2	**Computational visualization** of fractal formations	**L4: Analyzing**	**1,2,3,4,5,6,7,8,9**	**1,2,3**

Programme Articulation Matrix (CO-PO Matrix)

	CO	Program Outcome (PO) & Program Specific Outcome (PSO)											
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO8	PO9	PSO 1	PSO 2	PSO 3
Theory	1	3	3	-	-	-	1	2	1	2	3	3	3
	2	3	3	2	2	-	-	3	2	3	3	3	2
	3	2	2	3	3	3	-	3	3	3	2	2	3
	4	2	3	3	3	3	-	2	3	3	3	2	3
	5	3	3	3	3	3	3	3	3	3	3	3	3
Practical	1	3	3	3	3	3	3	3	3	3	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3
	Average	2.7	2.9	2.7	2.8	2.8	2.7	2.6	2.8	2.9	2.9	2.8	2.9