Department of Physics
Government General Degree College at Kalna -I
Lesson Plan
for
B.Sc. Semester-I (Honours) Courses Under CBCS
Subject: Physics
Course code: CC-I & CC-II

Course Code: CC-I
Course Title: Mathematical Physics (Theory)

Module-I
Calculus (21 lectures)

Contents

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]

Module Objectives:
1. Recapitulation of function, limit and continuity
2. To know the methods of solving the First order differential equation.
3. To know the methods of solving the second order differential equation.

Lecture Serial	Topics of Discussion
Lecture-1.	**Functions:** Definition, Single-valued function, Multi-valued function, Representation of a function: Analytical representation, Parametric representation, Graphical representation. Continuous and Discontinuous function, Piecewise continuous function, Periodic function, Monotonic function, Even and Odd function, Limits, continuity, differentiation.
Lecture-2.	**Taylor and Binomial Series:** Statements, A few basic problem on Taylor and binomial series.
Lecture-3.	**Nature of Differential Equations:** Definition of differential equation. Representation of differential equation. Ordinary differential equation, Degree of a differential equation, Partial differential equation.
Lecture-4.	**First Order Differential Equation:** Definition, Linear Equations, Bernoulli Equations, Homogeneous Equation, Some examples on 1st order homogeneous equation.
Lecture-5.	**Exact Differential Equation:** Condition for exact differential equation, Some examples regarding exact differential equation.
Lecture-6.	**Inexact Differential Equation:** Integrating factor, Some examples related to inexact differential equation.

Lecture Serial	Topics of Discussion
Lecture-7.	**Linear Equations:** Integrating factor, Some examples regarding line equations. Bernoulli's equation.
Lecture-8.	**Second Order Differential Equations:** Homogeneous equation an non-homogeneous equation
Lecture-9.	**Second Order Differential Equations:** Definition of Wronskian, Some problems regarding Wronskian.
Lecture-10.	**Second Order Differential Equations:** The use of a known solution to find a another solution. Homogeneous equation with constant coefficients.
Lecture-11.	**Second Order Differential Equations:** Nonhomogeneous second order differential equation, The method of undetermined coefficients. Example: Vibration in mechanical system.
Lecture-12.	**Nonhomogeneous Differential Equations:** The method of variation of parameter.
Lecture-13.	**Operator Method:** Particular solution of first and second order liner equations.
Lecture-14.	**Particular Integrals:** Properties of particular integrals. Some examples regarding the particular integrals.
Lecture-15.	**Existence and Uniqueness Theorems:** Statements and some examples.

Tutorial Assignment—I

Module-II

Vector Calculus (25 lectures)

Contents

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]

Module Objectives:

1. This module delivers idea about dot and cross products of vectors and their significance And one can understand the laws of vector algebra to solve various problems associated with Vector calculus.
2. This unit gives the students idea about vector differentiation
3. One can get knowledge about Gradient of scalar field, Divergence and curl of a vector field and their significance.
4. This unit enables the student to solve various problems associated with vector differentiation
5. This unit delivers idea about vector integration, both ordinary and multiple integration.
6. This unit enables the student to solve various problems associated with vector line, surface and volume integration.
7. One can also get knowledge about Vector Theorems and can apply them to solve various problems on vector integration.

Lecture Serial	Topics of Discussion
Lecture-1.	Vector definition, polar and axial vector, Properties of vectors under rotations, Product of two vectors, Scalar product and its invariance under rotations. Vector product, Significance of dot and cross product
Lecture-2.	Scalar triple product and their interpretation in terms of area and volume respectively. Vector triple product, Laws of vector algebra, Properties of dot and cross product, unit vector, Scalar and Vector fields.
Lecture-3.	Discussion on few problems
Lecture-4.	Discussion on few problems
Lecture-5.	Solutions of previous year questions

Lecture-6.	Recapitulation of Vector field, Directional derivatives and normal derivative, Gradient of a scalar field and its geometrical interpretation.
Lecture-7.	Divergence and curl of a vector field, significance of Divergence and curl of a vector field.
Lecture-8.	Conservative fields, Del and Laplacian operators. Vector identities.
Lecture-9.	Discussion on problems
Lecture-10.	Discussion on problems
Lecture-11.	Discussion on problems
Lecture-12.	Solutions of previous year questions
Lecture-13.	Solutions of previous year questions
Lecture-14.	**Vector integrals:** Ordinary Integrals of Vectors. Multiple integrals, Jacobian.
Lecture-15.	Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields.
Lecture-16.	**Line integral:** Example of line integral
Lecture-17.	Discussion on problems on line integral
Lecture-18.	**Surface integral:** example of surface integral
Lecture-19.	Discussion on problems on surface integral
Lecture-20.	Discussion on problems on surface integral
Lecture-21.	**Volume integral:** example of volume integral
Lecture-22.	Discussion on problems on volume integral
Lecture-23.	Discussion on problems on volume integral
Lecture-24.	**Vector Theorems:** Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications
Lecture-25.	Discussion on problems on Vector theorems

Tutorial Assignment—II

Module-III

Orthogonal Curvilinear Coordinates (6 lectures)

Contents

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

Module Objectives:

1. To understand the generalized coordinate system.
2. To learn and apply techniques of orthogonal curvilinear coordinate system in cylindrical and spherical coordinate system.

Lecture Serial	Topics of Discussion
Lecture-1.	**Curvilinear Coordinates:** Unit Vector in Curvilinear coordinate system, Arc length and Volume elements
Lecture-2.	**Differential operators:** Gradient of a scalar in orthogonal curvilinear coordinates.
Lecture-3.	**Differential operators:** Divergence of a vector in orthogonal curvilinear coordinates, Laplacian operator.
Lecture-4.	**Differential operators:** Curl of a vector in orthogonal curvilinear coordinates
Lecture-5.	**Spherical Polar Coordinate:** Differential operators in terms of spherical coordinate.
Lecture-6.	**Cylindrical Coordinate system:** Differential operators in terms of cylindrical coordinate.

Tutorial Assignment—III

Module-IV **Introduction to probability** (4 lectures)
Contents 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.
Module Objectives: 1. To understand the basic concept of probability and learn and apply techniques of probability to understand the probability distribution function.

Lecture Serial	Topics of Discussion
Lecture-1.	**Basic Concept of Theory of Probability:** Random variables, Probability and Frequency, Summation rule and Multiplication rule, Conditional probability.
Lecture-2.	**Random variables:** Continuous random variables, mean, variance of a discrete random variable. Probability distribution.
Lecture-3.	**Probability distribution:** Binomial distribution, Poisson distribution, Gaussian distribution.
Lecture-4.	**Bayes' Theorem:** Idea of hypothesis testing

Module-V **Dirac Delta function and its properties** (2 lectures)
Contents Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.
Module Objectives: 1. To learn and apply techniques of Dirac Delta function.

Lecture Serial	Topics of Discussion
Lecture-1.	**Dirac Delta Function:** Representation Of The Dirac Delta Function,
Lecture-2.	**Properties of the Dirac Delta function:**

Tutorial Assignment—IV

Text books

1. *Vector Analysis*, Murray R. Spiegel, Schaum's Outline.
2. *Differential Equations with Applications and Historical Notes*, George Simmons, Mc Graw Hill Education

Reference books

1. *Higher Engineering Mathematics*, B. S. Grewal , KHANNA PUBLISHERS.

Course Code: CC-I
Course Title: Mathematical Physics (Practical)

Module-I **Mathematical Physics (Practical)** (60 lectures)
Module Objectives: 1. The aim of this Lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. 2. Highlights the use of computational methods to solve physical problems 3. The course will consist of lectures (both theory and practical) in the Lab 4. Evaluation done not on the programming but on the basis of formulating the problem 5. Aim at teaching students to construct the computational problem to be solved 6. Students can use any one operating system Linux or Microsoft Windows

Serial No.	**Topics of Discussion**
Lab-1.	**Introduction and Overview:** Computer architecture and organization, memory and Input/output devices
Lab-2.	**Basics of scientific computing:** Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow and overflow- emphasize the importance of making equations in terms of dimensionless variables, Iterative methods
Lab-3.	**Errors and error Analysis:** Truncation and round off errors, Absolute and relative errors, Floating point computations.
Lab-4.	**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
Lab-5.	**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
Lab-6.	**Random number generation:** Area of circle, area of square, volume of sphere, value of pi
Lab-7.	Solution of Algebraic and Transcendental equations by Bisection, Newton Raphson and Secant methods: Solution of linear and quadratic equation
Lab-8.	Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation. Evaluation of trigonometric functions
Lab-9.	**Solution of Ordinary Differential Equations (ODE):** First order differential equation
Lab-10.	**Euler and Runge-Kutta (RK) second and fourth order method:**

Course Code: CC-II
Course Title: Mechanics (Theory)

Module-I **Fundamentals of Dynamics:** (6 lectures)
Contents 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.
Module Objectives: In this module, Newtonian mechanics is developed from Galilean transformation. Three laws of motion and their implications are discussed. Finally, Newtonian framework is being used to solve different problems.

Lecture Serial	Topics of Discussion
Lecture-1.	**Review of basic ideas of Classical mechanics:** Applicability, Limitation, Historical ideas
Lecture-2.	**Newton's laws of motion 1:** Three laws with their importance. How 1st law is not a byproduct of 2nd law? Inertial frame as a fundamental idea of classical dynamics. Galilean transformation
Lecture-3.	**Newton's laws of motion 2:** Problem solving using Newton's laws: Free body diagram
Lecture-4.	**Newton's laws of motion 3:** Third law of motion and conservation of linear momentum
Lecture-5.	**Motion of a projectile in Uniform gravitational field and rocket motion.**
Lecture-6.	**Dynamics of system of particles:** Center of mass and its usefulness

Module-II **Work and Energy** (4 lectures)
Contents 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.
Module Objectives: Force and Energy in Mechanics. Conservative and non-conservative forces and their implication. Energy diagram as a qualitative tool to analyze motion.

Lecture Serial	Topics of Discussion
Lecture-1.	**Work-Kinetic Energy Theorem as general consequence of Newton's laws of motion.**
Lecture-2.	**Conservative and non- conservative forces. Examples of both. Path independence of work done under conservative force field.**
Lecture-3.	**Idea of potential energy in context of conservative forces and conservation of mechanical energy for conservative forces.**
Lecture-4.	**Energy diagram as a tool of analyzing particles in conservative force field.**

Module-III **Collisions:** (3 lectures)
Contents Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.
Module Objectives: Theories Elastic and inelastic collision are discussed in this module.

Lecture Serial	Topics of Discussion
Lecture-1.	**Theory of collision and its significance in terms of modern aspects of Physics.**
Lecture-2.	**Elastic, inelastic and partially elastic collisions. Co-efficient of restitution in this aspect.**
Lecture-3.	**Laboratory frame and COM frame for analysis of collision.**

Tutorial Assignment—1

Module-IV **Rotational Dynamics:** (12 lectures)
Contents Angular momentum of a particle and system of particles. Torque.Principle of conservation of angular momentum.Rotation about a fixed axis.Moment of Inertia.Calculation of moment of inertia for rectangular, cylindrical and spherical bodies.Kinetic energy of rotation. Motion involving both translation and rotation.
Module Objectives: Angular momentum being a key physical quantity is discussed in this module and its conservation principle is highlighted. Also, moment of inertia and its tensorial form is discussed in some detail which leads to concepts like principal axes of inertia and ellipsoid of inertia.

Lecture Serial	Topics of Discussion
Lecture-1.	**Rotational dynamics and key ideas about them.**
Lecture-2.	**Angular momentum and Torque as key concepts in rotational dynamics.**
Lecture-3.	**Angular momentum of a particle and system of particles and its conservation.**
Lecture-4.	**Orbital and Spin angular momentum and their connection to Orbital and Spin components of torque.**
Lecture-5.	**Rotation about a fixed axis.Moment of Inertia tensor.**
Lecture-6.	**Calculation of moment of inertia. Parallel axis and Perpendicular axis theorem**
Lecture-7.	**Calculation of moment of inertia for rectangular, cylindrical and spherical bodies**
Lecture-8.	**Kinetic energy of rotation. Ellipsoid of inertia.**
Lecture-9.	**Motion involving both translation and rotation.**
Lecture-10.	Problem solving 1
Lecture-11.	Problem solving 2
Lecture-12.	Problem solving 3

Tutorial Assignment—2

Module-V **Elasticity** (3 lectures)
Contents Relation between Elastic constants. Twisting torque on a Cylinder or Wire.
Module Objectives: 1. This module gives knowledge about different elastic constants and relation between them 2. one can get knowledge about twisting torque on a cylindrical wire and Torsional pendulum

Lecture Serial	Topics of Discussion
Lecture-1.	**Elastic constants:** Hooke's law, stress-strain diagram, Youngs modulus, Bulk modulus, Rigidity modulus Poisson's ratio and relation between them
Lecture-2.	**Torsion of a wire:** Work done in deforming a wire, Torsional Pendulum, Twisting torque on a Cylindrical Wire.
Lecture-3.	Solutions of previous year questions

Module-VI
Fluid Motion: (2 lectures)
Contents
Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.
Module Objectives:
1. This unit gives students idea about kinematics of moving fluid. One can understand stream line and turbulent flow 2. One can get idea about derivation of Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.

Lecture Serial	Topics of Discussion
Lecture-1.	**Kinematics of Moving Fluids:** Viscosity, Stream line and turbulent flow, Raynold's number, Coefficient of viscosity, Derivation of Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.
Lecture-2.	Solutions of previous year questions

Module-VII
Gravitation and Central Force Motion: (3 lectures)
Contents
Law of gravitation. Gravitational potential energy.Inertial and gravitational mass.Potential and field due to spherical shell and solid sphere.
Module Objectives:
1. This unit gives idea about Gravitational potential energy and one can gain idea how to find Potential and field due to spherical shell and solid sphere inside and outside of it.

Lecture Serial	Topics of Discussion
Lecture-1.	**Basic theory of Gravitation:** Law of gravitation. Gravitational potential energy. Inertial and gravitational mass.
Lecture-2.	**Potential and field due to spherical shell and solid sphere:** Potential and field inside and outside of a spherical shell and solid sphere and their graphical variation with distance
Lecture-3.	Solutions of previous year questions

Module-VIII
Motion of a particle under a central force field (6 lectures)
Contents
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).
Module Objectives:
1. This unit delivers idea about the motion of a particle under central force field and the energy equation and energy diagram. 2. One can get idea about equation and types of orbits of a particle depending upon its energy. 3. One can also get knowledge about Kepler's Laws. 4. Basic idea about communication satellite can also be obtained.

Lecture Serial	Topics of Discussion
Lecture-1.	Two-body problem and its reduction to one-body problem and its solution
Lecture-2.	**Central force:** Definition and general properties, Form of equation of motion.
Lecture-3.	**The energy equation and energy diagram:** Effective potential, Motion of a particle in inverse square field, Equation of orbit.
Lecture-4.	**Kepler's Laws:** Kepler's Laws and their proofs
Lecture-5.	**Satellite in circular orbit and applications:** Communication Satellites, Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS).
Lecture-6.	Solutions of previous year questions

Tutorial Assignment—3

Module-IX **Oscillations:** (7 lectures)
Contents
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.
Module Objectives:
In this module, students will learn the motion of a simple harmonic oscillator and analyze the same in different domains.

Lecture Serial	Topics of Discussion
Lecture-1.	**Simple Harmonic Oscillations:** definition, different examples
Lecture-2.	**Differential equation of SHM and its solution:** $x(t) = A\sin(\omega t+\phi)$ significance of A and ϕ
Lecture-3.	**Energy of Simple harmonic oscillator:** Kinetic energy, potential energy, total energy and their time-average values
Lecture-4.	**Damped oscillation:** Solutions for (i) over, (ii) critical and (iii) under damping and its interpretation
Lecture-5.	**Forced oscillations:** Transient and steady states
Lecture-6.	**Resonances:** Amplitude resonance, velocity resonance
Lecture-7.	**Power dissipation and Quality Factor**

Module-X **Non-Inertial Systems:** (4 lectures)
Contents
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.
Module Objectives:
In this module, non-inertial frames will be discussed and physics in the same will be highlighted via Galilean transformations

Lecture Serial	Topics of Discussion
Lecture-1.	**Non-inertial frames and fictitious forces as their by-product.**
Lecture-2.	**Uniformly rotating frame.Laws of Physics in rotating coordinate systems.Centrifugal force.**
Lecture-3.	**Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems.**
Lecture-4.	**Apply the ideas of non-inertial frames to explain Foucault's pendulum and hence understand the rotation of earth.**

Module-XI **Special Theory of Relativity:** (10 lectures)
Contents
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.
Module Objectives:
In this module, Concept of Special theory of relativity is built upon from postulates of relativity and hence different outcome of STR is being discussed.

Lecture Serial	Topics of Discussion
Lecture-1.	**Michelson-Morley Experiment** and its outcome to nullify idea of Ether

Lecture-2.	**Postulates of Special Theory of Relativity and Gedankenexperiment I:** Time dilation formula
Lecture-3.	**Idea of length measurement and Gedankenexperiment II:** Length contraction formula
Lecture-4.	**Byproduct of Gedankenexperiment I and II:** The Lorenz transformation, Velocity addition formula
Lecture-5.	**Relativistic Doppler effect:** frequency and wave number
Lecture-6.	**Variation of mass with velocity.Massless Particles. Mass-energy Equivalence**
Lecture-7.	**Minkowski diagram** and its different regions. Concepts like Timelike, spacelike and lightlike world-lines
Lecture-8.	**Mathematical ideas of Lorenz transformation as matrices:** Covariant formulation in non-tensorial matrix formalism.
Lecture-9.	**Energy-momentum relation, Doppler effect from this formalism.**
Lecture-10.	**Paradoxes in STR:** Twin paradox and Barn-ladder paradox

Tutorial Assignment—4

Text books

1. *An introduction to mechanics*, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill
2. *Classical Mechanics*, John R. Taylor, 2003, University Science Books
3. *Introduction to Special Relativity*, R. Resnick, 2005, John Wiley and Sons

Reference books

1. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
2. *Feynman Lectures, Vol. I*, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education

Course Code: CC-II
Course Title: Mechanics (Practical)

Module-I **Mechanics (Practical)**	
Module Objectives: 1. To gain practical knowledge by applying the experimental methods to correlate with the theory of classical mechanics. 2. To apply the analytical techniques and graphical analysis to the experimental data.	
Serial No.	**Topics of Discussion**
Lab-1.	Measurements of length (or diameter) using vernier caliper, screw gauge and travelling microscope.
Lab-2.	To study the random error in observations.
Lab-3.	To study the Motion of Spring and calculate (a) Spring constant, (b) g and (c)Modulus of rigidity.
Lab-4.	To determine the Moment of Inertia of a Flywheel / regular shaped body.
Lab-5.	To determine g and velocity for a freely falling body using Digital Timing Technique.
Lab-6.	To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
Lab-7.	To determine the Young's Modulus of a Wire by Optical Lever Method.
Lab-8.	To determine the coefficient of viscosity of highly viscous liquid by Stoke's method.
Lab-9.	To determine the Modulus of Rigidity of a Wire by Maxwell's needle/ dynamical method.
Lab-10.	To determine the elastic Constants of a wire by Searle's method.
Lab-11.	To determine the value of g using Bar pendulum / Kater's Pendulum.
Lab-12.	To determine the value of Young's Modulus by Flexure method.

Department of Physics
Government General Degree College at Kalna -I
Lesson Plan
for
B.Sc. Semester-II (Honours) Courses Under CBCS
Subject: Physics
Course code: CC-III & CC-IV

Course Code: CC-III
Course Title: Electricity and Magnetism (Theory)

Module-I **Electric Field and Electric Potential** (30 lectures)
Contents Electric field: Electric field lines. Electric flux.Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. Conservative nature of Electrostatic Field. Electrostatic Potential.Laplace's and Poisson equations.The Uniqueness Theorem.Potential and Electric Field of a dipole. Force and Torque on a dipole. Electrostatic energy of system of charges.Electrostatic energy of a charged sphere.Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors.Parallel-plate capacitor.Capacitance of an isolated conductor. Method of Images and its application to (1) Plane infinite sheet (2) Sphere.
Module Objectives: To understand Coulomb's law of Electrostatics and its bi-products in free space. In this module, students would learn the origin and working principles in Electrostatics.

Serial No.	Topics of Discussion
Lecture-1.	**Introduction and Overview:** In this lecture, we begin by visiting Coulomb's law for a single particle and hence the concept of Electric field is being discussed. Then it is extended for system of particles using principle of superposition.
Lecture-2.	**Electric fields from Coulomb's law** Building upon the concepts of previous lecture, expression of $\vec{E}$ is written for line, surface and volume charge distributions. Then the the above expressions are used to compute $\vec{E}$ for few different geometries.
Lecture-3.	**Gauss's law (geometric derivation):** In this lecture, concept of solid angle and Electrostatic flux is introduced and then both concepts are merged to form Gauss's law in Electrostatics (Integral form).
Lecture-4.	**Gauss's law in differential form:** Since, the expression of $\vec{E}$ has been formulated from Coulomb's law we can use it to show that of $\vec{\nabla}.\vec{E} = \frac{\rho}{\epsilon_0}$. Which is known as Gauss's law in differential form. In this deduction, separate care was taken to show that $\vec{\nabla}.\left(\frac{\vec{r}}{r^3}\right) = 4\pi\delta^3(\vec{r})$.

Serial No.	Topics of Discussion
Lecture-5.	**Gauss's law in integral form:** In this lecture, Gauss's law for Electrostatics is been observed in its most "useful" form i.e. $$\oint \vec{E}.d\vec{S} = \frac{q_{enc}}{\epsilon_0}$$ It is then applied for few symmetrical cases (infinite charged sheet, sphere, infinitely long charged sphere) to calculate $\vec{E}$.
Lecture-6.	**Gauss's law continues:** More problems on application of Gauss's law for computing $\vec{E}$ are practiced to ensure that students do get proper hold on this particular calculation process.
Lecture-7.	**Electrostatic potential:** This lecture begins with showing that $\vec{E}$ is irrotational by nature. This is used to introduce a corresponding potential called Electrostatic potential.
Lecture-8.	**Superposition for potentials:** The superposition principle let us write Electrostatic potential for a system of particles. Which then is extended to write a closed form of potential for continuous charge distribution.
Lecture-9.	**Potential to $\vec{E}$ and vice versa** In this lecture, scalar nature of Electrostatic potential to generate the vector field $\vec{E}$ but at the same time, for specially symmetric conditions other way round is also an effective process.
Lecture-10.	**Electrostatic energy:** Electrostatic energy is discussed in this lecture from 1st principle and hence different equivalent forms of the same also being derived.
Lecture-11.	**Electrostatic energy 2:** For some symmetrical cases electrostatic self energy is being calculated and consistency of different forms are also cross-checked.
Lecture-12.	**Conductors:** Free charges and their atomic origin is first discussed in this lecture. Then it is argued that $\vec{E} = \vec{0}$ inside the conductor.
Lecture-13.	**Induced surface charge on conductor:** First, induced charge on surface of a conductor is understood and then Electrostatic pressure due to charge accumulation on conducting surface is computed.
Lecture-14.	**Capacitors:** Idea of capacitor and capacitance are also discussed in context of equipotential conducting surfaces. Few examples are practiced down the line.
Lecture-15.	**Laplace and Poisson equation:** In this lecture, Electrostatic potential is discussed in context of two legendary equations: The Laplace's and Poisson's equation.
Lecture-16.	**Uniqueness theorem(s):** Few uniqueness theorems are thoroughly discussed in this class to prepare the stage for image problem in Electrostatics.
Lecture-17.	**Method of images 1:** Here, a charge in front of a grounded conducting plate is solved using method images and special stress is given for its connection with uniqueness theorem. Different quantities like potential, electric field and charge density on the plate, force and electrostatic is calculated.
Lecture-18.	**Method of images 2:** In this lecture, a grounded conducting sphere in front of a point charge is solved using method of images. It is then stressed that method of images don't solve Electrostatics problems for arbitrary problems.
Lecture-19.	**boundary conditions and boundary value problems 1:** Boundary conditions for Electrostatic quantities like $\vec{E}$, potential are observed here. Then Laplace's equation is is solved for problem in Cartesian co-ordinate.
Lecture-20.	**boundary value problems 2:** Here, Laplace's equation is solved in spherical and cylindrical co-ordinates.

Serial No.	Topics of Discussion
Lecture-21.	**Multipole expansion:** Concepts of multipole is discussed here in context of both mathematical and physical origin. Very short introduction to Legendre Polynomial is also done here.
Lecture-22.	**Dipole and related quantities:** Here, potential and electric field due to electric dipole are calculated. Also, force, torque and energy of a dipole in external electric field are calculated and orientation favorable configuration of a dipole in an external $\vec{E}$ are discussed.
Lecture-23.	**Quadrupole Moment:** Here, we computed Quadrupole moment of an arbitrary charge configuration and applied the same to some simple charge distributions. Few notes on zero Qudrupole moment is passed on.
Lecture-24.	**Dielectric material:** Orientational and induced polarization processes are discussed in this lecture and thus polarization vector is introduced.
Lecture-25.	**Polarized charge densities:** In this lecture, polarized volume and surface charge densities are related to polarization vector from both physical and direct mathematical formulation of potential.
Lecture-26.	**Displacement vector:** For few cases surface and volume polarized charge densities are calculated. Displacement vector ($\vec{D}$) is defined in context of free charge density and a parallel form Gauss's law in vacuum is derived as $\vec{\nabla}.\vec{D} = \rho_f$.
Lecture-27.	**Gauss's law in dielectric :** In this lecture, integral form of Gauss's law in dielectric is computed and then applied on different symmetrical cases.
Lecture-28.	**Linear Dielectric :** Linear and non-linear types of dielectric mediums are first introduced and then linear medium is stressed with introduction of different quantities like susceptibility (χ) , dielectric constant (ϵ). For linear dielectric medium, symmetric problems are solved using Gauss's law in dielectric medium.
Lecture-29.	**Boundary value problems in dielectric medium :** Boundary condition and boundary value problems are exercised in context for dielectric medium.
Lecture-30.	**Problems related to dielectric medium :** Energy stored in dielectric medium. Then different capacitors incorporating linear dielectrics are considered. Finally, the whole lesson on Electrostatics is being summarized.

Tutorial Assignment—1

Module-II

Magnetic Field (13 lectures)

Contents

Magnetic force between current elements and definition of Magnetic Field $\vec{B}$. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field.Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability.Relation between B, H, M. Ferromagnetism. B-H curve and hysteresis.

Module Objectives:

Magnetic field due to steady current i.e.Magnetostatics is the subject that students will learn from this module. Also in this module, the parallel construction of Magnetostatics with respect to Electrostatics is stressed in each step with would be justified latter since Electric and Magnetic fields are just two sides of a underlying coin (theory).

Serial No.	Topics of Discussion
Lecture-1.	**Lorenz force law:** Lorentz force law has two components: one that is covered in Electrostatics, the second part, i.e. magnetic component is dealt here. Charged particle in magnetic field is observed.
Lecture-2.	**Boit-Savart's law:** Biot-Savart's law gives an equation which dictates the origin of Magnetic fields. It is then written for different types of current sources and used for different configurations. Lorentz forces between current carrying loops are derived here.
Lecture-3.	$\vec{\nabla}.\vec{B} = 0$**:** In this lecture, magnetic field is shown to be solenoidal and it is interpreted physically.
Lecture-4.	**Continuity equation and Ampere's law)** Continuity equation id derived from principle of Charge conservation. Then, Ampere's law is obtained : $\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}$. Finally, Using Stokes's theorem, its integral counter part is also derived.
Lecture-5.	**Application of Ampere's law**, Ampere's law in integral from is used to compute magnetic field for few symmetrical cases: Infinitely long straight current carrying wire, Current carrying infinite plane sheet, Infinitely long Solenoid, Toriod.
Lecture-6.	**Vector potential in Magnetostatics :** Starting from $\vec{\nabla}.\vec{B} = 0$ magnetic vector potential $\vec{A}$ is proposed and gauge freedom is discussed. Finally, a closed form of $\vec{A}$ is calculated under Coulomb's gauge.
Lecture-7.	**More on potentials:** Magnetic vector potential is calculated for few current configurations and using them, magnetic fields are also computed. Magnetic scalar potential is defined and its limitations also being highlighted in terms of simply connected loops.
Lecture-8.	**Boundary conditions and multipole expansion :** In this lecture, magnetostatic boundary conditions are exercised. Then multipole expansion for a tiny current carrying loop is derived. First significant term in the expansion turns out to be dipoler which re-establishes the divergence free nature of magnetic field.
Lecture-9.	**Magnetic dipole:** $\vec{A}_{dip}$ is written in a form similar to that we used to get for electric dipoles $\vec{A}_{dip} = \frac{\mu_0}{4\pi} \frac{\vec{m} \times \vec{r}}{r^3}$ (apart from the fact that one is a scalar and other is a vector quantity). Hence, dipole moment $\vec{m} = I \vec{\triangle S}$
Lecture-10.	**Dipoles continued:** Torque and energy of a magnetic dipole is computed in presence of external magnetic field. Then, assuming a simple model of electron spinning in a loop around nucleus, induced dipole moment is computed.
Lecture-11.	**Magnetostatics within matter:** Matters are classified according to their responses to external magnetic field : Dia, para and Ferro magnetism. Bound surface and volume currents for a magnetized material is obtained using form of vector potential. Their physical meanings are also being discussed.
Lecture-12.	**Magnetostatics within matter II :** Physical origin of bound currents are analyzed. Then concept of linear medium is introduced in this lecture.
Lecture-13.	**Magnetostatics within matter II :** Para and dia magnetism are revisited with developed theories and ferromagnetism is explained with the help of domain theories. Then hysteresis loops have been discussed. Finally a comparative table are formed to show parallel structures involving Electrostatics and Magnetostatics.

Tutorial Assignment—2

Module-III **Electromagnetic Induction** (6 lectures)
Contents 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.
Module Objectives: To understand the mixing of Electric and Magnetic fields: The beginning of Electromagnetic theory.

Serial No.	Topics of Discussion
Lecture-1.	**Electromotive force :** Electromotive forces are discussed at the beginning and then its magnetic counterpart is analyzed for a moving coil in a magnetic field. Faraday's law has been introduced in that context.
Lecture-2.	**: Self and Mutual inductances** Self and mutual inductances are introduced here and those quantities are calculated for few configurations. Reciprocity theorem for Mulutal inductance is also highlighted.
Lecture-3.	**Energy stored in a Magnetic Field:** Magnetic field energy density is obtained in this lecture. Few problems related to that are also being solved.
Lecture-4.	**Maxwell's equations:** Correction in Ampere's law in dynamic situation is obtained mathematically using equation of continuity which incorporates a displacement current $\vec{J}_d = \epsilon_0 \frac{\partial \vec{E}}{\partial t}$. Then the physical essence of the same is also discussed by taking a practical example of a parallel plate capacitor.
Lecture-5.	**Maxwell's equation continues:** The other correction comes in form of Faraday's law which essentially changes the irrotational nature of $\vec{E}$. It is then compared with Biot-Savart's law and shown that changing magnetic fields produce Electric field. All Maxwell's equations are then written together to have a final dig at magnetic monopole.
Lecture-6.	**Maxwell's equations in Matter:** We revisit Electric and Magnetic fields inside matter to incorporate few modifications of Maxwell's equations within matter.

Tutorial Assignment—3

Module-IV **Electrical Circuits, Network theorems, Ballistic Galvanometer** (11 lectures)
Contents 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. 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 Ballistic Galvanometer: Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping.Logarithmic damping.CDR.
Module Objectives: To understand the circuits and related practical issues.

Serial No.	Topics of Discussion
Lecture-1.	**AC vs DC circuits:** In this lecture, we apply our knowledge of Electromagnetism to differentiate between AC and DC circuits elements.
Lecture-2.	**Kirchoff's law in AC circuit:** Kirchoff's law has been used in context of AC circuit and idea of complex valued resistance which is called reactance is understood.

Lecture-3.	**Series LCR:** Different quantities like (1) Resonance, (2) Power Dissipation and (3)Quality Factor, and (4) Band Width of series LCR Circuit are analyzed.
Lecture-4.	**Parallel LCR:** Mechanical analog with spring-mass system is first clarified and then resonance criteria for parallel LCR circuit is obtained.
Lecture-5.	**Network theorems 1:** Concept of ideal Constant-voltage and Constant-current Sources being discussed. Then we discuss Thevenin's theorem.
Lecture-6.	**Network theorems 2:** In this lecture, Norton's and Maximum power transfer theorems are understood and applied for networks.
Lecture-7.	**Network theorems 3:** Reciprocity theorem, Maximum Power Transfer theorems are discussed here.
Lecture-8.	**Problem solving using Network theorems:** In this lecture different circuits are analyzed using theorems discussed in previous classes.
Lecture-9.	**Ballistic Galvanometer 1:** Galvanometers as measuring device and limitations of table Galvanometers are discussed. To begin understanding of Ballistic galvanometer, Torque on a current carring loop due to external magnetic field is revisited
Lecture-10.	**Ballistic Galvanometer 2:** Current and Charge Sensitivity of Ballistic Galvanometer, its Electromagnetic damping,Logarithmic damping and CDR being introduced. Working with these galvanometers are demonstrated in laboratory (if possible).
Lecture-11.	**Concluding remarks** Here we finish this paper by summarizing different aspects that were discussed in classes and possible further readings of the same.

Tutorial Assignment—4

Text books
1. Introduction to Electrodynamics - David J. Griffiths
2. Fundamentals of Electricity and Magnetism - Basudev Ghosh

Reference books
1. The Feynman Lectures on Physics- Volume 2 - Feynman, Leighton, Sands.

Course Code: CC-III
Course Title: Electricity and Magnetism (Practical)

Module-I **Electricity and Magnetism Practical**
Contents 1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DCCurrent, (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.
Module Objectives:
1. To gain practical knowledge by applying the experimental methods to correlate with the theory of electricity and magnetism. 2. To apply the analytical techniques and graphical analysis to the experimental data.

Serial No.	**Topics of Discussion**
Lab-1.	Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DCCurrent, (d) Capacitances, and (e) Checking electrical fuses.
Lab-2.	To study the characteristics of a series RC Circuit.
Lab-3.	To determine an unknown Low Resistance using Potentiometer.
Lab-4.	To determine an unknown Low Resistance using Carey Foster's Bridge.
Lab-5.	To compare capacitances using De'Sauty's bridge.
Lab-6.	Measurement of field strength B and its variation with distance using search coil.
Lab-7.	To verify the Thevenin and Norton theorems.
Lab-8.	To verify the Superposition, and Maximum power transfer theorems.
Lab-9.	To determine self inductance of a coil by Andersons bridge.
Lab-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.
Lab-11.	To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
Lab-12.	Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer
Lab-13.	Determine a high resistance by leakage method using Ballistic Galvanometer.
Lab-14.	To determine the mutual inductance of two coils by Carey-Foster's method.
Lab-15.	Construction of one ohm coil.

Course Code: CC-IV
Course Title: Waves & Optics (Theory)

Module-I **Superposition of Collinear Harmonic oscillations** (5 lectures)
Contents
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.
Module Objectives:
1. This unit aims to offer basic knowledge of linearity and superposition of multiple colinear SHM. 2. From this unit students can understand how the amplitude and phase of a resultant wave varies due to superposition of two or more colinear SHM. 3. Student can understand how Beats are formed

Serial No.	Topics of Discussion
Lecture-1.	**Linearity and Superposition Principle:** Linearity of SHM equation, Superposition principle, Superposition of harmonic oscillation, superposition of two colinear SHM with equal frequency. Determination of resultant amplitude and phase
Lecture-2.	**Beats:**superposition of two collinear SHM with different frequency, determination of amplitude and phase, condition of formation of beats, beat period, graphical representation of resultant amplitude variation with time and concept of wave packet
Lecture-3.	**Superposition of N collinear Harmonic Oscillations:** Superposition of N collinear SHM with equal amplitude, frequency and equal successive phase differences. Expression of the resultant wave, calculation of resultant amplitude and phase, Observation of the results for two terminal condition, $N >>$ and $N = 2$
Lecture-4.	**Superposition of N collinear Harmonic Oscillations:** Superposition of N collinear SHM with equal amplitude, phase constant and equal successive frequency differences, Expression of the resultant wave, calculation of resultant amplitude and phase
Lecture-5.	Discussion on few problems.

Module-II

Superposition of two perpendicular Harmonic Oscillations (2 lectures)

Contents

Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses.

Module Objectives:

1. In This chapter Student can have an idea about how Lissajous figures are formed due to superposition of two perpendicular SHM, both analytically and graphically
2. They can get an idea about visualization of Lissajous figures in a CRO

Serial No.	Topics of Discussion
Lecture-1.	**Superposition of two perpendicular Harmonic Oscillations (Analytical method):** Analytical analysis of superposition of two perpendicular SHM with equal frequency, with frequency ratio 1:2 and 1:3 (Lissajous figure)
Lecture-2.	**Superposition of two perpendicular Harmonic Oscillations (Graphical method):** Graphical analysis of superposition of two perpendicular SHM with equal frequency, with frequency ratio 1:2 and 1:3 (Lissajous figure). Application of Lissajous figure.

Tutorial Assignment—1

Module-III

Wave Motion (4 lectures)

Contents

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

Module Objectives:

1. In this chapter Student can get clear idea about wavefront, characteristics of wavefront and equation of motion for different types of progressive waves.
2. This chapter aims on understanding different physical properties of progressive waves

Serial No.	Topics of Discussion
Lecture-1.	**Different Types of waves:** Brief Discussion on Wavefront, Properties and classification of Wavefront, Characteristics, Equation of wave motion and equation of wavefront for Plane, Spherical and Cylindrical progressive waves.
Lecture-2.	**Different Types of waves and wave equation:** Longitudinal and Transverse waves. Classical wave equation, Particle and wave velocities
Lecture-3.	**Different Physical properties of waves:** Pressure of a Longitudinal Wave. Energy density. Intensity of Wave. Water Waves: Ripple and Gravity Waves.
Lecture-4.	Problems Discussion

Module-IV

Velocity of Waves (6 lectures)

Contents

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.

Module Objectives:

1. This chapter aims to understand how velocity of transverse and longitudinal waves are determined.

Serial No.	Topics of Discussion
Lecture-1.	**Velocity of transverse waves:** Frequency and Velocity of Transverse Vibrations of Stretched Strings, Alternative geometrical analysis for Velocity of Transverse Vibrations of Stretched Strings.
Lecture-2.	**Velocity of Longitudinal Waves:** Velocity of Longitudinal Waves in a gas or Fluid in a Pipe
Lecture-3.	**Velocity of Longitudinal Waves:** velocity of longitudinal waves in a gas in isothermal condition
Lecture-4.	**Velocity of Longitudinal Waves:** Laplace's Correction (velocity of longitudinal waves in a gas in adiabatic condition)
Lecture-5.	**Velocity of Longitudinal Waves:** Velocity of compressional/ longitudinal waves in a long thin bar.
Lecture-6.	Discussion on few problems

Tutorial Assignment—2

Module-V

Superposition of Two Harmonic Waves (7 lectures)

Contents

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

Module Objectives:

1. This chapter aims to offer idea about stationary waves (both transverse and longitudinal).
2. Student can get clear idea about wave packet, group and phase velocities of a wave.
3. Student can understand clearly about normal modes of vibration for a stretched string

Serial No.	Topics of Discussion
Lecture-1.	**Standing (Stationary) Waves:** Standing (Stationary) Waves in a String: Fixed and Free Ends. Frequency of standing waves in a vibrating string. Dependence of frequency on various parameters of vibrating string.
Lecture-2.	**Phase and Group Velocities:** Concept of wave packet, Phase velocity and group velocity. Relation between phase and group velocity, Dispersive and non-dispersive media.
Lecture-3.	**Normal Modes of Stretched Strings:** General solution of equation of motion of a transversely vibrating string, Eigen values, eigen function and eigen frequencies.
Lecture-4.	**Energy of transversely vibrating string:** Transfer of Energy, Kinetic and potential energy and total energy.
Lecture-5.	**Plucked and Struck Strings:** Examples of vibration of Plucked and Struck string, solution of equation of motion for a stationary wave in Plucked and Struck string, Variation of amplitude with order of harmonics, Young-Helmholtz law. Melde's Experiment
Lecture-6.	**Longitudinal stationary waves:** Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves
Lecture-7.	Discussion on few problems.

Tutorial Assignment—3

Module-VI
Wave Optics (3 lectures)

Contents

Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle.Temporal and Spatial Coherence.

Module Objectives:

1. This module aims to offer basic knowledge on electromagnetic nature of light.
2. From this portion students can get a clear idea about the Huygens principle.
3. Idea of temporal and spatial coherence help students to understand the properties of light.

Serial No.	Topics of Discussion
Lecture-1.	**Electromagnetic nature of light:** Maxwell Equation of EMT, Electromagnetic Wave, Transverse nature of Electromagnetic waves.
Lecture-2.	**Huygens Principle:** Spherical waves, Cylindrical waves, Plane wave, Properties and classification of Wavefront. Huygens Principle and Propagation of Wavefronts.
Lecture-3.	**Coherence:** Coherence time, Coherence length, The Temporal Coherence, The Spatial Coherence, Lateral coherence width.

Module-VII
Interference (9 lectures)

Contents

Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index.

Module Objectives:

1. This module attempts to provide the fundamental idea of interference of light.
2. From this portion students can get a key idea about the division of amplitude and division of wavefront.

Serial No.	Topics of Discussion
Lecture-1.	**Introduction:** Superposition Principle, Condition for stable Intensity pattern. Methods of creating Interference. **Division of Wavefront:** Young's Double-Slit Experiment: Intensity Distribution.
Lecture-2.	**Young's Double-Slit Experiment:** The Interference Pattern, Shape of interference fringes,
Lecture-3.	**Fresnel Biprism:** Determination of wavelength through Fresnel Biprism experiment, Displacement of Fringes.
Lecture-4.	**Lloyd's Mirror & Stokes' treatment:** The Lloyd's Mirror arrangement and phase change on reflection, Stokes's relation.
Lecture-5.	**Division of Amplitude:** Interference Phenomenon in parallel thin film and wedge shaped film. Cosine law. Fringe Width
Lecture-6.	**Haidinger Fringes:** Interference by a plane parallel film when illuminated by a point source and an extended source, Fringes of equal inclination.
Lecture-7.	**Fizeau Fringes:** Interference by a film with two non-parallel reflecting surface, Fringes of equal width.
Lecture-8.	**Newton's Rings:** Theory of Newton's rings, An arrangement for observing Newton's rings
Lecture-9.	**Newton's Rings:** Fringe width of Newton's Rings, Determination of wavelength of a monochromatic light and Determination of the refractive index of a liquid through Newton's Rings experiment.

Module-VIII
Interferometer (4 lectures)

Contents

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.

Module Objectives:

1. Michelson Interferometer helps the students to study the interference phenomenon of light.
2. From this portion students can attain background knowledge about Fabry-Perot interferometer.

Serial No.	Topics of Discussion
Lecture-1.	**Michelson Interferometer:** An arrangement for Michelson Interferometer, Formation of circular fringes, Interference pattern of Michelson Interferometer, Visibility of Fringes.
Lecture-2.	**Michelson Interferometer:** Determination of (a) wavelength of a monochromatic light, (b) two closely spaced wavelength, (c) the refractive index of a material.
Lecture-3.	**Multiple Beam Interferometry:** Multiple Reflections from a Plane Parallel Film: Coefficient of Finesse, Transmittivity of the Fabry-Perot elton and its sharpness.
Lecture-4.	**Fabry-Perot interferometer:** Variation of intensity of a monochromatic beam in Fabry-Perot interferometer, Resolving Power of a scanning Fabry-Perot Interferometer,

Tutorial Assignment—4

Module-IX
Diffraction (2 lectures)

Contents

Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only)

Module Objectives:

1. This module focus on the elementary knowledge of Kirchhoff's integral theorem and the Fresnel-Kirchhoff's integral formula.

Serial No.	Topics of Discussion
Lecture-1.	**Kirchhoff's Integral Theorem**
Lecture-2.	**Fresnel-Kirchhoff's Integral formula**

Module-X **Fraunhofer diffraction** (8 lectures)
Contents Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating.
Module Objectives: 1. From this part, students can procure fundamental knowledge about the Fraunhofer diffraction pattern. 2. From this portion students can get a clear idea about diffraction grating.

Serial No.	Topics of Discussion
Lecture-1.	**Introduction:** Geometrical Shadow, Diffraction Pattern, Classification of Diffraction, Fraunhofer Diffraction, Fresnel Diffraction.
Lecture-2.	**Single Slit Fraunhofer Diffraction Pattern:** Intensity distribution, Position of Maxima and Minima, Transcendental equation.
Lecture-3.	**Circular Aperture:** Fraunhofer diffraction from an arbitrary aperture and circular aperture, Airy pattern, Airy disk, Intensity variations with airy pattern.
Lecture-4.	**Two-slit Fraunhofer Diffraction Pattern:** Intensity distribution, Position of Maxima and Minima, Missing order.
Lecture-5.	**N-slit Fraunhofer Diffraction Pattern:** Intensity distribution, Position of Maxima and Minima, Principal maxima, Missing order, Width of the Principal Maxima
Lecture-6.	**The Diffraction Grating:** Theory of grating, construction of grating, Spectrum of grating.
Lecture-7.	**Resolving Power of a Grating:** Rayleigh criterion, $R = mN$
Lecture-8.	**Resolving Power of a Telescope** $\sin\theta = \frac{1.22\lambda}{D}$

Tutorial Assignment—5

Module-XI **Fresnel Diffraction** (7 lectures)
Contents 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.
Module Objectives: 1. This module attempts the basic knowledge on Fresnel diffraction which provides the clear idea of half-period zone, theory of zone plate as well as the multiple foci of a zone plate. 2. From this part, students can get a underlying idea about Fresnel diffraction pattern of a straight edge, a slit and a wire.

Serial No.	Topics of Discussion
Lecture-1.	**Huygens-Fresnel Principle:** Fresnel assumptions **Fresnel Half-Period Zones:** The radius of the nth circle, Area of zones, Phase consideration.
Lecture-2.	**Fresnel Half-Period Zones:** Intensity calculation, Explanation of Rectilinear Propagation of Light, Diffraction by a circular aperture, The Poisson Spot.
Lecture-3.	**The Zone Plate:** Principle of Zone Plate.

Serial No.	Topics of Discussion
Lecture-4.	**The Zone Plate:** Multiple Foci of a Zone Plate, Difference between convex lens and zone plate.
Lecture-5.	**Fresnel's Integral**
Lecture-6.	**Fresnel Diffraction at a Straight Edge:** Intensity distribution, Fringe width, Measurement of wavelength.
Lecture-7.	**Fresnel's Integral, Fresnel diffraction pattern of a slit and a wire** Intensity distribution.

Module-XII **Holography** (3 lectures)	
Contents Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves. Point source holograms.	
Module Objectives: 1. Techniques of holography help the students to record and reconstruct image in three dimensional form.	
Serial No.	**Topics of Discussion**
Lecture-1.	**Principle of Holography:** Recording and Reconstruction Method.
Lecture-2.	**Theory of Holography:** Interference between two Plane Waves
Lecture-3.	**Point source holograms**

Tutorial Assignment—6

Text books

1. *Optics*, E. Hecht, and A. R. Ganesan, Pearson.
2. *Optics*, A. Ghatak, Mc Graw Hill Education

Reference books

1. *A Text Book on Light*, B. Ghosh, and K. G. Mazumdar, Sheedhar Publishers.

Course code: CC-IV
Course Title: Waves & Optics (Practical)

Module-I **Waves & Optics Practical**
Contents 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.
Module Objectives: 1. To obtain practical knowledge by applying the experimental methods to correlate with the theory of waves. 2. To learn the usage of optical systems for various measurements.

Serial No.	Topics of Discussion
Lab-1.	To investigate the motion of coupled oscillators.
Lab-2.	To study Lissajous Figures.
Lab-3.	Familiarization with: Schuster's focusing; determination of angle of prism.
Lab-4.	To determine refractive index of the Material of a prism using sodium source.
Lab-5.	To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
Lab-6.	To determine wavelength of sodium light using Fresnel Bi-prism.
Lab-7.	To determine wavelength of sodium light using Newton's Rings.
Lab-8.	To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
Lab-9.	To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
Lab-10.	To determine dispersive power and resolving power of a plane diffraction grating.

Department of Physics
Government General Degree College at Kalna -I
Lesson Plan
for
B.Sc. Semester-III (Honours) Courses Under CBCS
Subject: Physics
Course code: CC-V, VI & CC-VII

Course Code: CC-V
Course Title: Mathematical Physics-II (Theory)

Module-I **Fourier Series** (10 lectures)	
Contents 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.	
Module Objectives: In this module students will learn the ideas behind Fourier Series and apply them to expand different functions in the Fourier bases. They will use these ideas to solve certain kind of physical problems.	
Serial No.	**Topics of Discussion**
Lecture-1.	**Discussion on linear algebra using different examples.**
Lecture-2.	**Linear independence of vectors, Basis in vector spaces**
Lecture-3.	**Inner product, Orthogonality in vector space, Application to function spaces**
Lecture-4.	**Periodic functions, Dirichlet condition for Fourier Series.**
Lecture-5.	**Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients**
Lecture-6.	**Discussion on mutual orthogonality of sine and cosine fuctions in connection of Fourier series.**
Lecture-7.	**Complex representation of Fourier series.Expansion of functions with arbitrary period.**
Lecture-8.	**Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series.**
Lecture-9.	**Parseval Identity and its application to summation of different series**
Lecture-10.	**Problems and solutions of Fourier series**

Tutorial Assignment—I

Module-II **Frobenius Method and Special Functions** (24 lectures)
Contents 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.
Module Objectives: In this module, students will be guided through ODEs and their solutions. They will able to solve different useful second order ODES using series solution methods. Special emphasis will be given on Legendre and Bessel differential equations and their respective polynomials.

Serial No.	**Topics of Discussion**
Lecture-1.	**Definition of different types of Differential equations. Importance of second order ordinary differential equation in context of Mechanics and electrostatics.**
Lecture-2.	**Singular Points of Second Order Linear Differential Equations and their importance. Removable and irremovable singular points.**
Lecture-3.	**Power series as a tool to solve ODEs. limitation of the same.**
Lecture-4.	**Introduction Frobenius method for solving ODEs. Removable singularity for Frobenius method**
Lecture-5.	**Strum-Liouville theory for ODEs**
Lecture-6.	**Orthogonality of solution sets**
Lecture-7.	**Special cases of Frobenius solution: (i)** $r_1 \neq r_2$ **and** $r_1 - r_2 \neq \mathbb{Z}$, **(ii)** $r_1 = r_2$
Lecture-8.	**Special cases of Frobenius solution: (iii)** $r_1 \neq r_2$ **and** $r_1 - r_2 = \mathbb{Z}$
Lecture-9.	**Wronskian and linear independence. Application of Wronskian for finding second solution.**
Lecture-10.	**Application of series solution for solving problems like Simple harmonic oscillator.**
Lecture-11.	**Legendre differential equation in context of spherically symmetric Laplace equation.**
Lecture-12.	**Solution of Legendre differential equation: 1st and 2nd solutions.**
Lecture-13.	**Legendre polynomial as solution of Legendre differential equation.**
Lecture-14.	**Gram-Schmidt orthogonalization and its application for generation of Legendre Polynomial in range** $[0 \leq x \leq 1]$
Lecture-15.	**Rodrigous formula for generation of Legendre polynomials. Application of the same for proving** $\int_{-1}^{1} dx P_l(x) P_m(x) = \frac{2}{2l+1}\delta_{lm}$
Lecture-16.	**Generating function for Legendre Polynomials and different relations among Legendre polynomials.**
Lecture-17.	**Bessel's differential equation and its importance in physical problems.**
Lecture-18.	**Solution of Bessel's differential equation. Discussion on singularities.**
Lecture-19.	**Bessel function as a solution of Bessel's differential equation.**
Lecture-20.	**Bessel Functions of the First Kind: Generating Function**
Lecture-21.	**simple recurrence relations**
Lecture-22.	**Zeros of Bessel Functions (**$J_0(x)$ **and** $J_1(x)$**) and Orthogonality.**
Lecture-23.	**Solution of other important differential equations namely Hermite,Laguerre**
Lecture-24.	**Problem and solution of ODEs**

Tutorial Assignment—II

Module-III **Some Special Integrals** (4 lectures)
Contents Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).
Module Objectives: To learn and apply techniques of beta, gamma and the error functions.

Serial No.	Topics of Discussion
Lecture-1.	**Gamma Functions:** Euler Gamma definition, Euler Integral, Euler reflection formula
Lecture-2.	**Gamma Functions:** Some examples, DiGamma Function, Incomplete Gamma Function
Lecture-3.	**Beta Function:** Definition, Relation between Gamma and Beta functions, Some examples
Lecture-4.	**Error Function:** Definition, complementary error function, some examples

Module-IV **Theory of Errors** (6 lectures)
Contents 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.
Module Objectives: In this module, students will understand the importance of error in Physics. They will also be able to apply these ideas to laboratory experiments. 1.

Serial No.	Topics of Discussion
Lecture-1.	**Introduction to error: Why is it fundamental idea to science.**
Lecture-2.	**Types of errors: Systematic, Random Errors and Experimental , computational error.**
Lecture-3.	**Absolute vs relative error. Truncation vs round off error. Quantification of error.**
Lecture-4.	**Propagation of error. Application of the same for different laboratory experiments.**
Lecture-5.	**Normal distribution and Central limit theorem. Standard deviation and confidence of prediction in a random event.**
Lecture-6.	**Fitting of data in a graph: least square fit.**

Tutorial Assignment—III

Module-V **Partial Differential Equations** (14 lectures)
Contents 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.
Module Objectives: Acquire knowledge of methods to solve partial differential equations and applications in various physical problems.

Serial No.	Topics of Discussion
Lecture-1.	**Partial Differential:** Exact And Inexact Differentials, integrating factors,
Lecture-2.	**Separation of variables:** Three dimensional wave equation in rectangular system
Lecture-3.	**Two-dimensional Laplace equation:** Rectangular system, polar coordinate system
Lecture-4.	**Two-dimensional Laplace equation:** Some examples
Lecture-5.	**Laplace's Equation In Cylinder Polar Coordinates**
Lecture-6.	**Laplace's Equation In Cylinder Polar Coordinates:** Some examples
Lecture-7.	**Laplace's Equation In Spherical Polar Coordinates**
Lecture-8.	**Laplace's Equation In Spherical Polar Coordinates:** Some examples
Lecture-9.	**Wave Equation:** Vibration of a stretched string
Lecture-10.	**Wave Equation:** Boundary value problem
Lecture-11.	**Solution of 2D wave equation-Rectangular membrane:** Boundary value problem
Lecture-12.	**Solution of 2D wave equation-Rectangular membrane:** Boundary value problem
Lecture-13.	**Diffusion Equation**
Lecture-14.	**Diffusion Equation:** Boundary value problem

Tutorial Assignment—IV

Text books

1. Differential Equations, George F. Simmons
2. Mathematical Methods for Physicists: Arfken, Weber
3. Fourier Analysis by M.R. Spiegel

Course Code: CC-V
Course Title: Mathematical Physics-II (Practical)

Module-I **Mathematical Physics-II (Practical)** (60 lectures)
Module Objectives: The aim of this Lab is to use the computational methods to solve physical problems. Course will consist of lectures (both theory and practical) in the Lab. Evaluation done not on the programming but on the basis of formulating the problem

Serial No.	**Topics of Discussion**
Lab-1.	**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).
Lab-2.	**Curve fitting, Least square fit, standard deviation:** Goodness of fit, Ohms law to calculate R, Hooke's law to calculate spring constant.
Lab-3.	**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)
Lab-4.	**Generation of Special functions using User defined functions in Scilab:** Generating and plotting Legendre Polynomials Generating and plotting Bessel function:
Lab-5.	**:Solution of ODE First order differential equation Euler, modified Euler and Runge-Kutta second 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
Lab-6.	**Second order differential equation: Fixed difference method** Second order Differential Equation: Harmonic oscillator (no friction), Damped Harmonic oscillator, Over damped, Critical damped, Oscillatory, Forced Harmonic oscillator, Transient and Steady state solution Apply above to LCR circuits also Solve $x^2\frac{d^2y}{dx^2} - 4x(1+x)\frac{dy}{dx} + 2(1+x) = x^3$ with the boundary conditions at $x = 1, y = 0.5e^2$, $\frac{dy}{dx} = -\frac{3}{2}e^2 - 0.5$ in the range $1 \leq x \leq 3$. Plot y and against x in the given range on the same graph.
Lab-7.	**Partial differential equations:** Wave equation, Heat equation, Poisson equation, Laplace equation, Generating square
Lab-8.	**Using Scicos / xcos:** Generating square wave, sine wave, saw tooth wave Solution to harmonic oscillator Study of beat phenomenon Phase space plots

Course Code: CC-VI
Course Title: Thermal Physics (Theory)

Module-I **Introduction to Thermodynamics** (8 lectures)
Contents 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 C_P and C_V. Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient.
Module Objectives: 1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Introduction to Thermodynamic:** Thermodynamic system: Open system, closed system and isolated system. Homogeneous system and heterogeneous system, Thermodynamic variables: intensive and extensive variables.
Lecture-2.	**Zeroth Law of Thermodynamics:** Thermodynamic Equilibrium: mechanical equilibrium, chemical equilibrium and thermal equilibrium. Statement of zeroth law. Concept of temperature.
Lecture-3.	**Thermodynamic Processes** Quasistatic process, isobaric process, isochoric process, isothermal process and adiabatic process,
Lecture-4.	**First Law of Thermodynamics:** Work dependent on the path, Internal Energy, Heat, State function. Statement of first law of thermodynamics and Differential form of 1st law of thermodynamics.
Lecture-5.	**Application Of The First Law Of Thermodynamics:** Heat Capacities: C_P and C_V. For real and ideal gas.
Lecture-6.	**Application Of The First Law Of Thermodynamics:** Enthalpy, Adiabatic relation of an ideal gas, Adiabatic laps rate,
Lecture-7.	**Application Of The First Law Of Thermodynamics:** Work in Various Quasistatic Processes: Isothermal processes, Adiabatic processes, Isochoric process, Isobaric Processes.
Lecture-8.	**Application Of The First Law Of Thermodynamics:** Compressibility and Expansion Co-efficien.

Tutorial Assignment—I

Module-II **Second Law of Thermodynamics** (10 lectures)
Contents 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.
Module Objectives: 1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Reversible and Irreversible Process:** Joule Expansion or free expansion. Cyclic Process
Lecture-2.	**Heat Engine:** Conversion of Work into Heat and Heat into Work, Thermal Efficiency
Lecture-3.	**Carnot Cycle:** The Carnot Cycle and its Efficiency (η)
Lecture-4.	**Refrigerator:** Coefficient of performance of a refrigerator (ω), Relation between η and ω.
Lecture-5.	**Second Law of Thermodynamics:** Kelvin-Plank And Clausius Statement and explanation.
Lecture-6.	**Equivalence Of The Kelvin-Plank And Clausius Statement:**
Lecture-7.	**Carnot Theorem:**
Lecture-8.	**Applications of Second Law of Thermodynamics**
Lecture-9.	**Applications of Second Law of Thermodynamics**
Lecture-10.	**Thermodynamic Scale of Temperature:** Perfect Gas Scale.

Tutorial Assignment—II

Module-III

Entropy (7 lectures)

Contents

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.

Module Objectives:

1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Entropy:** Clausius Theorem, Clausius Inequality, Concept of Entropy.
Lecture-2.	**Entropy:** Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas.
Lecture-3.	**Entropy Change In Different Processes:** The Carnot Cycle, $T - S$ diagrams. Reversible heat transfer, Irreversible heat transfer.
Lecture-4.	**Principle of Increase of Entropy:** Entropy of the Universe.
Lecture-5.	**Unavailable Energy And Thermal Death Of Universe**
Lecture-6.	**Unavailable Energy And Thermal Death Of Universe:** Entropy of an ideal gas, Entropy mixing.
Lecture-7.	**Third Law of Thermodynamics:** Unattainability of Absolute Zero.

Module-IV

Thermodynamic Potentials (7 lectures)

Contents

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.

Module Objectives:

1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Thermodynamic Potentials:** Clausius inequality
Lecture-2.	**An Adiabatic Process:** Adiabatic-Isobaric process: Enthalpy, Adiabatic-Isochoric process : Internal Energy
Lecture-3.	**An Isothermal Process:** Helmholtz energy, Isothermal-Isobaric Process: Gibbs-Helmholtz Equation, Isothermal-Isobaric Process: Gibbs Free Energy.
Lecture-4.	**Phase Transition:** First Order Phase Transition: Clausius-Clapeyron Equation, Second latent heat.
Lecture-5.	**Phase Transition:** Second Order Phase Transition: Ehrenfest Equation, Gibbs Phase Rule
Lecture-6.	**Surface Films:** Variation of Surface Tension with Temperature.
Lecture-7.	**Adiabatic Demagnetization:**

Module-V

Maxwell's Thermodynamic Relations (7 lectures)

Contents

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

Module Objectives:

1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Maxwell Relations:** Derivations of four Maxwell Relations.
Lecture-2.	**Applications Of Maxwell's Relations:** Clausius Clapeyron Equation.
Lecture-3.	**Applications Of Maxwell's Relations:** Thermal Expansion, Heat Capacities, Calculation of $C_P - C_V$ for ideal and real gas.
Lecture-4.	**Applications Of Maxwell's Relations:** The TdS Equations: Application of TDS equations.
Lecture-5.	**Applications Of Maxwell's Relations:** The Energy Equations: Application of Energy equations.
Lecture-6.	**Applications Of Maxwell's Relations:** Joule-Kelvin Effect: Joule-Kelvin coefficient for real gas.
Lecture-7.	**Change In Temperature During Adiabatic Process:**

Tutorial Assignment—III

Module-VI

Distribution of Velocities (7 lectures)

Contents

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.

Module Objectives:

1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Maxwell-Boltzmann Law:** Maxwell's Velocity Distribution law with derivations.
Lecture-2.	**Maxwell-Boltzmann Law:** Velocity Distribution Curves: Temperature dependence.
Lecture-3.	Doppler Broadening of Spectral Lines and Stern's Experiment.
Lecture-4.	Average speed, r.m.s. speed and most probable spped.
Lecture-5.	Energy and momentum distribution of molecules.
Lecture-6.	**Degrees of Freedom:**
Lecture-7.	**Law of Equipartition of Energy:** Statement. Specific heats of gases. Dulong and Petit's law.

Module-VII **Molecular Collisions** (4 lectures)
Contents 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
Module Objectives: 1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Mean Free Path:** Definition, Collision Probability, Mean fee path Calculation.
Lecture-2.	**Transport Phenomenon:** Viscosity of gases
Lecture-3.	**Transport Phenomenon:** Thermal Conductivity, Relation between Viscosity and Conductivity.
Lecture-4.	**Transport Phenomenon:** Diffusion and Brownian motion and its significance.

Tutorial Assignment—IV

Module-VIII **Real Gases** (10 lectures)
Contents Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants.Continuity of Liquid and Gaseous State. 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.
Module Objectives: 1.

Lecture Serial	Topics of Discussion
Lecture-1.	**Behavior of Real Gases:** Isotherms and derivations from ideal gas equation.
Lecture-2.	**Virial Coefficient:** Boyel temperature,
Lecture-3.	**Andrew's Experiments on CO_2 Gas:** Experiment and result.
Lecture-4.	**Critical consist of a gas:** Definitions, Physical explanation on the existence of critical temperature.
Lecture-5.	**Van der Wall's Equation of State:** Pressure and volume correction, evaluate value of the co-volume 'b'.
Lecture-6.	**Discussion on Van der Wall's equation in $P-V$ diagrams:**
Lecture-7.	**Critical Constants of Real gas**
Lecture-8.	**Joule's Experiment:** Free Adiabatic Expansion of a Perfect Gas.
Lecture-9.	**Joule-Thomson Porous Plug Experiment:** Joule-Thomson Effect for Real and Van der Waal Gases.
Lecture-10.	**Temperature of Inversion:** Joule-Thomson Cooling

Tutorial Assignment—V

Text books

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman
2. Thermal Physics, S. Garg, R. Bansal and Ghosh
3. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell

Course Code: CC-VI
Course Title: Thermal Physics (Practical)

Module-I **Thermal Physics (Practical)** (60 lectures)
Module Objectives: ABC

Serial No.	**Topics of Discussion**
Lab-1.	To determine Stefan's constant.
Lab-2.	To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
Lab-3.	To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
Lab-4.	To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) and determine the boiling point of a liquid.
Lab-5.	To study the variation of Thermo-emf of a Thermocouple with Difference of Temperature of its Two Junctions.
Lab-6.	o 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 code: CC- VII
Course Title: DIGITAL SYSTEMS AND APPLICATIONS (Theory)

Module-I Introduction to CRO (3 Lectures)	
Contents 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.	
Module Objectives: This Module delivers idea about working principle and application of CRO	
Serial No.	**Topics of Discussion**
Lecture-1.	**Working principle of CRO**: Block Diagram of CRO, Electron Gun, Deflection System and Time Base. Electric and Magnetic deflection system, Deflection Sensitivity
Lecture-2.	**Applications of CRO:** (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. Study of Lissajous figures
Lecture-3.	Solutions of previous year questions

Module-II Integrated Circuits (Qualitative treatment only): (3 Lectures)	
Contents 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.	
Module Objectives: This unit delivers idea about qualitative idea of Integrated circuit components and their classification	
Serial No.	**Topics of Discussion**
Lecture-1.	**Integrated Circuit:** Active & Passive components. Discrete components. Wafer. Chip. Advantages and drawbacks of ICs
Lecture-2.	**Classification of ICs:** Analog and digital ICs. Levels of integration: SSI, MSI, LSI and VLSI
Lecture-3.	Solutions of previous year questions

Tutorial assignment-1

Module-III Digital Circuits: (6 Lectures)	
Contents 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.	
Module Objectives: 1. This unit gives idea about logic operations and Logic gates 2. one can understand the operation of NOR and NAND as universal gates and XOR and XNOR as parity checker	
Serial No.	**Topics of Discussion**
Lecture-1.	**Number system:** Base of a number system, Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers
Lecture-2.	**Logic Operation**: OR, AND, NOT, NOR, XOR, XNOR operation, truth table
Lecture-3.	**Logic gates:** AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates
Lecture-4.	**Logic gates:** XOR and XNOR Gates and application as Parity Checkers.
Lecture-5.	Discussion on few problems
Lecture-6	Solutions of previous year questions

Module-IV Boolean algebra: (6 Lectures)	
Contents 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.	
Module Objectives: 1. This module gives idea of Boolean algebra. Using different laws of Boolean algebra one can simplify Logic circuits very easily 2. one can also convert Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map	
Serial No.	**Topics of Discussion**
Lecture-1.	**Boolean algebra:** De Morgan's Theorems. Boolean Laws (Commutative, associative, Distributive), Basic OR, AND operation
Lecture-2.	**Boolean algebra:** Absorption law, Boolean identities, Dual of Boolean expression
Lecture-3.	**Simplification of Logic Circuit using Boolean Algebra.**
Lecture-4.	**Standard representation of Logic function:** Fundamental Products. Idea of Minterms and Maxterms.
Lecture-5.	**Conversion of a Truth table into Equivalent Logic Circuit** : by (1) Sum of Products Method and (2) Karnaugh Map.
Lecture-6	Discussion on few problems and Solutions of previous year questions

Tutorial assignment-2

Module-V Data processing circuits: (4 Lectures)	
Contents Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders.	
Module Objectives: This unit gives basic idea about Multiplexers, De-multiplexers, Decoders, Encoders.	
Serial No.	**Topics of Discussion**
Lecture-1.	**Basic idea of Multiplexers (MUX) and De-multiplexers (DEMUX):** 4:1 MUX, Basic two input MUX, 1to 4-line DEMUX
Lecture-2.	**Encoders and Decoders:** Octal to Binary and Decimal to BCD encoder, 3-to-8-line Decoder
Lecture-3.	Discussion on few problems
Lecture-4.	Solutions of previous year questions

Module-VI Arithmetic Circuits: (5 Lectures)	
Contents Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor	
Module Objectives: 1. This module gives idea about binary addition and subtraction 2. One can get idea about Half and Full adder/Subtractor and their design using logic gates	
Serial No.	**Topics of Discussion**
Lecture-1.	**Binary Addition and Subtraction:** Binary addition, Subtraction using 1’s and 2’s complement method, Idea of Carry and Borrow, Signed magnitude
Lecture-2.	**Half and Full Adders:** idea of SUM bit and Carry bit, Design of Half and full adder using logic gates, Full adder using two Half adder
Lecture-3.	**Half & Full Subtractor:** Idea of DIFFERENCE and BORROW bit, Design of Half and Full Subtracter using logic gates
Lecture-4.	**4-bit binary Adder/Subtractor**
Lecture-5.	Solutions of previous year questions

Module-VII Sequential Circuits: (6 Lectures)
Contents 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
Module Objectives: 1. This module gives idea about Sequential Circuit or Flip-Flops 2. One can have idea about SR, JK, D Flip-Flop and their design using logic gates

3. One can also understand how race around condition is solved using M/S JK Flip-Flop	
Serial No.	**Topics of Discussion**
Lecture-1.	**SR Flip-Flop:** SR Flip-Flop by NOR and NAND, Truth Table, SET and RESET condition, Clocked SR Flip Flop, Problem with SR Flip-Flop
Lecture-2.	**JK FlipFlop:** JK Flip-Flop using AND and NAND, Truth table
Lecture-3.	**Clocked (Level and Edge Triggered) Flip-Flops**. **Preset and Clear operations**
Lecture-4.	**Race-around conditions in JK Flip-Flop**. M/S (MASRTER/SLAVE) JK Flip-Flop, D Flip-Flop
Lecture-5	Discussion on few Problems
Lecture-6	Solutions of previous year questions

Tutorial Assignment-3

Module-VIII Timers: IC 555: (3 Lectures)	
Contents block diagram and applications: Astable multivibrator and Monostable multivibrator.	
Module Objectives: This unit gives idea about IC 555 Timer Circuit and its application as Astable and Monostable multivibrator	
Serial No.	**Topics of Discussion**
Lecture-1.	**Astable multivibrator**: Block diagram of IC 555 Timer, Use of IC 555 as Astable multivibrator, Principle of operation, Time period of charging and discharging
Lecture-2.	**Monostable multivibrator:** Use of IC 555 as Monostable multivibrator, Principle of operation, Time period of charging
Lecture-3.	Solutions of previous year questions

Module-IX Shift registers: (2 Lectures)	
Contents Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).	
Module Objectives: This unit gives idea about Shift Registers and their uses as how to register data and one can get knowledge about different types of Shift Registers	
Serial No.	**Topics of Discussion**
Lecture-1.	**Shift registers:** Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers, comparison of number of clock pulses
Lecture-2.	Solutions of previous year questions

Module-X Counters (4 bits): (4 Lectures)	
Contents Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter.	
Module Objectives: This unit delivers idea about counter circuit and different types of counters	
Serial No.	**Topics of Discussion**
Lecture-1.	**Asynchronous counters/ Ripple counter:** Block diagram and Principle of operation
Lecture-2.	**Synchronous Counter and Ring Counter**: Block diagram and Principle of operation
Lecture-3	**Decade Counter:** Block diagram and Principle of operation
Lecture-4	Solutions of previous year questions

Tutorial Assignment-4

Module-XI Computer Organization: (6 Lectures)	
Contents Input/Output Devices. Data storage (idea of RAM and ROM). Computer memory. Memory organization & addressing. Memory Interfacing. Memory Map.	
Module Objectives: This unit gives idea about computer organization including computer memory, memory addressing and interfacing	
Serial No.	**Topics of Discussion**
Lecture-1.	**Input/Output Devices**.
Lecture-2.	**Data storage:** idea of RAM and ROM and their classification
Lecture-3.	**Computer memory**: Memory organization & addressing
Lecture-4.	**Memory Interfacing:** Memory interfacing to microprocessor
Lecture-5.	**Memory Map**
Lecture-6	Solutions of previous year questions

Module-XII Intel 8085 Microprocessor Architecture: (8 lectures)	
Contents 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.	
Module Objectives: This unit gives idea about basic architecture of 8085 Microprocessor and its components	
Serial No.	**Topics of Discussion**
Lecture-1.	**Intel 8085 Microprocessor Architecture:** Main features of 8085. Block diagram. Components. Pin-out diagram
Lecture-2.	**Buses:** System Bus, Address Bus and Control bus
Lecture-3.	**Registers:** General purpose and special purpose register
Lecture-4.	ALU. Memory. Stack memory. Timing & Control unit
Lecture-5.	**Timing & Control circuitry**:

Lecture-6	**Timing states and Instruction cycle**
Lecture-7	**Timing diagram of MOV and MVI.**
Lecture-8	Solutions of previous year questions

Module-XIII Introduction to Assembly Language: (4 Lectures)	
Contents 1 byte, 2 byte & 3 byte instructions.	
Module Objectives: This unit aims to give idea about Assembly language including 1byte, 2byte and 3 byte instruction	
Serial No.	**Topics of Discussion**
Lecture-1.	Assembly language: Machine language, Assembly language, High-level language
Lecture-2.	1 byte instructions
Lecture-3.	2 byte instructions
Lecture-4	3 byte instructions

Tutorial Assignment-5

Course code: CC-VII
Course Title: DIGITAL SYSTEMS AND APPLICATIONS (Practical)

Module-I
DIGITAL SYSTEMS AND APPLICATIONS Practical

Contents

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.

Module Objectives:
This unit aims to develop skill of the students to solve different digital electronic circuit problems and to gain practical knowledge by applying the experimental methods to correlate with the theory

Serial No.	Topics of Discussion	Remarks
Lab-1	To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO.	
Lab-2	To test a Diode and Transistor using a Multimeter	
Lab-3	To design a switch (NOT gate) using a transistor.	

Lab-4	To verify and design AND, OR, NOT and XOR gates using NAND gates	
Lab-5	To design a combinational logic system for a specified Truth Table.	
Lab-6	To convert a Boolean expression into logic circuit and design it using logic gate ICs.	
Lab-7	To minimize a given logic circuit.	
Lab-8	Half Adder, Full Adder and 4-bit binary Adder.	
Lab-9	Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C	
Lab-10	To build JK Master-slave flip-flop using Flip-Flop ICs	
Lab-11	To design an astable multivibrator of given specifications using 555 Timer	
Lab-12	To design a monostable multivibrator of given specifications using 555 Timer.	
Lab-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.	

Department of Physics
Government General Degree College at Kalna -I
Lesson Plan
for
B.Sc. Semester-IV (Honours) Courses Under CBCS
Subject: Physics
Course code: CC-VIII, CC-IX & CC-X

Course Code: CC-VIII
Course Title: Mathematical Physics-III (Theory)

Module-I **Complex Analysis** (30 lectures)
Contents 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.
Module Objectives: Main Objectives of this module are: 1. Representation of a complex number. 2. To know the methods of finding roots of a complex number. 3. To understand the analytic function and Cauchy-Riemann conditions. 4. To understand the different kind of singular functions. 5. To learn and apply techniques of Cauchy's integral formula to find the solution of complex integral. 6. To know the methods of finding the residual of a function using residual formula and apply it to find the solution of definite integrals.

Serial No.	Topics of Discussion
Lecture-1.	**Introduction:** Complex numbers, complex conjugate, Fundamental operation with complex numbers, modulus of complex number, Graphical Representation of complex numbers, Polar form of complex numbers.
Lecture-2.	**Euler's formula & De Moivre's Theorem:** Euler's formula and examples, De Moiver's theorem and its applications.
Lecture-3.	**Roots of Complex numbers:** $z^{1/n}$, Discussion on problems.
Lecture-4.	**Functions of Complex Variables:** Single and multiple-valued functions, Inverse function.
Lecture-5.	**The Elementary Functions:** Polynomial functions, Exponential functions, Trigonometric functions, Hyperbolic functions,
Lecture-6.	**The Elementary Functions:** Logarithmic functions, Inverse Trigonometric functions, Inverse Hyperbolic functions.
Lecture-7.	**Branch points & Branch lines:** Definition and Examples.
Lecture-8.	**Cauchy-Riemann Equations:** Analytic functions, Cauchy-Riemann Equations.

Serial No.	Topics of Discussion
Lecture-9.	**Polar form of Cauchy-Riemann Equations:** Derivation of Polar form of Cauchy-Riemann Equations and Examples.
Lecture-10.	**Harmonic Functions:** Relation between analytic functions and harmonic functions, Laplace's equation, Example of Harmonic Functions.
Lecture-11.	**Singular Points:** Isolated Singularities, Poles and Order, Branch Points, Removable Singularities, Essential Singularities, Singularities at Infinity,
Lecture-12.	**Complex Integration:** Complex line integrals,.
Lecture-13.	**Simply and Multiply Connected Region**
Lecture-14.	**Cauchy's Theorem:** Some Consequences of Cauchy's Theorem
Lecture-15.	**Cauchy's Theorem:** Some Consequences of Cauchy's Theorem
Lecture-16.	**Cauchy's Theorem:** Examples on Cauchy's Theorem.
Lecture-17.	**Cauchy's Integral formula:** Some solved problems.
Lecture-18.	**Cauchy's Integral formula:** Some solved problems.
Lecture-19.	**Cauchy's Integral formula:** Some solved problems.
Lecture-20.	**Cauchy's Integral formula:** Some solved problems.
Lecture-21.	**Cauchy's Integral formula:** Some solved problems.
Lecture-22.	**Cauchy's Integral formula:** Some solved problems.
Lecture-23.	**Taylor Series:** Taylor's theorem, Some special functions (e^z, $\sin z$, $\cos z$, $\ln(1 + z)$, $\cdots$), Some Solved problems on Taylor series.
Lecture-24.	**Laurent Series:** Laurent's Theorem, Discussion on special case $n = -1$.
Lecture-25.	**Residues:** Calculation of Residues, Examples.
Lecture-26.	**Residue Theorem:** Examples
Lecture-27.	**Residue Theorem:** Definite integrals of the type $\int_{-\infty}^{\infty} F(x)\,dx$
Lecture-28.	**Residue Theorem:** Definite integrals of the type $\int_0^{2\pi} G(\sin\theta, \cos\theta)\,d\theta$
Lecture-29.	**Residue Theorem:** Definite integrals of the type $\int_{-\infty}^{\infty} F(x)\,\cos mx\,dx$ and $\int_{-\infty}^{\infty} F(x)\,\sin mx\,dx$
Lecture-30.	**Miscellaneous Definite Integrals:** $\int_0^{\infty} \frac{\sin x}{x}$

Tutorial Assignment—1

Module-II

Integrals Transforms (15 lectures)

Contents

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.

Module Objectives:

Main Objectives of this module are:
1. The Fourier transform provides a representation of functions defined over an infinite interval and having no particular periodicity, in terms of a superposition of sinusoidal functions.
2. To learn and apply techniques of FT to solve the differential equations.

Serial No.	Topics of Discussion
Lecture-1.	**Fourier Transform:** Fourier transform and Inverse Fourier transform.
Lecture-2.	**Fourier Transform:** Examples on Fourier Transform
Lecture-3.	**Fourier Transform of Trigonometric functions** Examples
Lecture-4.	**Fourier Transform of Gaussian Function**
Lecture-5.	**Fourier transform of Finite Wave Train:** Examples
Lecture-6.	**Representation of Dirac delta function:** Some Important Properties.
Lecture-7.	**Convolution Theorem:** Statement and Proof.

Serial No.	Topics of Discussion
Lecture-8.	**Properties of Fourier Transform:** Differentiation, Linearity, Translation, Scaling.
Lecture-9.	**Properties of Fourier Transform:** Exponential multiplication, Complex Conjugation
Lecture-10.	**Examples on Fourier Transforms** Examples
Lecture-11.	**Examples on Fourier Transforms**
Lecture-12.	**Three dimensional Fourier transforms:** Representation of 3-D Fourier transforms, 3-D Dirac-δ function.
Lecture-13.	**Three dimensional Fourier transforms:** Examples
Lecture-14.	**Wave Equation:** Solution of 1-D wave equation.
Lecture-15.	**Heat Flow PDE:** $\frac{\partial \Psi}{\partial t} = a^2 \frac{\partial^2 \Psi}{\partial x^2}$

Tutorial Assignment—2

Module-III **Laplace Transforms** (15 lectures)
Contents 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.
Module Objectives: To learn and apply techniques of Laplace Transform for solving differential equations. In particular, it transforms linear differential equations into algebraic equations and convolution into multiplication

Serial No.	Topics of Discussion
Lecture-1.	**Laurent Transform:** Definition and Examples.
Lecture-2.	**Properties of Laplace Transform:** Linearity, First shifting theorem, Examples
Lecture-3.	**Properties of Laplace Transform:** Change of scale property and its Examples.
Lecture-4.	**Periodic Functions:** Laplace Transform of Periodic functions and Examples.
Lecture-5.	**Laplace transforms of derivatives:** Laplace transform of the first derivative, Laplace transform of the second derivative, Laplace transform of the nth derivative, Examples.
Lecture-6.	**Laplace transforms of Integrals:** Examples.
Lecture-7.	**Convolution Theorem:** Statement and Proof.
Lecture-8.	**Inverse Laplace Transformation:** Examples
Lecture-9.	**Properties of inverse Laplace Transform:** Linearity property, First shifting property, Change of scale property, Examples
Lecture-10.	**LT of Unit Step function, Dirac Delta function**
Lecture-11.	**Application of Laplace Transforms:** Damped harmonic oscillator
Lecture-12.	**Application of Laplace Transforms:** Simple Electrical Circuits.
Lecture-13.	**Application of Laplace Transforms:** Simple Electrical Circuits.
Lecture-14.	**Application of Laplace Transforms:** Coupled differential equations
Lecture-15.	**Application of Laplace Transforms:** Heat flow along infinite bar.

Tutorial Assignment—3

Text books

1. *Complex Variables*, Murray R. Spiegel, Schaum's Outline Series
2. *Fourier Analysis with Applications to Boundary Value Problems*, Murray R. Spiegel, Schaum's Outline

Series
3. *Theory and problems of Laplace transforms*, Murray R. Spiegel, Schaum's Outline Series

Reference books

1. *Mathematical methods for physics and engineering*, K. F. Riley, M. P. Hobson, S. J. Bence, Cambridge University Press; 3rd edition
2. *Higher Engineering Mathematics*, B. S. Grewal, Khanna Publishers

Course code: CC-VIII
Course Title: Mathematical Physics-III (Practical)

Module-I **Mathematical Physics-III Practical**
Contents Scilab/C++ based simulations experiments based on Mathematical Physics problems
Module Objectives: 1. This module aims to develop computational skill of the students to solve the problems based on Mathematical Physics and plot the results graphically.

Serial No.	**Topics of Discussion**
Lab-1.	Solve differential equations $\frac{dy}{dx} = e^{-x}$ with $y = 0$ for $x = 0$ $\frac{dy}{dx} + e^{-x}y = x^2$ $\frac{d^2y}{dt^2} + 2\frac{dy}{dt} = -y$ $\frac{d^2y}{dt^2} + e^{-t}\frac{dy}{dt} = -y$
Lab-2.	Dirac Delta Function: Evaluate $\frac{1}{\sqrt{2\pi\sigma}} \int_{\infty}^{\infty} e^{-\frac{(x-a)^2}{2\sigma^2}} (x+3)\, dx$ for $\sigma = 1, 0.1, 0.01$, and show it tends to 5.
Lab-3.	Fourier Series: Program to sum $\sum_{n=1}^{\infty} (0.2)^n$ Evaluate the Fourier coefficients of a given periodic function (square wave).
Lab-4.	Frobenius method and Special functions: $\int_{-\infty}^{\infty} P_n(x)P_m(x) = \delta_{mn}$ Plot $P_n(x)$, $j_v(x)$. Show recursion relation.
Lab-5.	Calculation of error for each data point of observations recorded in experimentsdone in previous semesters (choose any two).
Lab-6.	Calculation of least square fitting manually without giving weightage to error.Confirmation of least square fitting of data through computer program.

Serial No.	Topics of Discussion
Lab-7.	Evaluation of trigonometric functions e.g. $\sin\theta$, Given Bessel's function at N points find its value at an intermediate point. Complex analysis: Integrate $1/(x^2+2)$ numerically and check with computer integration.
Lab-8.	Compute the nth roots of unity for $n = 2$, 3, and 4.
Lab-9.	Find the two square roots of $-5+12\,j$.
Lab-10.	Integral transform: FFT of e^{-x^2}.
Lab-11.	Solve Kirchoff's Current law for any node of an arbitrary circuit using Laplace's transform.
Lab-12.	Solve Kirchoff's Voltage law for any loop of an arbitrary circuit using Laplace's transform.
Lab-13.	Perform circuit analysis of a general LCR circuit using Laplace's transform.

Course Code: CC-IX
Course Title: Elements of Modern Physics (Theory)

Module-I
Introduction to Quantum Mechanics: (39 lectures)

Contents

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

Module Objectives:

To understand introductory Quantum Mechanics and develop wave mechanics.

Inception of Quantum Mechanics

Lecture Serial	Topics of Discussion
Lecture-1.	**Introduction and Overview:** Historical overview of limitations of Classical Mechanics.
Lecture-2.	**Planck's theory of Radiation I:** Classical radiation theories and their deviations from experimental data.
Lecture-3.	**Planck's theory of Radiation II:** Planck's observation of the problem and possible solution.
Lecture-4.	**Planck's theory of Radiation III:** Concept of photon and introduction of new physical constant : The Planck's constant.
Lecture-5.	**Photoelectric Effect I:** Limitations of Classical explanation of Photoelectric effect.

Lecture Serial	Topics of Discussion
Lecture-6.	**Photoelectric Effect II:** Einstein's proposal of Photon picture consistent with Planck's hypothesis.
Lecture-7.	**Compton scattering:** Phenomena of Compton effect and reconfirmation of photon picture of light. Modified and Unmodified lines.
Lecture-8.	**Davisson-Germer experiment:** Davission-Germer Experiment with electrons and its outcome.
Lecture-9.	**De Broglie wavelength and matter waves:** Explanation of Davission-Germer Experiment with wave nature of electron.
Lecture-10.	**Wave description of particles by wave packets:** Group and Phase velocities and relation between them.
Lecture-11.	**Heisenberg's microscope:** Position measurement- gamma ray microscope thought experiment.
Lecture-12.	**Heisenberg's uncertainty principle I:** Formulation of Heisenberg's uncertainty principles for conjugate variables.
Lecture-13.	**Heisenberg's uncertainty principle II:** Physical application of position-momentum Uncertainty principle.
Lecture-14.	**Energy-time uncertainty principle:** Physical application of Energy-time Uncertainty principle.
Lecture-15.	**Wave-particle duality:** Wave particle dual nature complete picture.

Tutorial Assignment—I

Formulation of Quantum Mechanics

Lecture-16.	**Two-Slit experiment with light:** Recapitulation of Double slit experiment from Optics.
Lecture-17.	**Two-Slit experiment with electrons :** Observation from Two-Slit experiment with electrons.
Lecture-18.	**Two-Slit experiment with weak light :** Repetition of Double slit experiment from Optics with weak source.
Lecture-19.	**Two-Slit experiment :** All results from different types of double slit experiment being processed.
Lecture-20.	**Superposition principle:** Out come of double slit experiment: Validity of superposition principle and linear nature of theory.
Lecture-21.	**Schroedinger equation:** Construction of Schroedinger's equation.
Lecture-22.	**probabilities and normalization** Wave-function and its normalization, Copenhagen interpretation of wave-function.
Lecture-23.	**probability current density** probability current density and continuity equation in Quantum Mechanics.

Tutorial Assignment—II

Mathematical Formulation of Quantum Mechanics

Lecture-24.	**Linear Vector Space:** Introduction to linear vector space (LVS) strictly with examples.
Lecture-25.	**Linear dependence and independence:** Linear dependence and independence of vectors with examples.
Lecture-26.	**Basis:** Idea of basis and dimensionality of a vector space.
Lecture-27.	**Operators in LVS:** Operators in Linear vector space.
Lecture-28.	**Quantum Mechanics and LVS:** Relevance of Linear vector space in context of Quantum Mechanics.
Lecture-29.	**Operators in Quantum Mechanics:** States and operators in Quantum Mechanics.

Lecture Serial	Topics of Discussion
Lecture-30.	**Eigenvalues and Eigenfunctions:** Eigenvalues and Eigenvectors in Quantum Mechanics.
Lecture-31.	**Time dependent and independent Schroedinger's equation:** Hamiltonian operator and Time dependent and independent Schroedinger's equation.
Lecture-32.	**Stationary states:** Stationary states in Quantum Mechanics and its importances.

Tutorial Assignment—III

	Application of Quantum Mechanics
Lecture-33.	**One dimensional infinitely rigid box I:** Construction of the problem (potential's form).
Lecture-34.	**One dimensional infinitely rigid box II:** Solution of Time independent schroedinger's equation.
Lecture-35.	**One dimensional infinitely rigid box III:** Interpretation of solutions and derived quantities.
Lecture-36.	**Quantum mechanical scattering I:** Difference between bound and scattering states in quantum mechanics.
Lecture-37.	**Step potential :** Construction of the problem. Initialization of solution of the problem.
Lecture-38.	**Step potential:** Solution and interpretation of step potential.
Lecture-39.	**Concluding remarks:** Concluding summery of introductory quantum mechanics and further possibilities.

Tutorial Assignment—IV

Module-II **Introductory Nuclear Physics and LASER:** (21 lectures)
Contents
Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. Nature of nuclear force, NZ graph, Liquid Drop model: semi-empirical mass formula and binding energy, Nuclear Shell Model and magic numbers. Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay; Beta decay- energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus. Fission and fusion- mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235; Fusion and thermonuclear reactions driving stellar energy (brief qualitative discussions). 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.
Module Objectives:
To understand introductory Nuclear physics and basic LASER action.

Introduction to Nuclear Physics	
Lecture Serial	**Topics of Discussion**
Lecture-40.	**Overview:** Historical overview of limitations of Classical Mechanics.
Lecture-41.	**Introductory topics:** 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.
Lecture-42.	**Nature of nuclear force:** Nuclear force and its nature, NZ curve and its importance.
Lecture-43.	**Liquid Drop model I:** Derivation of Liquid drop model in Nuclear physics.
Lecture-44.	**Liquid drop model II:** Application of Liquid drop model for understanding stabilities of different nuclei.
Lecture-45.	**Nuclear Shell Model:** Brief description to Shell model and its application to explanation of magic numbers.
Lecture-46.	**Radioactivity:** Stability of the nucleus and radioactive decay.
Lecture-47.	**Law of radioactive decay:** Law of radioactive decay, Half-life and mean-life of a nucleus in the connection.
Lecture-48.	**Law of radioactive decay:** Law of radioactive decay, Half-life and mean-life of a nucleus in the connection.
Lecture-49.	**Beta decay** Introduction to beta decay. Experimental findings.
Lecture-50.	**Fermi's theory of Beta decay** Fermi's theory of beta decay and expansion of beta spectrum.
Lecture-51.	**Gamma ray emission:** Introduction to Gamma decay. Experimental history of Gamma deacy.
Lecture-52.	**Gamma ray:** Gamma ray as an electromagnetic ray, its applications to science.
Lecture-53.	**Pair production:** energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.
Lecture-54.	**Revisiting STR:** Revisiting concept of variable mass and relative measurements in different reference frames in Special theory of relativity.
Lecture-55.	**Mass deficit:** Mass defect and conversion of mass defect into energy. Historical importance.
Lecture-56.	**Nuclear reactor:** Features of Nuclear reactor, controlled nuclear chain reaction for energy production.
Lecture-57.	**Solar nuclear cycle:** Nuclear Fission and Fusion. Brief introduction to nuclear fission in Sun.

Introduction to LASER	
Lecture-58.	**LASER:** Introduction to LASER, Einstein's A and B co-efficients.
Lecture-59.	**Working principle of LASER:** Metastable states. Spontaneous and Stimulated emissions, Optical pumping and Population inversion.
Lecture-60.	**Different types of LASERs:** Three-Level and Four-Level LASERs. Ruby LASER and He-Ne LASER.

Tutorial Assignment—V

Text books
1. Introduction to Quantum Mechanics - David J. Griffiths
2. Concepts of Modern Physics - Arthur Beiser
3. Quantum Physics - Robert Eisberg and Robert Resnick.

Reference books
1. Modern Physics- John R. Taylor
2. Quantum Physics, Berkeley Physics, Vol.4.- E.H.Wichman

Course code: CC-IX
Course Title: Elements of Modern Physics (Practical)

Module-I Elements of Modern Physics Practical
Contents 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 using graph paper.
Module Objectives: 1. To gain practical knowledge by applying the experimental methods to correlate with the theory of electricity and magnetism. 2. To apply the analytical techniques and graphical analysis to the experimental data.

Serial No.	Topics of Discussion
Lab 1.	Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
Lab 2.	To determine work function of material of filament of directly heated vacuum diode.
Lab 3.	To determine the Planck's constant using LEDs of at least 4 different colours.
Lab 4.	To determine the wavelength of H-alpha emission line of Hydrogen atom.
Lab 5.	To determine the excitation potential of mercury/Argon by Franck-Hertz experiment.
Lab 6.	To determine the absorption lines in the rotational spectrum of Iodine vapour.
Lab 7.	To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
Lab 8.	To setup the Millikan oil drop apparatus and determine the charge of an electron.
Lab 9.	To show the tunnelling effect in tunnel diode using I-V characteristics.
Lab 10.	To determine the wavelength of laser source using diffraction of single slit using graph paper.

Course code: CC-X

Course Title: ANALOG SYSTEMS AND APPLICATIONS (Theory)

Module-I **Semiconductor Diodes**: (10 Lectures)	
Contents 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.	
Module Objectives: 1. This unit aims to deliver idea about formation of semiconductor diode and its current flow mechanism 2. How potential barrier is formed across the junction can be clearly understood 3. One can also get idea about how a PN junction diode operates in forward and reverse biased condition and the I-V characteristics of junction diode can be clearly understood.	
Serial No.	**Topics of Discussion**
Lecture-1.	**Semiconductor diode**: idea of conduction and valance band, impurity states, P and N type semiconductors. Concept of donor and acceptor level, Energy Level Diagram,
Lecture-2.	**Current flow in semiconductor**: Majority and minority charge carrier Current flow mechanism, Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea)
Lecture-3.	**Potential Barrier formation in PN junction diode**: Abrupt step junction and graded junction, Formation of potential barrier, Depletion layer, idea of Contact Potential
Lecture-4.	**Forward and Reverse Biased Diode:** Current flow mechanism in Forward and Reverse Biased PN junction Diode, Energy level diagram of Forward and Reverse Biased Diode
Lecture-5.	**Derivation of different parameters associated with depletion layer:** Derivation for Barrier Potential, Barrier Width, electric field at barrier and Current for Step Junction
Lecture-6	**Expression of current in PN junction Diode:** Derivation of Rectifier equation for current flow in a semiconductor diode, I-V characteristics
Lecture-7	**Diode resistance:** Static and Dynamic Resistance
Lecture-8	Discussion on few problems
Lecture-9	Solutions of previous year questions
Lecture-10	Solutions of previous year questions

Module-II Two-terminal Devices and their Applications: (6 Lectures)
Contents (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.

Module Objectives:	
1. This unit gives idea about two-terminal devices and their applications 2. One can understand how diodes and filters can be used as rectifier 3. Operation of Zener-Diode as voltage regulator can be understood 4. One can get basic knowledge about LED, Photodiode and solar cell	
Serial No.	**Topics of Discussion**
Lecture-1.	**Rectifier Diode:** Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Peak inverse voltage
Lecture-2.	**Factors determining rectifier performance:** Average and R.M.S. voltage, current, Calculation of Ripple Factor and Rectification Efficiency of half wave and full wave rectifier
Lecture-3.	**Filter circuit:** C-filter, Calculation of ripple factor
Lecture-4.	**Zener Diode:** Concept of Avalanche and Zener breakdown, Zener Diode as voltage and load regulator
Lecture-5.	**Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell.**
Lecture-6	Discussion on few problems

Tutorial assignment-1

Module-III Bipolar Junction transistors: (6 Lectures)	
Contents 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, Cut-off and Saturation Regions.	
Module Objectives: 1. This unit gives idea about Bipolar Junction transistors, Characteristics of n-p-n and p-n-p transistors 2. One can get information about different modes of transistor operation 3. current flow mechanism in BJT can also be understood	
Serial No.	**Topics of Discussion**
Lecture-1.	**Bipolar junction Transistors**: n-p-n and p-n-p Transistors, Energy band diagram, Current components in n-p-n and p-n-p transistors
Lecture-2.	**Transistor Characteristics**: CB, CE and CC Configurations, Input and output characteristics, Early effect, Current gains α and β Relations between α and β
Lecture-3.	**Different regions of Transistor operation:** Active, Cut-off and Saturation Regions of transistor operation.
Lecture-4.	**Load Line analysis of Transistors**: DC biasing of transistor, DC Load line and Q-point,
Lecture-5.	Discussion on few problems
Lecture-6	Solutions of previous year questions

Module-IV

Amplifiers: (10 Lectures)

Contents

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.

Module Objectives:

1. This unit gives idea about transistor as amplifier and need of biasing to operate the transistor as amplifier
2. different biasing techniques can be understood
3. h-parameter analysis technique helps to solve any transistor circuit problem very easily.

Serial No.	Topics of Discussion
Lecture-1.	**Transistor Biasing:** Transistor as amplifier, Need of transistor biasing, choice of Q-point for fruitful reproduction of input signal
Lecture-2.	**Biasing stability:** Different stability factors for Fixed bias, collector to base bias, self-bias /voltage divider bias circuits
Lecture-3.	**Transistor as 2-port Network:** Blackbox approach, h-parameter analysis, $h_{ie,}$ h_{re}, h_{fe} and h_{oe} parameters, h-parameter Equivalent Circuit
Lecture-4.	**Analysis of a single-stage CE amplifier using Hybrid Model:** Input and Output Impedance
Lecture-5.	**Analysis of a single-stage CE amplifier using Hybrid Model:** Current, Voltage and Power Gains
Lecture-6	**Simplified hybrid model**
Lecture-7	**Classification of transistors:** Class A, B, AB & C Amplifiers.
Lecture-8	Discussion on few problems
Lecture-9	Discussion on few problems
Lecture-10	Solutions of previous year questions

Tutorial assignment-2

Module-V

Coupled Amplifier: (4 Lectures)

Contents

Two stage RC-coupled amplifier and its frequency response.

Module Objectives:

1. This unit gives idea about frequency response of coupled Amplifier
2. One can get idea about voltage gain at different frequency range, lower and upper cut-off frequency of such coupled amplifier

Serial No.	Topics of Discussion
Lecture-1.	**Two stage RC-coupled amplifier**: Effect of junction capacitance, h-parameter equivalent circuit, Frequency response of RC-Coupled amplifier Mid frequency range,
Lecture-2.	**Two stage RC-coupled amplifier:** Frequency response of RC-Coupled amplifier Low and High frequency range,

Lecture-3.	**Two stage RC-coupled amplifier:** Plot of Mid frequency gain, Low frequency gain, High frequency gain with frequency, Lower and upper cut-off frequency, band width, figure of merit.
Lecture-4.	Solutions of previous year questions

Module-VI Feedback in Amplifiers: (4 Lectures)	
Contents Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.	
Module Objectives: 1. This unit aims to deliver idea about positive and negative feedback and their effects on different parameters	
Serial No.	**Topics of Discussion**
Lecture-1.	**Feedback in Amplifiers:** Positive and Negative Feedback, Different types of Feedback: Voltage series, voltage shunt, current series and current shunt feedback
Lecture-2.	**Effects of Positive and Negative Feedback**: improved stability of gain, reduction of distortion and noise, change of band width, effect of feedback on input and output impedance
Lecture-3.	Discussion on few Problems
Lecture-4.	Solutions of previous year questions

Module-VII Sinusoidal Oscillators: (4 Lectures)	
Contents Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.	
Module Objectives: 1. This unit aims to deliver idea about sustained oscillation criterion 2. one can understand how to determine frequencies of different types of oscillators	
Serial No.	**Topics of Discussion**
Lecture-1.	**Sinusoidal Oscillators:** basic principle of oscillation, Barkhausen's Criterion for self-sustained oscillations.
Lecture-2.	**Reactance oscillator:** h-parameter equivalent circuit, Calculation of gain, frequency of Hartley & Colpitts oscillators
Lecture-3.	**RC Phase shift oscillator:** Thevenin’s equivalent circuit, Calculation of frequency
Lecture-4.	Discussion on few Problems and Solutions of previous year questions

Tutorial Assignment-3

Module-VIII Operational Amplifiers (Black Box approach): (4 Lectures)	
Contents 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.	
Module Objectives: 1. This unit helps students to understand characteristics of Op-Amp and few Op-Amp parameters 2. One can understand the concept of Virtual ground of input terminal for an ideal Op-Amp 3. Also frequency response of Op-Amp can be understood	
Serial No.	**Topics of Discussion**
Lecture-1.	**Characteristics of Op-Amp**: Characteristics of an Ideal and Practical Op-Amp Open-loop and Closed-loop Gain, Common mode rejection ratio (CMRR), Slew Rate and concept of Virtual ground
Lecture-2.	**Frequency Response of Op-Amp:** Variation of AC closed-loop gain with frequency
Lecture-3.	Discussion on few Problems
Lecture-4.	Solutions of previous year questions

Module-IX Applications of Op-Amps: (9 Lectures)	
Contents 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.	
Module Objectives: 1. This unit gives practical idea about application of Op-Amps as various electronic circuits used to fulfill different purposes	
Serial No.	**Topics of Discussion**
Lecture-1.	**(1) Inverting and non-inverting amplifiers**: Voltage gain, input resistance, unity gain buffer or voltage follower amplifier
Lecture-2.	**(2) Adder:** Output voltage is algebraic sum of input voltage, **(3) Subtractor:** Difference of input voltage is amplified at the output
Lecture-3.	**(4) Differentiator:** Output voltage proportional to the time derivative of input signal, AC response, **(5) Integrator:** Output voltage proportional to the time integral of input signal, AC response
Lecture-4.	**(6) Log amplifier:** Output voltage proportional to the logarithm of input signal, **(7) Zero crossing detector**: Voltage comparator
Lecture-5.	**(8) Wein bridge oscillator:** Frequency calculation, Condition for sustained oscillation (open loop gain, A>3)
Lecture-6	Discussion on few Problems
Lecture-7	Discussion on few Problems
Lecture-8	Solutions of previous year questions
Lecture-9	Solutions of previous year questions

Module-X Conversion: (3 Lectures)	
Contents Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion (Successive approximation)	
Module Objectives: 1. This unit aims to give idea about Digital to Analog signal conversion	
Serial No.	**Topics of Discussion**
Lecture-1.	**Digital to Analog converter:** The weighted resistor D/A converter
Lecture-2.	**Digital to Analog converter:** R-2R Ladder converter, Accuracy and Resolution
Lecture-3.	Solutions of previous year questions

Tutorial Assignment-4

Course code: CC-X

Course Title: ANALOG SYSTEMS AND APPLICATIONS (Practical)

Module-I **Analog Systems and Applications Practical**		
Contents 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.		
Module Objectives: This unit aims to develop skill of the students to solve different electronic circuit problems and plot the results graphically		
Serial No.	**Topics of Discussion**	**Remarks**
Lab-1	To study V-I characteristics of PN junction diode, and Light emitting diode	
Lab-2	To study the V-I characteristics of a Zener diode and its use as voltage regulator.	
Lab-3	Study of V-I & power curves of solar cells, and find maximum power point & efficiency.	
Lab-4	To study the characteristics of a Bipolar Junction Transistor in CE configuration	
Lab-5	To study the frequency response of voltage gain of a RC-coupled transistor amplifier	
Lab-6	To study a Wien bridge oscillator for given frequency using an op-amp.	
Lab-7	To design an inverting / non-inverting amplifier using Op-amp (741) for dc voltage of given gain	
Lab-8	To add two dc voltages using Op-amp in inverting and non-inverting mode	
Lab-9	To investigate the use of an op-amp as an Integrator / Differentiator.	

Department of Physics
Government General Degree College at Kalna -I
Lesson Plan
for
B.Sc. Semester-V (Honours) Courses Under CBCS
Subject: Physics
Course code: CC-XI, XII, DSE-1, & DSE-2

Course code: CC-XI
Course Title: Quantum Mechanics And Applications (Theory)

Module-I **Time dependent Schrodinger equation** (6 lectures)
Contents 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.
Module Objectives: To learn the interpretation of wave function of sub-atomic particle and probabilistic nature of its location.

Lecture Serial	Topics of Discussion
Lecture-1.	**Introduction:** Black Body Radiation, Photo-Electric effect, Compton Effect & Pair-Production
Lecture-2.	**Introduction:** Particle Vs Wave
Lecture-3.	**Time dependent Schrodinger equation:** Dynamical evolution of a quantum state,
Lecture-4.	**Wave Function:** Interpretation of Wave Function Probability and probability current densities in one and three dimensions, Conditions for Physical Acceptability of Wave Functions, Normalization. Linearity and Superposition Principles.
Lecture-5.	**Eigenvalues and Eigenfunctions:** Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum.
Lecture-6.	**Wave Function of a Free Particle** The general solution of one-dimensional Schrodinger equation for a free particle

Module-II **Time independent Schrodinger equation** (10 lectures)
Contents Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wave function as a linear combination of energy eigenfunctions; General solution of the time dependent 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 wave function; Position-momentum uncertainty principle.
Module Objectives: 1. To understand the time independent Schrodinger equation and represented a quantum system in a linear combination of energy eigenfunctions. 2. To represent the free partial in quantum mechanics. 3. To know the position-momentum uncertainty principle.

Lecture Serial	**Topics of Discussion**
Lecture-1.	**Introduction:** Potential is time independent, Hamiltonian, stationary states and energy eigenvalues
Lecture-2.	**Energy Eigenvalues:** Expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions, orthogonality of eigenfunctions.
Lecture-3.	**General solution of the time dependent Schrodinger equation:** General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states
Lecture-4.	**Wave-packet:** Gaussian wave-packet for a free particle in one dimension, The time evolution of a wave packet
Lecture-5.	**Momentum space wavefunction:** Fourier transforms and momentum space wavefunction
Lecture-6.	**Wave-packet:** Group velocity of wave-packet
Lecture-7.	**Gaussian wave packet:** Calculation of $\langle x\rangle$, $\langle x^2\rangle$
Lecture-8.	**Gaussian wave packet:** Calculation of $\langle p\rangle$, $\langle p^2\rangle$
Lecture-9.	Discussion of some problems
Lecture-10.	**Position-momentum uncertainty principle:**

Tutorial Assignment—I

Module-III **General discussion of bound states in an arbitrary potential** (12 lectures)
Contents 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.
Module Objectives: To know the methods of finding the eigenfunctions and energy eigenvalues and the behavior of quantum particle when encountering a different barrier potential

Lecture Serial	**Topics of Discussion**
Lecture-1.	**Introduction:** Stationary states, Boundary and Continuity Conditions
Lecture-2.	**Degeneracy & Parity**
Lecture-3.	**Particle in a one-dimensional infinitely deep potential wall:** Energy eigenvalues, Eigenfunctions
Lecture-4.	**Particle in a one-dimensional infinitely deep potential wall:** Orthogonality of eigenfunctions, Completeness condition

Lecture-5.	**Particle in a one-dimensional potential well of finite depth:** Energy eigenvalues, Eigenfunctions
Lecture-6.	**Particle in a three-dimensional box**
Lecture-7.	**The Harmonic Oscillator:** Potential energy function, Hamiltonian,
Lecture-8.	**The Harmonic Oscillator:** Solution of the time dependent Schrodinger equation
Lecture-9.	**The Harmonic Oscillator:** The eigenfunctions, Hermite polynomials, Normalized eigenfunctions
Lecture-10.	**The Harmonic Oscillator:** Simple harmonic oscillator-energy levels
Lecture-11.	**The Harmonic Oscillator:** Discussion on Ground state, Zero point energy
Lecture-12.	**The Harmonic Oscillator:** Discussion on uncertainty principle

Tutorial Assignment—II

Module-IV
Quantum theory of hydrogen-like atoms (10 lectures)

Contents

Time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wave functions 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.

Module Objectives:

To learn the method to find the eigenfunctions and eigenvalues of a non-relativistic hydrogen atom and explain its spectrum.

Lecture Serial	Topics of Discussion
Lecture-1.	**Spherically Symmetric Potential:** Time independent Schrodinger equation in spherical polar coordinates
Lecture-2.	**Spherically Symmetric Potential:** Separation of variables
Lecture-3.	**Angular momentum operator**
Lecture-4.	**Quantum numbers**
Lecture-5.	**Radial wave functions from Frobenius method**
Lecture-6.	**Probability Densities:** Shapes of the probability densities for ground & first excited states
Lecture-7.	**Orbital Angular Momentum:** Orbital angular momentum quantum numbers l and m
Lecture-8.	**s, p, d,.. shells**
Lecture-9.	Problems and solutions on Hydrogen atom problems
Lecture-10.	Discussion previous year questions.

Tutorial Assignment—III

Module-V
Atoms in Electric & Magnetic Fields (8 lectures)

Contents

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.

Module Objectives:

From this chapter one can understand the space quantization and electron spin.

Lecture Serial	Topics of Discussion
Lecture-1.	**Electron angular momentum**
Lecture-2.	**Space quantization:** Electron Spin and Spin Angular Momentum.

Lecture-3.	**Larmor's Theorem:** Spin Magnetic Moment
Lecture-4.	**Stern-Gerlach Experiment** Experimental Set-up, Discussion on space quantization
Lecture-5.	**Zeeman Effect:** Experimental Set-up, Normal Zeeman effect, Anomalous Zeeman effect
Lecture-6.	**Zeeman Effect:** Electron Magnetic Moment and Magnetic Energy
Lecture-7.	**Gyromagnetic Ratio and Bohr Magneton**
Lecture-8.	Problems and solutions on Atoms in Electric & Magnetic Fields

Module-VI

Atoms in External Magnetic Fields (4 lectures)

Contents

Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only)

Module Objectives:

One can understand Zeeman Effect,Paschen Back and Stark Effect

Lecture Serial	**Topics of Discussion**
Lecture-1.	**Zeeman Effect:** Experimental Set-up, Normal Zeeman effect, Anomalous Zeeman effect
Lecture-2.	**Paschen Back Effect**
Lecture-3.	**Stark Effect**
Lecture-4.	Discussion previous year questions.

Tutorial Assignment—IV

Module-VII

Many electron atoms (10 lectures)

Contents

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.).

Module Objectives:

1. This unit aims to deliver idea of Vector atom model.
2. One can understand spin-orbit coupling in atoms (L-S and J-J couplings).
3. One can also obtain idea aboutthe fine structure og hydrogen and alkali atoms.

Lecture Serial	**Topics of Discussion**
Lecture-1.	**Pauli's Exclusion Principle:** Statement & Discussion
Lecture-2.	**Symmetric & Antisymmetric Wave functions**
Lecture-3.	**Fine structure:** Alkali atoms
Lecture-4.	**Spin orbit coupling**
Lecture-5.	**Spectral Notations for Atomic States**
Lecture-6.	**Vector Model:** Total angular momentum
Lecture-7.	**Spin-orbit coupling in atoms-L-S and J-J couplings**
Lecture-8.	**Hund's Rule**
Lecture-9.	**Spectra of Hydrogen and Alkali Atoms**
Lecture-10.	**:** Discussion previous year questions.

Tutorial Assignment—V

Course code: CC-XI
Course Title: Quantum Mechanics And Applications (Practical)

Module-I **Quantum Mechanics And Applications Practical**
Contents Use C/C++/Scilab for solving the following problems based on Quantum Mechanics
Module Objectives: In the laboratory course, with the exposure in computational programming in the computer lab, the student will be in a position to solve Schrodinger equation for ground state energy and wave functions of various simple quantum mechanical one-dimensional and three dimensional potentials.

Serial No.	**Topics of Discussion**
Lab-1.	Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom: $$\frac{d^2u}{dr^2} = A(r)u(r),\ A(r) = \frac{2m}{hslah}\big[V(r) - E\big],\ \text{where } V(r) = -\frac{e^2}{r}$$ Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wave functions. Remember that the ground state energy of the hydrogen atom is $\simeq -13.6$ eV. Take $e = 3.795(eVA)^{1/2}$, $\hbar c = 1973(eVA)$ and $m = 0.511 \times 10^6 eV/c^2$.
Lab-2.	Solve the s-wave radial Schrodinger equation for an atom: $$\frac{d^2u}{dr^2} = A(r)u(r),\ A(r) = \frac{2m}{hslah}\big[V(r) - E\big],$$ 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 $e = 3.795(eVA)^{1/2}$, $m = 0.511 \times 10^6 eV/c^2$, and $a = 3A, 5A, 7A$. In these units $\hbar c = 1973(eVA)$. The ground state energy is expected to be above $-12eV$ in all three cases.
Lab-3.	Solve the s-wave radial Schrodinger equation for a particle of mass m: $$\frac{d^2u}{dr^2} = A(r)u(r),\ A(r) = \frac{2m}{hslah}\big[V(r) - E\big],$$ For the anharmonic oscillator potential $$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$ or the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose $m = 940\,MeV/c^2$, $k = 100\,MeVfm^{-2}$, $b = 0, 10, 30\,MeVfm^{-3}$. In these units, $c\hbar = 197.3\,MeVfm$. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

Lab-4.	Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule: $$\frac{d^2u}{dr^2} = A(r)u(r),\ A(r) = \frac{2\mu}{hslah}\left[V(r) - E\right],$$ 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: $m = 940 \times 10^6\, eV/C^2$, $D = 0.755501eV$, $\alpha = 1.44$, $r_0 = 0.131349A$

Module-II **Quantum Mechanics And Applications Practical**
Contents Laboratory based experiments
Module Objectives: 1.

Serial No.	Topics of Discussion
Lab-1.	Study of Electron spin resonance-determine magnetic field as a function of the resonance frequency
Lab-2.	Study of Zeeman effect: with external magnetic field.
Lab-3.	To show the tunneling effect in tunnel diode using I-V characteristics.

Course code: CC-XII
Course Title: Solid State Physics (Theory)

Module-I Crystal Structure: (12 lectures)	
Contents 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.	
Module Objectives: 1. This unit aims to deliver concept about basic crystal structure 2. From this unit one can understand the concept of Reciprocal lattice 3. One can also can obtain idea about Diffraction of X-rays by Crystal and Bragg's Law	
Serial No.	**Topics of Discussion**
Lecture-1.	**Basic idea of Crystal structure:** Solids: Amorphous and Crystalline Materials, Idea of lattice, basis, unit cell, Lattice Translation Vectors
Lecture-2.	**Elements of symmetry:** Unit cells are not unique, primitive and non-primitive unit cell, Elements of symmetry: Macroscopic and microscopic symmetry elements, Rotation, reflection, inversion, roto-reflection, roto-inversion, 5-fold rotation is not allowed, idea of Quasi crystal
Lecture-3.	**Lattice with a Basis:** Central and Non-Central Elements, idea of point group (32) and space group (230), Bravais lattice (14) and crystal systems (7)
Lecture-4.	**Miller Indices:** idea of Miller Indices, how to calculate Miller Indices? Spacing between planes of same Miller Indices,
Lecture-5.	**Reciprocal Lattice:** Concept of reciprocal lattice vector, Reciprocal lattice of SC is SC, Reciprocal lattice of BCC is FCC, Reciprocal lattice of FCC is BCC, Reciprocal lattice vector of a plane is perpendicular to that plane
Lecture-6	**Packing fraction:** calculation of packing fraction for SC, BCC, FCC lattice
Lecture-7	**Diffraction of X-rays by Crystals:** Bragg's Law, Von-Laue treatment
Lecture-8	**Geometrical interpretation of Bragg's Law:** Brillouin Zones
Lecture-9	**Atomic and Geometrical structure Factor:** Structure factor calculation for SC, BCC and FCC, Systematic vanishing condition
Lecture-10	Discussion on few problems
Lecture-11	Solutions of previous year questions
Lecture-12	Solutions of previous year questions

Tutorial assignment-1

Module-II Elementary Lattice Dynamics: (10 lectures)
Contents Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Pettit's Law, Einstein and Debye theories of specific heat of solids. T^3 law
Module Objectives: 1. This unit aims to deliver idea about elementary lattice dynamics 2. From this unit one can get idea about phonon and phonon spectrum in solids 3. One can also get idea about classical and quantum theory of lattice specific heat

Serial No.	Topics of Discussion
Lecture-1.	**Lattice Vibrations and Phonons:** Basic idea of Phonon, Vibration of 1-D Monoatomic lattice of infinite length, Dispersion relation
Lecture-2.	**Vibration of 1-D Monoatomic lattice:** Group and phase velocities at limiting cases of frequency, Frequency variation with wave vector within 1st Brillouin Zone
Lecture-3.	**Vibration of 1-D Diatomic lattice:** Analysis of Dispersion relation
Lecture-4.	**Vibration of 1-D Diatomic lattice:** Optical and Acoustic branch, Frequency variation with wave vector within 1st Brillouin Zone, Concept of Forbidden frequency branch
Lecture-5.	**Vibration of 1-D Diatomic lattice:** Physical difference between vibration represented by optical and acoustic branch, Acoustical and Optical Phonons Qualitative Description of the Phonon Spectrum in Solids
Lecture-6	**Theory of Specific heat:** Classical Theory of lattice specific heat, Dulong and Pettit's Law, Limitation of classical theory, Quantum theory of lattice specific heat, Einstein Theory of lattice specific heat
Lecture-7	**Theory of Specific heat:** Debye theory of lattice specific heat of solids. T^3 law
Lecture-8	Discussion on few Problems
Lecture-9	Solutions of previous year questions
Lecture-10	Solutions of previous year questions

Tutorial Assignment- 2

Serial No.	Topics of Discussion
Module-III Magnetic Properties of Matter: (8 Lectures)	
Contents 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.	
Module Objectives: 1. This unit aims to deliver concept of magnetic properties of matter 2. one can understand concept of classical theory of Dia- and Paramagnetism, quantum theory of Paramagnetism (why it was introduced?), Weiss's theory of Ferromagnetism 3. one can get idea about spontaneous magnetization, and ferromagnetic domains 4. One can understand the concept of hysteresis and energy loss in B-H loop and its practical application in memory devices.	
Serial No.	**Topics of Discussion**
Lecture-1.	**Classification of Magnetic materials**: Dia-, Para-, Ferri- and Ferromagnetic Materials and their properties, concept of magnetic susceptibility and its variation with temperature for Dia-, Para-, Ferri- and Ferromagnetic Materials, examples of Dia-, Para-, Ferri- and Ferromagnetic Materials
Lecture-2.	**Classical theory of Diamagnetism:** Larmor's precession, Curie's law, Susceptibility is negative and independent of magnetic field and temperature
Lecture-3.	**Classical theory of Paramagnetism**: Assumptions of Langevin Theory, Langevin's function, Variation of magnetization at very low temperature (magnetic saturation) and high temperature
Lecture-4.	**Quantum theory of Paramagnetism:** orbital and spin angular momentum, Larmor's precession of total angular momentum, Lande-g-

	factor, Narrow and wide multiplates, Calculation of susceptibility
Lecture-5.	**Weiss's Theory of Ferromagnetism:** Concept of spontaneous magnetization, internal/molecular field, Courie-Weiss law, Para to ferromagnetic transition
Lecture-6	**Domain theory of Ferromagnetism:** Ferromagnetic domains, Displacement of the walls of domains and rotation of domains due to application of external magnetic field, Discussion of B-H Curve. Hysteresis and Energy Loss. Elementary idea about Anti-ferromagnetism
Lecture-7	Discussion on few Problems
Lecture-8	Solutions of previous year questions

Module-IV

Dielectric Properties of Materials: (8 Lectures)

Contents

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

Module Objectives:

1. This unit helps the students to understand dielectric properties of material
2. They can get concept about polarization, local field, polarizability and theory of various kind of polarizability
3. They can get idea about variation of refractive index with frequency (phenomenon of dispersion) and normal and Anomalous dispersion
4. they can get elementary knowledge about plasma optics

Serial No.	Topics of Discussion
Lecture-1.	**Polarization:** Concept of polarization, Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility.
Lecture-2.	**Polarizability:** Concept of polarizability, Clausius-Mosotti Equation, Classical Theory of Electronic Polarizability
Lecture-3.	**Dispersion:** Variation of Refractive index with wavelength, Dispersive and nondispersive media, Complex Dielectric Constant, Normal and Anomalous Dispersion. Cauchy and Sellmeir relations.
Lecture-4.	**Langevin-Debye equation**: concept of electronic, orientational and ionic polarizability, Total polarizability, Langevin-Debye equation
Lecture-5.	**Plasma optics:** Concept of plasma, EM wave in plasma, Optical Phenomena, Plasma Oscillations, Plasma Frequency, Dielectric constant as a function of frequency, Dispersion relation, concept of Plasmons, Transverse optical modes in plasma
Lecture-6	Discussion on few Problems
Lecture-7	Solutions of previous year questions
Lecture-8	Solutions of previous year questions

Tutorial Assignment-3

Module-V

Ferroelectric Properties of Materials: (6 lectures)

Contents

Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect,

Ferroelectric effect, Electro strictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.
Module Objectives: 1. This unit aims to deliver knowledge about ferroelectric properties of materials 2. structural phase transition due to application of electric field on a crystal can be understood 3. one can get idea about spontaneous electric polarization, and ferroelectric domains 4. One can understand the concept of hysteresis and energy loss in P-E loop

Serial No.	Topics of Discussion
Lecture-1.	**Classification of crystals:** Different types of Crystal, structural phase transition
Lecture-2.	**Different phenomena in crystal:** Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electro strictive effect
Lecture-3.	**Ferroelectricity:** Classical theory of Ferroelectricity, Curie-Weiss Law, Ferroelectric domains
Lecture-4.	**Ferroelectricity:** PE hysteresis loop, hysteresis loss
Lecture-5.	Discussion on few Problems
Lecture-6	Solutions of previous year questions

Module-VI Elementary band theory: (10 Lectures)
Contents 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.
Module Objectives: 1. This module aims to deliver knowledge about behaviour of electron under symmetric ionic potential 2. Existence of band gap comes out as a consequence of Kronig Penny model 3. one can understand the concept of carrier concentration, conductivity and mobility of carriers in semiconductor 4. One can have idea about 4 probe method of measuring electrical conductivity

Serial No.	Topics of Discussion
Lecture-1.	**Electron under symmetric ionic potential**: Bloch Theorem, Proof of Bloch Theorem
Lecture-2.	**Kronig Penny model:** Theory of Kronig Penny model and existence of forbidden gap/ band gap
Lecture-3.	**E-K diagram:** change of Width of allowed band and forbidden gap with energy, E-K diagram
Lecture-4.	Variation of Electron velocity and effective mass with energy within energy band, Band structure in metal semiconductor and insulator
Lecture-5.	**Band Structure in Semiconductor:** Carrier concentration calculation, intrinsic semiconductor, impurity states (P and N type semiconductor), Donor and acceptor level, band diagram
Lecture-6	**Conductivity of Semiconductor:** Electrical conductivity and mobility, Hall effect in metal and semiconductor
Lecture-7	**04 probe method:** Measurement of conductivity () & Hall coefficient**.** Necessity of 4 probe rather than two probe
Lecture-8	Discussion on few Problems
Lecture-9	Solutions of previous year questions
Lecture-10	Solutions of previous year questions

Tutorial Assignment-4

Module-VII Superconductivity: (6 Lectures)	
Contents 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)	
Module Objectives: 1. This module aims to deliver knowledge about normal to superconducting state phase transition for a critical temperature and magnetic field 2. one can understand diamagnetic behaviour of superconducting state as a consequence of Meissner Effect 3. one can have idea of penetration depth of magnetic lines of force and also can get elementary idea about BCS theory	
Serial No.	**Topics of Discussion**
Lecture-1.	**Superconductivity**: Experimental evidence of superconducting state, normal to superconducting state phase transition, critical temperature and critical magnetic field for such transition, concept of persistence current
Lecture-2.	**Meissner effect:** Diamagnetic behaviour of super conducting state, Isotope effect
Lecture-3.	**Type I and type II Superconductors:** Classification of superconductor on transition behaviour from normal to superconducting state, Vortex state
Lecture-4.	**Penetration Depth:** Concept of penetration depth from Meissner effect, London's Equation, Elementary concept of BCS theory
Lecture-5.	Discussion on few Problems
Lecture-6	Solutions of previous year questions

Tutorial Assignment-5

Course code: CC-XII

Course Title: SOLID STATE PHYSICS (Practical)

Module-I		
Contents 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.		
Module Objectives: 1. To gain practical knowledge by applying the experimental methods to correlate with the theory of Solid State Physics. 2. To apply the analytical techniques and graphical analysis to the experimental data.		
Serial No.	**Topics of Discussion**	**Remarks**
Lab-1	To measure the Dielectric Constant of a dielectric Materials with frequency.	
Lab-2	To determine the band gap using a thermistor	
Lab-3	To study the PE Hysteresis loop of a Ferroelectric Crystal.	
Lab-4	To draw the BH curve of Ferromagnetic material using Solenoid & determine energy loss from Hysteresis.	
Lab-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	
Lab-6	To determine the Hall coefficient of a semiconductor sample.	

Course code: DSE-1
Course Title: Advanced Mathematical Physics

Module-I **Linear Vector Spaces** (12 lectures)
Contents 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 Transformations. Algebra of Linear Transformations. Non-singular Transformations. Representation of Linear Transformations by Matrices.
Module Objectives: In this module, students will go through the construction of Abstract mathematical formulations like Group theory and LVS and understand their importance to unify apparently disjoint disciplines of physical world as well as use them to solve different problems.

Lecture Serial	Topics of Discussion
Lecture-1.	**Introduction to Vector Space:** Examples from physical sciences
Lecture-2.	**Abstract Systems:** Binary Operations and Relations
Lecture-3.	**Introduction to Groups and Fields:** Definition of Groups, Examples
Lecture-4.	More examples of groups. Discrete and Continuous groups
Lecture-5.	Definition of vector space. Examples of vector spaces
Lecture-6.	Linear independence of vectors. Determination of the same. Examples and counter examples
Lecture-7.	Basis and dimension of a vector space. Expanding vectors in basis
Lecture-8.	Orthogonality of vectors. Orthogonal basis as a powerful tool. Examples of orthogonal basis
Lecture-9.	Change of basis. Homomorphism and Isomorphism of Vector Spaces
Lecture-10.	Linear Transformations. Algebra of Linear Transformations. Non-singular Transformations
Lecture-11.	Representation of Linear Transformations by Matrices. Examples
Lecture-12.	Problems and solutions from Vector spaces

Tutorial Assignment—1

Module-II **Matrices** (8 lectures)
Contents 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.
Module Objectives: In this module students will encounter different types of matrices, understand their properties.

Lecture Serial	Topics of Discussion
Lecture-1.	Matrices as arrays of data. Importance of matrices from different disciplines
Lecture-2.	Addition and Multiplication of Matrices. Null Matrices.Diagonal, Scalar and Unit Matrices
Lecture-3.	Upper-Triangular and Lower-Triangular Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix.
Lecture-4.	Hermitian and Skew- Hermitian Matrices and their importance in Physics
Lecture-5.	Singular and Non- Singular matrices.Orthogonal and Unitary Matrices
Lecture-6.	Trace of a Matrix. Inner Product
Lecture-7.	Matrices as operators of vector space. Different examples of the same
Lecture-8.	Problems and solutions of Matrices

Module-III

Eigen-values and Eigenvectors (10 lectures)

Contents

Cayley- Hamiliton Theorem. Diagonalization of Matrices. Solutions of Coupled Linear Ordinary Differential Equations. Functions of a Matrix.

Module Objectives:

In this module, students will understand the matrices as operators of vector space and learn the key concepts related to eigenvalues and eigenvectors.

Lecture Serial	Topics of Discussion
Lecture-1.	Eigen values and eigen vectors from generic point of view
Lecture-2.	Eigen value problem in terms of matrices
Lecture-3.	Cayley- Hamiliton Theorem. Its applications
Lecture-4.	Diagonalization of matrices: Mathematical point of view
Lecture-5.	Diagonalization of matrices: Geometrical significance
Lecture-6.	Matrices as operators : $\hat{A}X = b$. Diagonalization and its implication to solve a set of linear algebraic equations
Lecture-7.	Solutions of Coupled Linear Ordinary Differential Equations. Applications of the same for solving coupled oscillator problem
Lecture-8.	Functions of a Matrix and its difference from function of a variable. Baker-Campbell-Hausdorff formula in this connection
Lecture-9.	Fun exercise: Derivatives to Matrices: An idea key to quantum mechanical understanding
Lecture-10.	Problems and solutions related to this module

Tutorial Assignment—2

Module-IV **Cartesian Tensors** (20 lectures)
Contents 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.
Module Objectives: 1. From this chapter one can understand some basic properties Cartesian tensors, their symmetric and antisymmetric nature. 2. It can also be understood that how Quotient law define the rank of a tensor. 3. From this unit, student can understand clearly about the moment of inertia tensor, energy momentum tensor, stress tensor, strain tensor etc.

Lecture Serial	**Topics of Discussion**
Lecture-1.	**Introduction:** Coordinate Transformations
Lecture-2.	**Einstein's Summation Convention:** The Summation Convention, Covariant and Contravariant Tensor, Covariant, Contravariant Mixed Tensor, Relation between Direction Cosines Tensor
Lecture-3.	**Fundamental Relations with Tensor:** Addition, Subtraction, Product, Contraction, Inverse Transformation
Lecture-4.	**Quotient Law of Tensors:** Explanation, Some examples
Lecture-5.	**Symmetric and Anti- symmetric Tensors:** Symmetric and Anti-symmetric Tensors with examples
Lecture-6.	**Rank of a Tensors:** Scalars or Invariants, Kronecker Delta, Levi-Civita symbol
Lecture-7.	**Vector Algebra in Cartesian Tensors:** Scalar and Vector Products.
Lecture-8.	**Vector Algebra in Cartesian Tensors:** Scalar and Vector Triple Products. Differentiation.
Lecture-9.	**Vector Algebra in Cartesian Tensors:** Gradient, Divergence and Curl of Tensor Fields
Lecture-10.	**Vector Algebra in Cartesian Tensors:** Vector Identities.
Lecture-11.	**Vector Algebra in Cartesian Tensors:** Vector Identities.
Lecture-12.	**Vector Algebra in Cartesian Tensors:** Vector Identities.
Lecture-13.	**The Line Element and Metric Tensor:** Angle Between Lines. Projection of a Line on another Line.
Lecture-14.	**Co-planar:** Condition for Two Lines to be Co-planar, Foot of the Perpendicular from a Point on a Line
Lecture-15.	**Rotation Tensor & Isotropic Tensors:**
Lecture-16.	**Tensorial Character of Physical Quantities**
Lecture-17.	**Moment of Inertia Tensor**
Lecture-18.	**Stress and Strain Tensors: Symmetric Nature**
Lecture-19.	**Elasticity Tensor:**
Lecture-20.	**Generalized Hooke's Law:**

Tutorial Assignment—3

Module-V **General Tensors** (10 lectures)
Contents
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.
Module Objectives:
This module attempts the basic idea of generalized tensor and some basic properties of tensor.

Lecture Serial	**Topics of Discussion**
Lecture-1.	**Transformation of Co-ordinates**
Lecture-2.	**Minkowski Space**
Lecture-3.	**Contravariant & Covariant Vectors:** Contravariant, Covariant and Mixed Tensors
Lecture-4.	**Kronecker Delta and Permutation Tensors**
Lecture-5.	**Algebra of Tensors:** Sum, Difference & Product of Two Tensors. Contraction
Lecture-6.	**Quotient Law of Tensors:** Some examples
Lecture-7.	**Symmetric and Anti-symmetric Tensors**
Lecture-8.	**Metric Tensor**
Lecture-9.	**Metric Tenso:** Some transformation
Lecture-10.	**Christoffel's symbols:** Some examples

Tutorial Assignment—4

Course Code: DSE-I
Course Title: Advanced Mathematical Physics (Practical)

Module-I **Advanced Mathematical Physics (Practical)**
Contents
Scilab/ C++ based simulations experiments based on Mathematical Physics problems
Module Objectives:
In the laboratory course, the students are expected to solve the linear vector space problem and find out the wave functions for stationary states as eigenfunctions of Hermitian differential operators and also the energy eigenvalues using the Scilab/C++ computer language:

Serial No.	**Topics of Discussion**
Lab-1.	**Linear algebra:** Multiplication of two 3 x 3 matrices Eigenvalue and eigenvectors of $\begin{pmatrix} 2 & 1 & 1 \\ 1 & 3 & 2 \\ 3 & 1 & 4 \end{pmatrix}; \begin{pmatrix} 1 & -i & 3+4i \\ i & 2 & 4 \\ 3-4i & 4 & 3 \end{pmatrix}; \begin{pmatrix} 2 & -i & 2i \\ i & 4 & 3 \\ -2i & 3 & 5 \end{pmatrix}$
Lab-2.	Orthogonal polynomials as eigenfunctions of Hermitian differential operators
Lab-3.	Determination of the principal axes of moment of inertia through diagonalization
Lab-4.	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.
Lab-5.	Lagrangian formulation in Classical Mechanics with constraints.
Lab-6.	Study of geodesics in Euclidean and other spaces (surface of a sphere, etc). pi
Lab-7.	Estimation of ground state energy and wave function of a quantum system

Course code: DSE-2
Course Title: Classical Dynamics

Module-I Classical Mechanics of Point Particles: (22 Lectures)	
Contents 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.	
Module Objectives: **1.** This module aims to deliver concept about motion of point particles 2. one can have idea about constrained motion, generalised coordinates, generalised velocity and momentum 3. one can have idea of Lagrangian and Hamiltonian 4. from calculus of variation one can establish Lagrange’s equation and apply it to various problems of classical mechanics of point particle 5. From Hamilton’s variational principle one can establish Hamilton’s canonical equation of motion and can apply it to find equation of motion of different systems	
Serial No.	**Topics of Discussion**
Lecture-1.	**Review of Newtonian Mechanics**: motion of a charge particle in external electric and magnetic fields- motion in uniform electric field with and without initial velocity, motion in uniform magnetic field (Circular and Helical motion), Gyro radius/ Larmor radius and gyrofrequency
Lecture-2.	**Review of Newtonian Mechanics:** motion in crossed electric and magnetic fields-Concept of cycloid motion
Lecture-3.	**Constrained motion:** Constrains and classification of constrains with examples, forces of constrains
Lecture-4.	**Generalized coordinates:** Degrees of freedom, generalized coordinates, generalized displacement, generalized velocity
Lecture-5.	**Calculus of variation**: Variational principle and Lagrange’s function, concept of Lagrangian
Lecture-6	**Euler-Lagrange equation:** Derivation of Euler-Lagrange equation
Lecture-7	**Application of Euler-Lagrange equation:** shortest distance between two points in a plane, Brachistochrone problem
Lecture-8	**Application of Euler-Lagrange equation**: Linear harmonic oscillator, simple pendulum, spherical pendulum, particle moving on the surface of earth, particle falling under uniform gravity, particle moving under central force field
Lecture-9	**Application of Euler-Lagrange equation:** Compound pendulum, LC electrical circuit, Atwood’s machine, beed sliding on a uniformly rotating wire, coupled pendulum, coupled oscillator
Lecture-10	**Hamilton’s variational principle:** Statement of Hamilton’s variational principle, Lagrange’s equation from Hamilton’s variational principle, Hamilton’s variational principle from Lagrange’s equation, Newton’s

	second law from Hamilton's variational principle
Lecture-11	Principle of virtual work, generalized momentum, cyclic coordinate, Principle of least action
Lecture-12	**Hamiltonian mechanics:** Hamilton's canonical equations for conservative and non-conservative system
Lecture-13	**Hamiltonian mechanics:** Hamilton's equation of motion from Hamilton's variational principle
Lecture-14	**Applications of Hamilton's equation of motion:** Simple pendulum, compound pendulum, Linear harmonic oscillator
Lecture-15	**Applications of Hamilton's equation of motion:** Particle moving near surface of earth, Particle in central force field
Lecture-16	**Applications of Hamilton's equation of motion:** Conservation of angular momentum and energy of a particle moving under central force field
Lecture-17	**Conservation of linear momentum, angular momentum and energy**: Homogeneity of space and conservation of linear momentum, isotropy of space and conservation of angular momentum, homogeneity of time and conservation of energy
Lecture-18	Discussion on few problems
Lecture-19	Discussion on few problems
Lecture-20	Solutions of previous year questions
Lecture-21	Solutions of previous year questions
Lecture-22	Solutions of previous year questions

Tutorial assignment-1

Module-II Small Amplitude Oscillations: (10 Lectures)	
Contents 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.	
Module Objectives: Learn about the small oscillation problems	
Serial No.	**Topics of Discussion**
Lecture-1.	**Potential energy:** Minima of potential energy and points of stable equilibrium
Lecture-2.	**Potential energy:** Expansion of the potential energy around a minimum
Lecture-3.	**Theory of Small Oscillations:** Two Masses and Three Springs, The First Normal Mode, The Second Normal Mode
Lecture-4.	**Theory of Small Oscillations:** Lagrangian formulation of the system
Lecture-5.	**Theory of Small Oscillations:** Eigenvalues and Eigenfunctions
Lecture-6	**Theory of Small Oscillations:** The Orthogonality of the Eigenvectors
Lecture-7	**Two Coupled Harmonic Oscillators, Vibrations of Triatomic Molecule**
Lecture-8	**N identical masses connected in a linear fashion to (N -1) - identical springs**
Lecture-9	Discussion on some problem on small oscillation
Lecture-10	Discussion on previous year problem

Module-III Special Theory of Relativity: (33 Lectures)
Contents 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.
Module Objectives: 1. Revision of STR, fundamental ideas. 2. Conceptualization of covariance in STR. 3. Implications of covariance principles to understand different ideas in STR in a compact form.

Serial No.	Topics of Discussion
Lecture-1.	Postulates of Special Theory of Relativity. Review of ideas behind STR.
Lecture-2.	Revision of Lorenz transformation, difference from Galilean transformation.
Lecture-3.	Geometrical ideas of Spacetime: Minkowski diagram.
Lecture-4.	The invariant interval, light cone and world lines.
Lecture-5.	Paradoxes in STR 1: Twin paradox.
Lecture-6	Paradoxes in STR 1: Twin paradox, further discussions.
Lecture-7	Paradoxes in STR 2: Barn-ladder (Snake-knife) paradox.
Lecture-8	Paradoxes in STR 2: Barn-ladder (Snake-knife) paradox, further discussions.
Lecture-9	Mathematical formulation of STR: Brief ideas behind Tensors 1.
Lecture-10	Mathematical formulation of STR: Brief ideas behind Tensors 2.
Lecture-11	Mathematical formulation of STR: Brief ideas behind Tensors 3.
Lecture-12	Metric tensor: $\boldsymbol{\eta}$, short discussion on more generic form of metric.
Lecture-13	Covariance and its implications.
Lecture-14	Four vectors: why and how?
Lecture-15	Inner products of four vectors and invariants.
Lecture-16	Proper time interval $\boldsymbol{\tau}$ and its importance.
Lecture-17	Creation of new four vectors from space-time four vector: Four velocity and Four acceleration.
Lecture-18	Four Momentum: a fundamental four vector. Enengy-momentum relation.
Lecture-19	Doppler effect from Newtonian framework.
Lecture-20	Doppler effect from a four-vector perspective.
Lecture-21	Doppler effect: Application of the same for Celestial bodies.
Lecture-22	Concept of four-force: validity of work-energy theorem.
Lecture-23	Conservation of four-momentum and its implications.
Lecture-24	Relativistic kinematics: Application to two-body decay of an unstable particle.
Lecture-25	Electromagnetic theory: brief recap.
Lecture-26	Electrostatics and Magnetostatics as non-covariant theries.

Lecture-27	Emergence of Electrodynamics from covariance principles 1.
Lecture-28	Emergence of Electrodynamics from covariance principles 2.
Lecture-29	Transformation of Electric and Magnetic fields under Lorenz transformation.
Lecture-30	Discussions on further possibilities.
Lecture-31	Problems and discussions
Lecture-32	Problems and discussions
Lecture-33	Problems and discussions

Module-IV

Fluid Dynamics: (10 Lectures)

Contents

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.

Module Objectives:

Learn about the basic theroy on fluid dynamics

Serial No.	Topics of Discussion
Lecture-1.	**The Equation of Continuity:** Mass conservation
Lecture-2.	**Euler's Equation**
Lecture-3.	**Hydrostatics system :** Stream-lined motion, laminar flow
Lecture-4.	**Bernoulli's Equation :**
Lecture-5.	**The Equation of Motion of a Viscous Fluid**
Lecture-6	**Flow in a pipe : P**oiseuille‟s equation for flow of a liquid through a pipe
Lecture-7	**Navier-Stokes equation**
Lecture-8	Qualitative description of turbulence, Reynolds number.
Lecture-9	Discussion on some problem on small oscillation
Lecture-10	Discussion on previous year problem

Department of Physics
Government General Degree College at Kalna -I
Lesson Plan
for
B.Sc. Semester-VI (Honours) Courses Under CBCS
Subject: Physics
Course code: CC-XIII, CC-XIV, DSE-3 & DSE-4

Course Code: CC-XIII
Course Title: Electromagnetic Theory (Theory)

Module-I
Maxwell Equations (12 lectures)

Contents

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.

Module Objectives:

1. From this chapter one can understand significance of Maxwell equations and how classical wave equations are derived from Maxwell equations.
2. It can also be understood that how a time varying electric field can induce a magnetic field.
3. significance of displacement current density.
4. The boundary conditions across an interface can attribute to solutions of plane wave equations associated to bounded media.
5. one can understand the conservation of energy flux from Poynting theorem

Serial No.	Topics of Discussion
Lecture-1.	**Review of Maxwell's equations:** Electrodynamics before Maxwell, Gauss's law in electrostatics and magnetostatics, Faraday's law of EM induction, Ampere's circuital law in differential and integral form
Lecture-2.	**Modification of Ampere's circuital law:** Equation of continuity, Modification of Ampere's circuital law by Maxwell, introduction of displacement current density, Physical aspect of displacement current density, vector and scalar potential
Lecture-3.	**Gauge Transformations:** Interrelation between Maxwell equations, Lorentz and coulomb gauge, Gauge transformation equation
Lecture-4.	**Boundary Conditions at Interface between Different Media:** Boundary condition on D, E, B, H at the interface between two different media. Continuity of different components of D, E, B, H across boundary.
Lecture-5.	**Wave Equations:** Classical wave equation. Homogeneous and inhomogeneous wave equation
Lecture-6.	**Plane Waves in Dielectric Media:** Maxwell equation in vacuum and dielectric medium. Equation of plane wave, Plane waves in dielectric medium.

Serial No.	Topics of Discussion
Lecture-7.	**Poynting theorem:** Poynting vector and Poynting theorem. Physical significance of Poynting vector. Poynting Theorem in differential form.
Lecture-8.	**Electromagnetic (EM) Energy Density:** Expression of EM energy density, equal distribution of energy between electric and magnetic field in dielectric media. Physical Concept of Electromagnetic Field Energy Density
Lecture-9.	**Momentum Density and Angular Momentum Density:** Expression of Linear and angular momentum density, Radiation pressure
Lecture-10.	Discussion on few problems
Lecture-11.	Solutions of previous year questions
Lecture-12.	Solutions of previous year questions

Tutorial Assignment—1

Module-II

EM Wave Propagation in Unbounded Media (10 lectures)

Contents

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.

Module Objectives:

1. This chapter is emphasized on propagation of EM wave in dielectric and conducting unbounded media. One can understand the transverse nature of EM wave clearly.
2. Students can understand the difference of behaviour of EM wave in dielectric and conducting media.
3. One can also get an idea about EM wave propagation through plasma and how a transmitted signal gets reflected back from ionosphere and received at the receiver end.

Serial No.	Topics of Discussion
Lecture-1.	**Plane EM waves through vacuum and isotropic dielectric medium:** Recapitulation of Maxwell equation in dielectric medium, equation of plane progressive wave. Electric and magnetic field satisfying homogeneous wave equation from Maxwell equations
Lecture-2.	**Transverse nature of plane EM waves:** EM wave is transverse in nature, Proof of Electric field and magnetic field are perpendicular to each other and also both perpendicular to direction of propagation, Velocity of EM wave.
Lecture-3.	**Relation between electric and magnetic field vector:** How electric and magnetic field vectors are related to each other, Characteristic impedance
Lecture-4.	**Refractive index and dielectric constant:** Expressions for refractive index and dielectric constant
Lecture-5.	**EM wave in conducting medium:** Maxwell equations in conducting medium, Wave equation in conducting media, condition for good and bad conductor.
Lecture-6.	**EM wave in conducting medium:** Exponential decay of amplitude of electric or magnetic field vector in conducting medium. Skin depth, relaxation time.
Lecture-7.	**EM wave in conducting medium:** Phase lag between electric and magnetic field in conducting medium, Energy associated with electric and magnetic field in conductor (not equally shared like dielectric).

Serial No.	Topics of Discussion
Lecture-8.	**Wave propagation through dilute plasma:** Electrical conductivity of ionized gases, plasma frequency, dispersion relation, complex nature of refractive index, Phase and group velocity of EM wave in plasma
Lecture-9.	**Propagation and reflection of EM wave in plasma:** Skin depth, application to propagation through ionosphere.
Lecture-10.	Discussion on few Problems

Tutorial Assignment—2

Module-III **EM Wave in Bounded Media** (10 lectures)
Contents 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)
Module Objectives: 1. This chapter aims to offer knowledge about transmission and reflection of EM wave for incidence at an boundary between two media. 2. Students can understand how reflection and transmission coefficients are determined. 3. One can understand how laws of reflection, refraction can be derived. 4. It can also be understood why mirrors are usually made up of metals.

Serial No.	Topics of Discussion
Lecture-1.	**Boundary conditions at a plane interface between two media:** Recapitulation on boundary condition on D, E, B, H at a plane interface between two media
Lecture-2.	**Reflection & Refraction of plane waves:** Equation of plane progressive incident, reflected and transmitted wave, Reflection and transmission coefficient, Phase reversal of reflected wave to incident wave
Lecture-3.	**Reflection & Refraction of plane waves:** Reflection and transmission at normal incidence, Expressions of reflection and transmission coefficient in terms of refractive index
Lecture-4.	**Reflection & Refraction of plane waves:** Reflection and transmission at oblique incidence
Lecture-5.	**Reflection & Refraction of plane waves:** Laws of Reflection & Refraction.
Lecture-6.	**Reflection & Refraction of plane waves:** Introductory idea about polarization, Parallel and perpendicular polarization, Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law
Lecture-7.	**Total internal reflection:** Variation of reflection and transmission coefficient with angle of incidence, total internal reflection, evanescent waves
Lecture-8.	**Reflection on conducting surface:** Boundary conditions for conducting interface, 180 0 phase shift between incident and reflected wave and no transmission at normal incidence at perfectly conducting interface. Good conductors are good mirrors
Lecture-9.	Discussion on few Problems
Lecture-10.	Solutions of previous year questions

Tutorial Assignment—3

Module-IV **Polarization of Electromagnetic Waves** (12 lectures)
Contents 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.
Module Objectives: 1. This module focus on the fundamental idea of polarization of the electromagnetic waves which build up the clear idea of nature of the light. 2. From this portion student can get an elementary idea about the propagation of the E.M. Wave in an anisotropic media. 3. The phenomenon of double reflection helps the students to study how the E.M. Wave propagate into the calcite crystal.

Serial No.	Topics of Discussion
Lecture-1.	**Nature of Polarized Wave:** Plane-polarized, Linear Polarized, Circular Polarized, Elliptical Polarized.
Lecture-2.	**Propagation of E.M. Waves in Anisotropic Media**
Lecture-3.	**Dielectric Tensor:** Dielectric Tensor properties
Lecture-4.	**Fresnel's Formula:** Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law.
Lecture-5.	**Polarizer:** Malus's Law, Polaroid.
Lecture-6.	**Birefringence:** Calcite, Optic axis, Ordinary rays, Extraordinary rays,
Lecture-7.	**Birefringent Crystal:** Uniaxial, Biaxial, Light Propagation in Uniaxial Crystal,
Lecture-8.	**Polarization by Double Refraction:** Construction of Nicol Prism, Ordinary & extraordinary refractive indices.
Lecture-9.	**Circularly and Elliptically Polarized Light:** Few problems on circular and elliptically polarized Light.
Lecture-10.	**Phase Retardation Plates:** Quarter-Wave and Half-Wave Plates.
Lecture-11.	**Babinet Compensator:** Working Principle and its used.
Lecture-12.	**Analysis of Polarized Light:** Characterize different type state of polarization.

Module-V **Rotatory Polarization** (5 lectures)
Contents 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.
Module Objectives: Learning of polarization rotation help the learner to understand the rotation of the orientation of the plane of polarization about the optical axis of linearly polarized light as it travels through certain materials.

Serial No.	Topics of Discussion
Lecture-1.	**Optical Rotation:** Classical interpretation and Quantum interpretation, Biot's Laws for Rotatory Polarization.
Lecture-2.	**Fresnel's Theory of optical rotation:** Calculation of angle of rotation.
Lecture-3.	**Experimental verification of Fresnel's theory:**
Lecture-4.	**Specific rotation:** Measurement and applications.
Lecture-5.	**Laurent's half-shade polarimeter:** Construction, Working Principle.

Tutorial Assignment—4

Module-VI **Wave Guides** (8 lectures)
Contents
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.
Module Objectives:
1. This module attempts the basic idea of wave guides which provides the central idea of TE wave and TM wave as well as phase shift on total reflection. 2. From this unit, student can understand clearly about energy flow and power flow inside the wave guides.

Serial No.	Topics of Discussion
Lecture-1.	**Wave guides:** Electromagnetic wave in a hollow pipe. Boundary condition on **E** and **B**.
Lecture-2.	**TEM Waves:** Transverse electric (TE) waves, Transverse magnetic (TM) waves, TEM waves, TEM waves cannot occur in a hollow wave guide.
Lecture-3.	**TE waves in a Rectangular Wave Guide:** Eigenvalue equations, TE_{mn} mode, cutoff frequency.
Lecture-4.	**TM waves in a Rectangular Wave Guide:** Eigenvalue equations, TM_{mn} mode, cutoff frequency.
Lecture-5.	**Phase shift on total reflection:** Reflection and Refraction at the Boundary between two Media.
Lecture-6.	**Power flow:** The average power density for the TE_{mn} mode, The average power in the wave guide.
Lecture-7.	**Energy flow:** The average energy density for the $\text{TE}_m n$ mode, The average energy in the wave guide.
Lecture-8.	**Phase and group velocity of guided waves:** $\frac{P}{U} = v_g$, Relation between phase and group velocity.

Module-VII **Optical Fibres** (lectures)
Contents
Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibres (Concept and Definition Only).
Module Objectives:
Optical fiber helps the students to study how the E.M. waves propagate through the fiber optics.

Serial No.	Topics of Discussion
Lecture-1.	**Introduction:** Optical fiber, Structure of optical fiber: core and cladding.
Lecture-2.	**Classification of Optical Fiber:** Single mode fiber, Multi-mode fiber, Step index optical fiber, Graded-index optical fiber. Use of optical fiber.
Lecture-3.	**Numerical Aperture:** Calculation of Acceptance Angle, Calculation of Numerical Aperture.

Tutorial Assignment—5

Text books

1. *Introduction to Electrodynamics* - David J. Griffiths, Benjamin Cummings.
2. *Fundamentals of Electricity and Magnetism* - Basudev Ghosh, Books & Allied Ltd

Reference books

1. *The Feynman Lectures on Physics- Volume 2* - Feynman, Leighton, Sands.
2. *Optics* - E. Hecht, A. R. Ganesan, Pearson.

Course code: CC-XIII
Course Title: Electromagnetic Theory (Practical)

Module-I **Electromagnetic Theory Practical**
Contents 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 Stefan's law of radiation and to determine Stefan's constant. 6. To determine the Boltzmann constant using V-I characteristics of PN junction diode.
Module Objectives: 1. To learn the usage of optical systems for various measurements. 2. To apply the analytical techniques and graphical analysis to the experimental data.

Serial No.	**Topics of Discussion**
Lab-1.	To determine the specific rotation of sugar solution using Polarimeter.
Lab-2.	To analyze elliptically polarized Light by using a Babinet's compensator.
Lab-3.	To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
Lab-4.	To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
Lab-5.	To verify the Stefan's law of radiation and to determine Stefan's constant.
Lab-6.	To determine the Boltzmann constant using V-I characteristics of PN junction diode.

Course Code: CC-XIV
Course Title: Statistical Mechanics (Theory)

Module-I **Classical Statistics** (18 lectures)
Contents 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.
Module Objectives: 1. This unit aims to offer basic knowledge about classical statistics including mathematical formulation of statistical mechanics 2. elementary concept of ensemble and ensemble average of a physical quantity can be understood 3. Method of calculation of different thermodynamic functions for different systems can be understood

Lecture Serial	**Topics of Discussion**
Lecture-1.	**Macrostate & Microstate:** What is statistical mechanics? Relation between thermodynamics and statistical mechanics, microstate and microstate, Entropy and thermodynamic probability

Serial No.	Topics of Discussion
Lecture-2.	**Mathematical formulation of statistical mechanics:** Phase space, phase point, phase trajectory, phase volume, calculation of number of microstates
Lecture-3.	**Elementary Concept of Ensemble:** Definition of ensemble, Density of phase point, Liouville's theorem
Lecture-4.	**Elementary Concept of Ensemble:** classification of ensemble, Microcanonical, Canonical and Grand canonical ensemble with examples, ensemble average
Lecture-5.	**Canonical ensemble and Thermodynamic probability:** calculation of thermodynamic probability, Maxwell-Boltzmann Distribution Law, Partition Function
Lecture-6.	**Calculation of thermodynamic functions from partition function:** Helmholtz free energy, average energy, specific heat at constant volume, pressure, entropy
Lecture-7.	**Thermodynamic Functions of an Ideal Gas:** Thermodynamic limit, Expression of partition function at thermodynamic limit, calculation of Helmholtz free energy, average energy, specific heat at constant volume, pressure
Lecture-8.	**Thermodynamic Functions of an Ideal Gas:** Calculation of entropy, Classical Entropy Expression, entropy as an extensive parameter, Gibbs Paradox
Lecture-9.	**Resolution of Gibbs Paradox:** Consideration of indistinguishability, Sackur-Tetrode formula
Lecture-10.	**Law of Equipartition of Energy:** Statement of equipartition of energy, Proof of equipartition of energy
Lecture-11.	**Law of Equipartition of Energy:** Applications of equipartition of energy to Specific Heat and its Limitations
Lecture-12.	**Two-Energy Levels System:** Difference between infinite and finite energy level system, Population inversion and concept of negative temperature for two-state system, Physical analogy of negative temperature
Lecture-13.	**Two-Energy Levels System:** Thermodynamic Functions of a Two-Energy Levels System (Helmholtz free energy, average energy, specific heat at constant volume, pressure, Entropy)
Lecture-14.	**Two-Energy Levels System:** Thermodynamic functions at limiting cases Temperature tending to infinity and zero, Schottky anomaly in specific heat at constant volume for two level system
Lecture-15.	Discussion on few problems
Lecture-16.	Discussion on few problems
Lecture-17.	Solutions of previous year questions
Lecture-18.	Solutions of previous year questions

Tutorial Assignment—1

Module-II **Classical Theory of Radiation** (9 lectures)
Contents
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
Module Objectives:
1. This unit aims to deliver basic concept of Blackbody radiation and its analogy to uniformly heated enclosure 2. One can understand how energy density of thermal radiation varies with temperature 3. One can understand how Wien's Distribution Law and Rayleigh-Jean's Law are attributed to explain characteristics of Blackbody radiation

Lecture Serial	Topics of Discussion
Lecture-1.	**Blackbody:** Basic concept of black body, ideal Blackbody, Practical example of Blackbody, Emissive and absorptive power
Lecture-2.	**Properties of Thermal Radiation:** Blackbody radiation, Pure temperature dependence of Blackbody radiation, Characteristics of Black body radiation, Analogy to uniformly heated enclosure
Lecture-3.	**Kirchhoff's law:** statement of Kirchhoff's law, Radiation pressure
Lecture-4.	**Stefan-Boltzmann law:** Statement of Stefan-Boltzmann law and Thermodynamic proof, Stefan's constant
Lecture-5.	**Wien's Displacement law:** Statement and Thermodynamic proof
Lecture-6.	**Wien's Distribution Law:** Statement and Thermodynamic proof, Saha's Ionization Formula
Lecture-7.	**Rayleigh-Jean's Law:** Electromagnetic modes of vibration in cavity radiation, Calculation of number of modes of vibration and energy density, Derivation of Rayleigh-Jean's Law, Ultraviolet Catastrophe
Lecture-8.	Discussion on few problems
Lecture-9.	Solutions of previous year questions

Module-III
Quantum Theory of Radiation (5 lectures)

Contents

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

Module Objectives:

1. From this chapter one can understand the quantum theory of radiation including Planck's quantum postulates
2. One can understand how the Failure of Wien's Distribution Law and Rayleigh-Jeans Law in the explanation of whole spectral distribution of blackbody radiation was cured by Planck's Law
3. One can also understand How Planck's law in two limiting cases of frequency scale reduces to Wien's Distribution Law and Rayleigh-Jeans Law

Lecture Serial	Topics of Discussion
Lecture-1.	**Spectral Distribution of Black Body Radiation:** Spectral distribution curve of Blackbody radiation with frequency. Failure of Wien's Distribution Law and Rayleigh-Jeans Law in the explanation of whole spectral distribution of blackbody radiation
Lecture-2.	**Planck's Law of Blackbody Radiation:** Planck's Quantum Postulates, Derivation of Planck's Law of Blackbody Radiation
Lecture-3.	**Deduction of different laws from Planck's law:** Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law
Lecture-4.	Discussion on few problems
Lecture-5.	Solutions of previous year questions

Tutorial Assignment—2

Module-IV
Bose-Einstein Statistics (13 lectures)

Contents

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.

Module Objectives:
1. This unit aims to deliver idea of Boson and its properties 2. One can understand B-E condensation as macroscopic occupation of particles in a single energy state governed by a single wavefunction 3. One can also obtain idea about radiation as a photon gas and how to determine Thermodynamic functions of photon gas

Lecture Serial	Topics of Discussion
Lecture-1.	**Characteristics of B-E system:** Properties of Boson
Lecture-2.	**B-E distribution law:** Derivation of B-E distribution law
Lecture-3.	**Chemical Potential:** Restriction on chemical potential for B-E system (negative or zero), Chemical potential for photon gas
Lecture-4.	**Strongly Degenerate Bose Gas:** Distribution function and density of states, Thermodynamic functions of a strongly Degenerate Bose Gas
Lecture-5.	**Bose Einstein condensation:** Macroscopic occupation of a single energy state
Lecture-6.	**Bose Einstein condensation:** Calculation of condensation Temperature, energy, pressure, specific heat of B-E condensate, B-E condensation as 1 st order phase transition
Lecture-7.	**Properties of liquid He:** Liquid He as Super fluid, He-I to He-II transition as second order phase transition
Lecture-8.	**Bose derivation of Planck's law:** Radiation as a photon Gas, Calculation of density of states, Planck's radiation formula from B-E distribution function
Lecture-9.	**Planck's law in two limiting cases of frequency scale:** Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law
Lecture-10.	**Thermodynamic functions of photon gas:** Calculation of energy, Specific heat, Helmholtz free energy, Pressure, Entropy
Lecture-11.	Discussion on few Problems
Lecture-12.	Solutions of previous year questions
Lecture-13.	Solutions of previous year questions

Tutorial Assignment—3

Module-V **Fermi-Dirac Statistics** (15 lectures)
Contents
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.
Module Objectives:
1. This unit aims to deliver idea of Fermion and its properties 2. One can understand how to determine thermodynamic functions of strongly degenerate Fermi gas at $T = 0$ K and $T \neq 0$ K 3. One can get idea about relativistic Fermi gas that occur in celestial bodies like White Dwarf and Neutron Stars

Lecture Serial	Topics of Discussion
Lecture-1.	**Characteristics of F-D system:** Properties of Fermion
Lecture-2.	**F-D distribution law:** Derivation of F-D distribution law
Lecture-3.	**Fermi energy:** Chemical potential as Fermi energy, F-D distribution law as probability, Variation of F-D distribution curve with energy at $T = 0$K and $T \neq 0$K
Lecture-4.	**Strongly Degenerate Fermi Gas at T=0K:** Fermi energy calculation at T=0K
Lecture-5.	**Strongly Degenerate Fermi Gas at T=0K:** Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas at T=0K

Lecture-6.	**Strongly Degenerate Fermi Gas at $T \neq 0$K:** Calculation of Fermi energy at $T \neq 0$K
Lecture-7.	**Strongly Degenerate Fermi Gas at $T \neq 0$K:** Total number of particles and total energy of a Completely and strongly Degenerate Fermi Gas at $T \neq 0$K
Lecture-8.	**Strongly Degenerate Fermi Gas at $T \neq 0$K:** Specific heat and entropy of a Completely and strongly Degenerate Fermi Gas at $T \neq 0$K
Lecture-9.	**Electron gas in metal:** Thermionic emission and electrical conduction, specific heat of metals
Lecture-10.	**Relativistic Fermi gas:** Density of states, Total energy and number of particles of relativistic Fermi gas
Lecture-11.	**Relativistic Fermi gas:** Pressure of relativistic Fermi gas, Fermi energy corresponding to very high temperature for relativistic Fermi gas
Lecture-12.	**Relativistic Fermi gas:** White Dwarf Stars, Chandrasekhar Mass Limit.
Lecture-13.	Discussion on few Problems
Lecture-14.	Solutions of previous year questions
Lecture-15.	Solutions of previous year questions

Tutorial Assignment—4

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

Reference books
1. *An Introductory Course of Statistical Mechanics*, P. B. Pal, 2009, Narosa

Course Code: CC-XIV
Course Title: Statistical Mechanics (Practical)

Module-I
Statistical Mechanics Practical

Contents

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 C_v, 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) Debyedistribution 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
Module Objectives: This unit aims to develop computational skill of the students to solve the problems based on Statistical Mechanics and plot the results graphically

Serial No.	Topics of Discussion
Lab-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
Lab-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 C_v, 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.
Lab-3.	Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at high temperature and low temperature.
Lab-4.	Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debyedistribution function for high temperature and low temperature and compare them for these two cases.
Lab-5.	Plot the following functions with energy at different temperatures a) Maxwell-Boltzmann distribution b) Fermi-Dirac distribution c) Bose-Einstein distribution

Course code: DSE-3
Course Title: Nuclear and Particle Physics

Module-I **General Properties of Nuclei** (10 lectures)
Contents 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
Module Objectives: Main Objectives of this module are: 1. Basic knowledge on constituents of nucleus and its properties. 2. Understanding the binding energy of the nucleus and its variation with mass number. 3. Learning the nuclear properties, such as angular momentum, magnetic momentum, parity.

Serial No.	**Topics of Discussion**
Lecture-1.	**Inception and Overview:** From Greek philosopher Democritus to particle accelerator in present time. **Some Introductory Terminology:** Constituents of nucleus, Atomic number, Mass number, Labeling of nuclei, Isotopes, Isobars, Isotones, Mirror nuclei.
Lecture-2.	**Unit and Dimension:** Nuclear radius in fm, Nuclear energy in MeV, Nuclear mass in atomic mass unit (u). Relation between amu and MeV. **Nuclear Size:** Qualitative idea, Nuclear density, Charge density.
Lecture-3.	**Packing Fraction:** Mass defect and packing fraction, Packing fraction curve and its significant.
Lecture-4.	**Binding Energy:** Binding energy and binding fraction.
Lecture-5.	**Binding Fraction Curve:** Binding fraction Vs mass number curve and its important features.
Lecture-6.	**Binding Fraction and Packing Fraction:** Relation between binding fraction and packing fraction
Lecture-7.	N/A **Plot:** e-e, e-o, o-e, o-o nuclei, Stable nuclide, Important of N/A plot for stable and unstable nuclide.
Lecture-8.	**Angular Momentum and Parity:** Nuclear spin angular momentum, intrinsic spin and total angular momentum. Significance of a parity, odd and even parity.
Lecture-9.	**Magnetic Moment and Electric Moments:** Orbital angular momentum and magnetic moment, Bohr magneton, Rabi magneton, Proton and Neutron magnetic moment.
Lecture-10.	**Nuclear Excites States:** Excites state of the individual nucleons.

Tutorial Assignment—1

Module-II **Nuclear Models** (12 lectures)
Contents 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.

Module Objectives:
Main Objectives of this module are: 1. Understanding the binding energy of the nucleons through Liquid drop model and Bethe-Weizsacker formula. 2. Formation of the idea of the shell structure of nucleus which explain the magic number of nuclei and stability of nuclei. 3. Comprehending the Fermi gas model describe the properties of the heavy nucleus in excited state.

Serial No.	Topics of Discussion
Lecture-1.	**Liquid Drop Model:** Similarities between the nucleus of an atom and a liquid drop. Binding energy of the nucleus and Limitation.
Lecture-2.	**Bethe-Weizsacker Formula:** Volume Energy, Surface Energy, Coulomb energy,
Lecture-3.	**Semi-empirical Mass Formula:** Calculation of a_c, Asymmetry Energy, Pairing Energy
Lecture-4.	**Mass Parabola:** Semi-empirical mass formula in terms of mass parabola, Condition of nuclear stability
Lecture-5.	**β-disintegration Energy of Mirror Nuclei**, **Two nucleon separation energies**
Lecture-6.	**Fermi gas model:** Degenerate gas, Symmetry potential in Fermi gas
Lecture-7.	**Nuclear Shell Structure:** Evidence for nuclear structure, Nuclear magic number, semi-magic number.
Lecture-8.	**Assumption of shell model:** Basic assumption of shell model, Concept of mean field.
Lecture-9.	**Spin-Orbit interaction:** Nuclear spin-orbit coupling, Spin-orbit potential, Spin-orbit energy.
Lecture-10.	**Explanation of Shell Structure:** Explanation of magic number and semi-magic number
Lecture-11.	**Spin and Parity:** Spin and parity of nuclear ground state
Lecture-12.	**Nuclear Force:** Properties of the nuclear force.

Tutorial Assignment—2

Module-III **Radioactivity decay** (10 lectures)
Contents (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 and kinematics, internal conversion.
Module Objectives: 1. To understand the spontaneous transition from one state to another nuclei state through the emission of α, β γ particles. 2. To make out the emission of alpha-decay. 3. To explain the beta spectrum by the help of neutrino hypothesis. 4. To Comprehend the beta-decay with the help of Fermi theory.

Serial No.	Topics of Discussion
Lecture-1.	**Radioactivity decay:** Type of radioactivity. **Alpha decay:** α-decay processes, Alpha disintegration energy and Fine Structure of α-decay.
Lecture-2.	**Range of α particle:** Geiger law and it's validation, Geiger-Nuttall Law, Straggling of alpha particle.
Lecture-3.	**Theory of Alpha Emission:** Quantum mechanics description of alpha decay.
Lecture-4.	**Gamow's Theory of α-decay:** Gamow factor, The rate of emission of alpha particles.

Serial No.	Topics of Discussion
Lecture-5.	**Beta Decay:** Kinetic energy of β-decay, Energy spectrum of β-decay, Momentum distribution.
Lecture-6.	**Energetic of β-decay:** Condition for β^-, β^+ and Electron capture or K-capture, Difficulties in interpretation of β-spectrum.
Lecture-7.	**Neutrino Hypothesis:** Neutrino Hypothesis of Pauli, Properties of a neutrino, Left-hand neutrino and right-hand antineutrino, The Weak Interaction.
Lecture-8.	**Fermi's Theory of Beta Decay:** Fermi's Golden Rule, Density of states, Selection rule, Fermi-Kurie plot.
Lecture-9.	**Gamma Decay:** Energy of gamma decay, Internal Conversion
Lecture-10.	**Quantum Mechanical Theory of Gamma Decay:** Density of states, The vector potential, Dipole transition for gamma decay, Selection Rules

Tutorial Assignment—3

Module-IV
Nuclear Reactions (8 lectures)

Contents

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).

Module Objectives:

1. To understand the nuclear nuclear reaction process and conservation laws.
2. To calculate the Q-value of a nuclear reaction.
3. To comprehend the the nuclear cross section of a nuclear reaction.
4. To explain the scattering of alpha particle with the assistant of Ratherford scattering theory.

Serial No.	Topics of Discussion
Lecture-1.	**Types of Reactions:** Elastic Scattering, Inelastic Scattering, Radiative Capture, Disintegration Process, Photo-disintegration, Nuclear fission, Many body Reaction, Elementary particle reaction **Conservation Laws:** Conservation of mass number, Conservation of atomic number, Conservation of energy, Conservation of linear momentum, Conservation of the angular momentum, Conservation of parity, Conservation of isotopic spin
Lecture-2.	**Q-value:** Q-values of a reaction, Exoergic reaction, Endoergic reaction
Lecture-3.	**Kinematics of Reactions:** Q-value of a nuclear reaction, Threshold energy of an endoergic reaction
Lecture-4.	**Cross section of Nuclear reaction:** Nuclera cross section (σ), Geometrical significant of σ, Unit.
Lecture-5.	**Direct Reaction**
Lecture-6.	**Compound Reaction**
Lecture-7.	**Ratherford Scattering:** Impact parameter
Lecture-8.	**Ratherford Scattering:** α-particle scattering cross section.

Tutorial Assignment—4

Module-V
Interaction of Nuclear Radiation with matter (8 lectures)

Contents

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.

Module Objectives:

1. To understand the energy loss of charge particles when they pass through the matter.
2. To apprehend the interaction of gamma rays with matter.

Serial No.	Topics of Discussion
Lecture-1.	**Energy Loss due to Ionization :** Energy-loss of heavy charged particles in matter, Calculation of $b_{\max}$ and $b_{\min}$
Lecture-2.	**Bethe-Block formula:** Bohr's formula for specific ionization, Quantum mechanical correction, Effect of the polarization, Theoretical calculation of the range of heavy charged particles
Lecture-3.	**Energy Loss of an Electron:** Relativistic correction of Bethe-Block formula, Bremsstrahlung process and Radiative energy loss.
Lecture-4.	**Cerenkov Radiation:** Emission angle, Frank-Tamm formula, Threshold energy
Lecture-5.	**Interactions of Gamma-rays with Matter:**Attenuation coefficient, Absorption coefficient, Scattering coefficient, Half-thickness
Lecture-6.	**Photoelectric absorption of Gamma-rays:** Photoelectric effect, Photoelectric absorption cross-section.
Lecture-7.	**Compton Scattering of Gamma-rays:** Compton Scattering, Compton wavelength, Compton scattering cross-section.
Lecture-8.	**Neutron Interaction With Matter:**

Tutorial Assignment—5

Module-VI
Detector for Nuclear Radiations (8 lectures)

Contents

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.

Module Objectives:

Main Objectives of this module are:
1. Knowledge of the classification of the radiation detectors.
2. Learning about Gas detectors, Scintillation Detector, and Semiconductor detector. 3. Detection of Neutron and Photon.

Serial No.	Topics of Discussion
Lecture-1.	**Radiation detector:** Classification of radiation detector, Primary Ionization, Secondary ions, and Recombination. **Gas detectors:** Ionization Chamber, Estimation of electric field, Mobility of particle
Lecture-2.	**Proportional Counter:** Ionization current density, Townsend or avalanche ionization, Region of limited proportionality
Lecture-3.	**GM Counter:** Basic Principle, Basic construction, Geiger discharge
Lecture-4.	**GM Counter:** Quenching of the discharge, Quenching material, Dead time
Lecture-5.	**Semiconductor Detectors:** Semiconductor, Depletion region, Si and Ge detector
Lecture-6.	**Scintillation Detectors:** Scintillator, Inorganic Scintillators, Organic Scintillators,
Lecture-7.	**PMT:** Photocathode, Dynode, Efficiency, Multiple Stage Multiplication
Lecture-8.	**Photon detection and Neutron Detector:**

Tutorial Assignment—6

Module-VII
Particle Accelerators (5 lectures)

Contents

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

Module Objectives:
Main Objectives of this module are: 1. Basic knowledge of Van-de Graaff Generator. 2. Understanding Linear accelerator. 3. Learning Cyclotron and Synchrotrons.

Serial No.	**Topics of Discussion**
Lecture-1.	**Van-de Graaff Generator:** Working Principle, Applications, Limitation. **Tandem accelerator:** Working Principle
Lecture-2.	**Linear Accelerator:** Working Principle, Drift tube length calculation, Energy Calculation, Applications, Limitation.
Lecture-3.	**Cyclotron:** Working Principle, Cyclotron frequency, Resonance Condition, Applications, Limitation.
Lecture-4.	**Synchrocyclotron** Working Principle, Applications, Limitation.
Lecture-5.	**Synchrotrons:** Working Principle, Applications, Limitation.

Tutorial Assignment—7

Module-VIII **Particle physics** (14 lectures)
Contents
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.
Module Objectives:
Main Objectives of this module are: 1. Understanding the basic features of particle interaction and its conservation principles. 2. Learning the type of particles and subdivision them into different families. 3. Conception of quark model and color quantum number.

Serial No.	**Topics of Discussion**
Lecture-1.	**Fundamental Interaction in Nature:** Gravitational interaction, Electromagnetic interaction, Weak interaction, Strong nuclear interaction
Lecture-2.	**Conservation Laws:** Conservation of energy, Conservation of linear momentum, Conservation of angular momentum, Conservation of charge,
Lecture-3.	**Types of Particles:** Lepton and its classification, Lepton number, spin and charge of the lepton, Anti-lepton, Conservation of lepton number.
Lecture-4.	**Meson & Baryon:** Hadrons, π-meson, K-meson and hyperons, Baryon and its features, Conservation of baryon number.
Lecture-5.	**Parity & Isospin:** Odd and Even Parity, Conservation of parity, Isospin and its features, Conservation of isospin.
Lecture-6.	**Strangeness and Charm** Strange particle and its features, Conservation of strangeness. Charm particles.
Lecture-7.	**Conservation Relation**Gell-Mann-Nishijima Relation, Hypercharge, Conservation of hypercharge and its violation.
Lecture-8.	**Charge-parity or C-parity & Conservation of T** Charge conjugation operation, Conservation of C-parity conservation, Time-reversal invariance.
Lecture-9.	**The Standard Model:** Quark – Classification and characteristic (charge, spin, mass, isospin, hypercharge).
Lecture-10.	**The Standard Model:** Lepton, Quark, Mediator, Quark hypothesis, Quark contain of some mesons and baryons.
Lecture-11.	**Symmetry of elementary particles:** SU_2 symmetry, Weight diagram for generating an isospin triplet. SU_3 symmetry, Octet symmetry of baryons.
Lecture-12.	**Symmetry of elementary particles:** Weight diagram for a meson octet.

Serial No.	Topics of Discussion
Lecture-13.	**Quantum Chromodynamics:** Concept of color, Quark bound state and colorless, Color composition of hadrons. Color quantum number
Lecture-14.	**Gluons:** Mediator of strong interaction, Color of gluons, Color singlet.

Tutorial Assignment—8

Text books
1. *Nuclear Physics*, S. N. Ghoshal, S. Chand.
2. *Introductory Nuclear Physics*, Kenneth S. Krane, Wiley.

Reference books
1. *Introduction to Nuclear and Particle Physics*, A. Das and T. Ferbe, World Scientific.
2. *Atomic and nuclear physics*, A. B. Gupta and Dipak Ghosh, Books and Allied (P) Ltd.

Course code: DSE-4
Course Title:Applied Dynamics

Module-I **Introduction to Dynamical systems:** (26 lectures)
Contents
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.
Module Objectives:
1.To build up basic concepts of dynamical systems.

Introduction	
Lecture Serial	**Topics of Discussion**
Lecture-1.	**Introduction to dynamical systems:** In this lecture, concept of dynamical systems are introduced. Autonomous and Non-autonomous systems are defined and shown that n dimensional non-autonomous system is equivalent to an $n+1$ dimensional autonomous system.
Lecture-2.	**Types and dimension of dynamical systems:** Dynamical systems can be broadly divided into two categories: discrete time dynamical systems or maps and continuous time dynamical systems. Then dimensionality of a dynamical system is introduced and few examples were given.

One dimensional dynamical systems	
Lecture Serial	**Topics of Discussion**
Lecture-3.	**1D flow:** Qualitative ideas of continuous time dynamical system's flow on one dimension discussed. Fixed point for a dynamical system is introduced.
Lecture-4.	**1D flow cont.:** Linearization technique, stability of a fixed point is discussed both from graphical and also from analytical point of view.
Lecture-5.	**Bifurcation in 1D system:** Introduction to the idea of bifurcation, bifurcation diagram and its application to understand different classes of bifurcations. Saddle node bifurcation in normal form and also in some other form being discussed to stress upon qualitative nature of classification of bifurcation from bifurcation diagram.
Lecture-6.	**Bifurcation in 1D system:** Transcritical and pitchfork are being discussed. Supercritical and subcritical bifurcations are introduced and concept of Hysteresis is being shown.
Lecture7.	**Bifurcation in 1D system:** Bead on a rotating hoop and a system consisting hoop hooked up to a wire and fixed with a vertical spring are discussed as prototype examples of bifurcations.
Lecture-8.	**Examples of 1D system:** Few examples like Logistic model is being discussed as an example of 1D system. It is then extended to insect outbreak model by Ludwig which relies on saddle-node bifurcation.
Lecture-9.	**Flow on a circle:** Special kind of 1D system, flow on a circle is discussed in this lecture. Bifurcations in this aspect are also visited. Idea of intemittency is also practiced here.

Two dimensional dynamical systems	
Lecture Serial	**Topics of Discussion**
Lecture-10.	**Introduction to 2D flow:** In this lecture we start to look at flows in two dimension. We fist define phase space in generic sense. Then examples of two dimensional systems are introduced.
Lecture-11.	**Fixed points and Linearization:** Fixed points are defined for a dynamical system $\dot{\vec{x}} = \vec{f}(\vec{x})$ as $\vec{f}(\vec{x}) = \vec{0}$. Then the equations are linearized about the fixed points.
Lecture-12.	**Linear Algebra I:** Eigenvalues and Eigenvectors are dealt from scratch. Physical and mathematical concept of similarity transformation is discussed.
Lecture-13.	**Linear Algebra II:** Eigenvalues and Eigenvectors are specifically tackled and eigenvalue of a 2×2 matrix is determined in terms of its trace and determinant (which are shown to be conserved under similarity transformation).
Lecture-14.	**2D linear flow I:** Linearized 2D flow $\dot{\vec{X}} = A\vec{X}$ is analyzed using knowledges obtained from linear algebra point of view. Importance of eigenvalues for flow along eigendirection is being discussed.
Lecture-15.	**2D linear flow II:** In this lecture, we continue to probe linear 2D flow. Different combinations of real eigenvalues and their characteristics along eigen directions being observed.
Lecture-16.	**2D linear flow III:** In this lecture, a new possibility of having pair of complex conjugate eigenvalues are analyzed and new type of motion : Stable and Unstable spirals along with the boundary line case of center being discussed.
Lecture-17.	**2D linear flow IV:** At the beginning of this lecture, we classify different possibilities of qualitative motions in 2D phase space by drawing a $\triangle - \tau$ plot. Then the all important Hartman-Grobman theorem is discussed to validate the usefulness of linearization technique for a general nonlinear map.

Lecture-18.	**Lotka-Volterra model:** To practice all the techniques learned, in this lecture, the famous Lotka-Volterra model from population dynamics being studied.
Lecture-19.	**Nonlinear centers:** We define here what is meant by nonlinear centers. Conservative and reversible systems are discussed to identify them.
Lecture-20.	**Pendulum as an example:** In this lecture, we look at undamped pendulum motion as an example of nonlinear center. Phase portraits of different types of possible trajectories are also considered here.
Lecture-21.	**Ruling out periodic orbits:** Index theory, Gradient system, Lyapunov function and Dulac's criteria are used to eliminate the possibilities of ruling out periodic orbits.
Lecture22.	**Limit cycle I:** Its a completely new kind of object "isolated closed trajectory" called limit cycle in nonlinear dynamical regime. Poincare-Bendixson theorem is discussed in the connection.
Lecture-23.	**Limit cycle II:** Sel'kov model and Chemical oscillations are discussed as an example of limit cycle. Many other physical examples also being pointed out and importance of having stable limit cycles in place of centers are also being stressed.
Lecture-24.	**Bifurcations in 2D I:** Saddle-node, Transcritical and Pitchfork bifurcations are revisited in 2D flows.
Lecture-25.	**Bifurcations in 2D II:** Hopf Bifurcation which is a completely new kind of bifurcation in 2D is discussed in this class. Along with that, concept of Infinite period and Homoclinic bifurcations are also understood.
Lecture-26.	**Softwares and Programming:** In this lecture, software package pplane was demonstrated for visualization of 2D flows. Solving a generic set of differential equation using RK4 algorithm in Scilab was also demonstrated and students are encouraged to practice the same in their own machine.

Tutorial Assignment—1

Module-II **Introduction to Chaos and Fractals** (20 Lectures)
Contents 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.
Module Objectives: To understand structure and origin of Chaos.

Discrete maps	
Lecture Serial	**Topics of Discussion**
Lecture-27.	**Introduction to discrete maps:** In this lecture, discrete dynamical systems are defined. Few physical examples also introduced. Reversible and Irreversible maps are also being distinguished.
Lecture-28.	**One dimensional map:** To analyze map $\vec{x}_{n+1} = \vec{f}(\vec{x}_n)$, fixed points corresponding to roots of $\vec{f}(\vec{x}_n) = \vec{0}$ is introduced. For one dimensional case, then concept of linearization is also introduced.
Lecture-29.	**Cobweb diagram:** To understand the stability of a map, both analytic result and also graphical Cobweb diagram are introduced.
Lecture-30.	**Logistic map I:** Logistic map $x_{n+1} = rx_n(1-x_n)$ as an example of one dimensional irreversible discrete map being introduced. Fixed points of the map is being found along with their stabilities.
Lecture-31.	**Logistic map II:** Both fixed points become unstable at $r \geq 3$. In this context, first, a general period-n-cycle is introduced and then showed that there exists a period two cycle for $r \geq 3$.
Lecture-32.	**Logistic map III:** Stability of period-2-cycle is being analyzed and shown that it becomes unstable for a certain parameter value. Birth and death of period-2-cycle are shown to be through tangent and flip bifurcations, respectively.
Lecture-33.	**Logistic map IV:** Techniques to study period-2^n-cycle is discussed to higher iterative map and general framework to study this cascade of bifurcations is also introduced. Orbit/bifurcation diagram for the same is also drawn.
Lecture-34.	**Logistic map V:** Period-doubling-cascade gives chaos as a limiting case at r_∞. Orbit digram for Logistic map was drawn both using Scilab and Chaos software. Further structures were also probed in the computer plotted orbit diagram.
Lecture-35.	**Logistic map VI:** Period-3-window and Intermittency. $r_\infty \geq r \geq 4$ region is probed using orbit diagram.
Lecture-36.	**Logistic map VII:** Chaos: formal definition of chaos. Lyapunov Exponent (λ). A computer algorithm to plot $\lambda = \lambda(r)$ for logistic map. Explanation of different features of the graph. Analytic calculation of Lyapunov exponent for Tent map.
Lecture-37.	**Logistic map VIII:** Universality of chaos: Basic idea of renormalization and Feigenbaum number. Visualization of Chaos via stretching and folding mechanism.
Lecture-38.	**Two dimensional map:** Henon map and Baker map as an example to two dimensional map. Baker map is used extensively to picture Stretching and Folding mechanism to Chaos.

Fractals	
Lecture Serial	**Topics of Discussion**
Lecture-39.	**Fractals I:** Introduction to self similarities and Fractals, Cantor set as and example of Fractal. Dimension of self similar objects: Similarity dimension : Possibility of fractal dimension Ex. Cantor set, Koch curve, Sierpinski Gasket.
Lecture-40.	**Fractals II:** Attractor, Basin of attraction. Other definitions of dimensions: Box counting, Pointwise and Correlation dimension. Strange attractors for chaotic systems.

Three dimensional dynamical systems	
Lecture Serial	**Topics of Discussion**
Lecture-41.	**Lorenz system I:** Here we introduce the Lorenz model as an example of three dimensional dynamical system. Its trajectories being analyzed in computer using both packaged software "Chaos" and also by Scilab programming.
Lecture-42.	**Lorenz system II:** Concept of Poincare section is introduced to study different types of continuous time dynamical system by a discrete map counter part. Chaotic behavior of Lorenz system is analyzed with the help of Poincare section and logistic map.
Lecture-43.	**Chaotic time series:** Time series, Power spectrum and correlation functions are discussed as a tool to analyze chaotic system. Also concept of delay dimensions are discussed in the regard.

Other Aspects of dynamical systems	
Lecture Serial	**Topics of Discussion**
Lecture-44.	**Billiards as dynamical systems:** Examples of 2-dimensional billiard, Projection of the trajectory on momentum space. Sinai Billiard and its variants.
Lecture-45.	**Billiards as dynamical systems II:** 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.
Lecture-46.	**Current aspects of Dynamical systems:** Many emerging topics like Synchronization, pattern formation, Computational aspects are discussed and summarized the whole content.

Tutorial Assignment—2

Module-III **Elementary Fluid Dynamics** (14 lectures)
Contents
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 and non-uniform flows, viscous and inviscid flows, incompressible and compressible flows, laminar and turbulent flows, rotational and irrotational flows,separated and unseparated flows. Flow visualization -streamlines, pathlines, Streaklines.
Module Objectives:
To understand the elementary fluid dynamics.

Lecture Serial	Topics of Discussion
Lecture-47.	Introduction to Fluid dynamics: In this lecture, elementary concepts of Fluid dynamics is introduced. Its importance in pure and applied science is highlighted.
Lecture-48.	Fluid flow visualizations: Stremlines, Pathlines, Streaklines are discussed here. Steady and Unsteady flows are also distinguished in these aspect. Also the idea of streamtube been captured in this lecture.
Lecture-49.	Vortex and Vortex tube: To quantify vortex, a quantity named vorticity is introduced and thus the idea of vortex line and vortex tube followed. A vortex free motion implies the flow is irrotational and hence called a potential flow.
Lecture-50.	Continuity Equation : All important equation of continuity in the context of fluid dynamics was established in this lecture. From this, it was shown that incompressible flows are solenoidal by nature. It was thus shown that if a potential flow is incompressible it satisfies Laplace's equation.
Lecture-51.	Euler's equation I: A compact form of fluid acceleration is derived for inviscid flow. A form of Euler's equation is derived from momentum conservation law.
Lecture-52.	Euler's equation II: Alternative form of Euler's equation involving vorticity is derived from earlier expression.
Lecture-53.	Bernoulli's eqution: Two different cases of Bernoulli's equation being derived for conservative external force field. Its application to simple problems are also highlighted.
Lecture-54.	Viscous Flow: Modification of Euler's equation in presence of viscosity has been obtained which is known as Navier-Stokes's law in fluid dynamics.
Lecture-55.	Viscous, Incompressible flow: Navier-Stokes equation takes a simpler form for incompressible flow in which the second viscosity term drops out.
Lecture-56.	Flow dimension: Concept of flow dimension is discussed in this lecture and flew one dimensional flows are solved as an example.
Lecture-57.	Flow in 2D: In this lecture, we tackle the problem of two dimensional flow and few words about complications in three dimensional flows.
Lecture-58.	Types of flows I: Laminar and Turbulent flows and Reynold's number is introduced in this lecture. Also the dynamical system's point of view of the transition from laminar to turbulent flow is highlighted.
Lecture-59.	Types of flows II: Separated and Unseparated flows are qualitatively discussed in this lecture.
Lecture-60.	Programming and Software: In Scilab flow visualization is possible by drawing velocity vector fields and solving partial differential equations. Dedicated software packages are also introduced in the class for easier methods of visualization.

Tutorial Assignment—3

Text books

1. Nonlinear dynamics and Chaos- Steven Strogatz.
2. Chaos and Nonlinear Dynamics- Robert Hilborn.
3. Fluid mechanics- Lev Landau and Evgeny Lifshitz.

Reference books

1. Understanding Nonlinear dynamics- D. Kaplan and L. Glass.
2. Introduction to Fluid Mechanics - Y. Nakayama and R.F. Boucher.

Course Code: DSE-4
Course Title: Applied Dynamics (Practical)

Module-I **Applied Dynamics Practical**
Contents Use C/C++/Scilab/other numerical simulations for solving the problems based on Applied Dynamics problem 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.
Module Objectives: This module attempts to develop computational skill of the students to solve the problems based on applied dynamics problem and plot the results graphically.

Serial No.	**Topics of Discussion**
Lab 1.	To determine the coupling coefficient of coupled pendulums.
Lab 2.	To determine the coupling coefficient of coupled oscillators.
Lab 3.	To determine the coupling and damping coefficient of damped coupled oscillator.
Lab 4.	To study population models e.g. exponential growth and decay, logistic growth,species com- petition, predator-prey dynamics, simple genetic circuits.
Lab 5.	To study rate equations for chemical reactions e.g. auto catalysis, bistability.
Lab 6.	To study examples from game theory.
Lab 7.	Computational visualization of trajectories in the Sinai Billiard.
Lab 8.	Computational visualization of trajectories Electron motion in mesoscopic conductors as a chaotic billiard problem.
Lab 9.	Computational visualization of fractal formations of Deterministic fractal.
Lab 10.	Computational visualization of fractal formations of self-similar fractal.
Lab 11.	Computational visualization of fractal formations of Fractals in nature – trees,coastlines, earthquakes.
Lab 12.	Computational Flow visualization - streamlines, pathlines, Streaklines.