DU M.Sc Syllabus

Total No. of Question: 50

Time: 2 Hours **Maximum Marks: 200**

Syllabus

The Syllabus for M.Sc entrance test is based on the existing B.Sc Physics papers (w.e.f. 2009).

First Year Semester 1: Mathematical Physics-I, Mechanics

First Year Semester 2: Mathematical Physics-II, Oscillations and Waves, Electricity and Magnetism, Digital Electronics

Second Year Semester 3: Mathematical Physics-III, Thermal Physics

Second Year Semester 4: Mathematical Physics-IV, Optics

Third Year Semester 5: Mathematical Physics-V, Quantum Mechanics, Atomic and Molecular Physics, Electronic Devices

Third Year Semester 6: Electromagnetic Theory, Statistical Physics, Solid State Physics, Nuclear and Particle Physics

First Year: Semester-1

Mathematical Physics-I

Vector Calculus:-

Vector Differentiation **:-** Scalar and Vector Fields. Ordinary and Partial Derivative of a Vector w.r.t. Coordinates. Space Curves. Unit Tangent Vector and Unit Normal Vector (without Frenet - Serret Formulae). 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.

Vector Integration:- Ordinary Integral of Vectors. Line, Surface and Volume Integrals. Flux of a Vector Field. Gauss' Divergence Theorem, Green's Theorem and Stokes Theorem.

Orthogonal Curvilinear Coordinates

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

Multiple Integrals

Double and Triple Integrals : Change of Order of Integration. Change of Variables and Jacobian. Applications of Multiple Integrals : (1) Area Enclosed by Plane Curves, (2) Area of a Curved Surface, (3) Volumes of Solids.

Some Special Integrals

Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).

Theory of Errors

Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error.

Fourier Series:-

Fourier Series. Dirichlet Conditions (Statement only). Kronecker's Method for Computation of Fourier Coefficients. Even and Odd Functions. Orthogonality of Sine and Cosine Functions. Sine and Cosine Series. Applications: Square Wave, Triangular Wave, Output of Full Wave Rectifier and other Simple Functions. Summing of Infinite Series Term-by-Term Differentiation and Integration of a Fourier Series.

Mechanics

Fundamentals of Dynamics

Dynamics of a System of Particles. Centre of Mass. Conservation of Momentum. Idea of Conservation of Momentum from Newton's Third Law. Impulse. Momentum of Variable Mass System: Motion of Rocket.

Work and Energy Theorem:- Work and Kinetic Energy Theorem. Conservative and Non-Conservative Forces. Potential Energy. Energy Diagram. Stable and Unstable Equilibrium.

Gravitational Potential Energy. Elastic Potential Energy. Force as Gradient of Potential Energy. Work and Potential energy. Work done by Non-conservative Forces. Law of Conservation of Energy.

Elastic and Inelastic Collisions between particles. Centre of Mass and Laboratory Frames.

Rotational Dynamics

Angular Momentum of a Particle and System of Particles. Torque. 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.

Gravitation and Central Force Motion

Law of gravitation. Inertial and Gravitational Mass. Potential and Field due to Spherical Shell and Solid Sphere.

Motion of a Particle under Central Force Field. Two Body Problem and its Reduction to One Body Problem and its Solution. The Energy Equation and Energy Diagram. Kepler's Laws (Ideas Only). Orbits of Artificial Satellites.

Elasticity

Relation Between Elastic Constants. Twisting Torque on a Cylinder or Wire.

Fluid Motion

Kinematics of Moving Fluids:- Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.

Inertial and Non- Inertial Systems

Reference Frames :- Inertial Frames and Galilean Transformations. Galilean Invariance and Conservation Laws. Non-inertial Frames and Fictitious Forces. Uniformly Rotating Frame.

Physics Laws in Rotating Coordinate Systems. Centrifugal forces: Coriolis Force and its Applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems.

Special theory of Relativity

Michelson-Morley Experiment and its Outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and Order of Events. Lorentz Contraction. Time Dilation. Relativistic Transformation of Velocity, Frequency and Wave Number. Relativistic Addition of Velocities. Variation of Mass with Velocity. Rest Mass. Massless Particles. Massenergy Equivalence. Bucherer's experiment. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum. Energy-Momentum Four Vector.

Second Year: Semester-2

Mathematical Physics-II

Differential Equations

Classification: Ordinary and Partial, Order and Degree, Linear and Nonlinear, Homogeneous and Non-homogeneous. Solution : Explicit and Implicit, Number of Arbitrary Constants.

Linear Ordinary Differential Equations

First order:- (1) Separable Equations. Initial Value Problem. (2) Exact Equations. Integrating Factor. (3) Linear Equations. Lagrange's Method of Variation of Parameters.

Second order:- Homogeneous Equations with Constant Coefficients. Wronskian and General Solution. Statement of Existence and Uniqueness Theorem for Initial Value Problems. Solution of Non-homogeneous Equations by D Operator Method. Particular Integral. Methods of Undetermined Coefficients and Variation of Parameters. Equations Reducible to those with Constant Coefficients. Bernoulli and Euler Equations.

Coupled Differential Equations :- Solution by Method of Elimination.

Calculus of Variations

Variational Calculus: Variational Principle. Euler's Equation and its Application to Simple Problems. Geodesics. Concept of Lagrangian. Generalized Coordinates. Definition of Canonical Momenta. Euler-Lagrange's Equations of Motion and its Applications to Simple Problems: (e.g., simple pendulum and one dimensional harmonic oscillator). Definition of Canonical Momenta. Canonical Pair of Variables. Definition of Generalized Force.: Definition of Hamiltonian (Legendre Transformation). . Hamilton's Principle. Poisson Brackets and their Properties. Lagrange Brackets and their Properties.

Constrained Maxima and Minima. Lagrange's Method of Undetermined Multipliers and its Application to Simple Problems in Physics.

Oscillations and Waves

Oscillations

SHM:- Simple Harmonic Oscillations. Differential Equation of SHM and its Solution. Amplitude, Frequency, Time Period and Phase. Velocity and Acceleration. Kinetic, Potential and Total Energy and their Time Average Values. Reference Circle. Rotating Vector Representation of SHM.

Free Oscillations of Systems with One Degree of Freedom :- (1) Mass-Spring system, (2) Simple Pendulum, (3) Torsional Pendulum, (4) Oscillations in a U-Tube, (5) Compound pendulum: Centres of Percussion and Oscillation, and (6) Bar Pendulum.

Superposition of Two Collinear Harmonic Oscillations :- Linearity and Superposition Principle. (1) Oscillations having Equal Frequencies and (2) Oscillations having Different Frequencies (Beats). Superposition of N Collinear Harmonic Oscillations with (1) Equal Phase Differences and (2) Equal Frequency Differences.

Superposition of Two Perpendicular Harmonic Oscillations :- Superposition of Two Mutually Perpendicular Simple Harmonic Motions with Frequency Ratios 1:1 and 1:2 using Graphical and Analytical Methods. Lissajous Figures and their Uses.

System with Two Degrees of Freedom : Coupled Oscillators. Normal Coordinates and Normal Modes. Energy Relation and Energy Transfer. Normal Modes of N Coupled Oscillators.

Free Oscillations. Damped Oscillations : Damping Coefficient, Log Decrement. Forced Oscillations : Transient and Steady States, Amplitude, Phase, Resonance, Sharpness of Resonance, Power Dissipation and Quality Factor. Helmholtz Resonator.

Waves

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

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

Superposition of Two Harmonic Waves :- Standing (Stationary) Waves in a String : Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes wrt 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.

Electricity and Magnetism

Electric Circuits

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: (1) Thevenin theorem, (2) Norton theorem, (3) Superposition theorem, (4) Reciprocity theorem, and (5) Maximum Power Transfer theorem.

Electric Field and Electric Potential

Electric Field :- Electric Field and Lines. Electric Field **E** due to a Ring of Charge. Electric Flux. Gauss's law. Gauss's law in Differential form. Applications of Gauss's Law : **E** due to (1) an Infinite Line of Charge, (2) a Charged Cylindrical Conductor, (3) an Infinite Sheet of Charge and Two Parallel Charged Sheets, (4) a Charged Spherical Shell, (5) a Charged Conducting Sphere, (6) a Uniformly Charged Sphere, (7) Two Charged Concentric Spherical Shells and (8) a Charged Conductor. Force on the Surface of a Charged Conductor and Electrostatic Energy in the Medium surrounding a Charged Conductor.

Electric Potential:- Line Integral of Electric Field. Electric Potential Difference and Electric Potential V (Line integral). Conservative Nature of Electrostatic Field. Relation between **E** and V . Electrostatic Potential Energy of a System of Charges. Potential and Electric Field of (1) a Dipole, (2) a Charged Wire and (3) a Charged Disc. Force and Torque on a Dipole. Conductors in an Electrostatic Field. Description of a System of Charged Conductors. An Isolated Conductor and Capacitance. Method of Images and its Application to:- (1) Plane Infinite Sheet and (2) Sphere.

Electrostatic Energy of (1) a Point Charge, (2) a System of Point Charges, (3) a Uniform Sphere, (4) a Capacitor.

Dielectric Properties of Matter

Dielectrics:- Electric Field in Matter. Dielectric Constant. Parallel Plate Capacitor with a Dielectric. Polarization, Polarization Charges and Polarization Vector. Electric Susceptibility. Gauss's law in Dielectrics. Displacement vector **D**. Relations between the three Electric Vectors. Capacitors filled with Dielectrics.

Magnetic Field

Magnetic Effect of Currents :- Magnetic Field **B**. Magnetic Force between Current Elements and Definition of **B.** Magnetic Flux. Biot-Savart's Law : **B** due to (1) a Straight Current Carrying Conductor and (2) Current Loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital law (Integral and Differential Forms): B due to (1) a Solenoid and (2) a Toroid. Properties of **B.** Curl and Divergence of **B**. Vector Potential.

Forces on an Isolated Moving Charge. Magnetic Force on a Current Carrying Wire. Torque on a Current Loop in a Uniform Magnetic Field.

Magnetic Properties of Matter

Magnetism of Matter:- Gauss's law of magnetism (Integral and Differential Forms). Magnetization current. Relative Permeability of a Material. Magnetic Susceptibility. Magnetization Vector (**M**). Magnetic Intensity (**H**). Relation between **B**, **M** and **H**. Stored Magnetic Energy in Matter. Magnetic Circuit. B-H Curve and Energy Loss in Hysteresis.

Electromagnetic induction

Faraday's law (Differential and Integral forms). Lenz's Law. Self and Mutual Induction. Energy stored in a Magnetic Field.

Ballistic Galvanometer

Potential Energy of a Current Loop. Ballistic Galvanometer: Current and Charge sensitivity. Electromagnetic Damping. Logarithmic Damping. CDR.

Digital Electronics

Introduction to CRO

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

Analog Circuits

Integrated Circuits (Qualitative Treatment only) :- Active and Passive components. Discrete Circuit Component. Wafer. Chip. Advantages and Drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (Basic Idea and Definitions Only). Classification of ICs. Fabrication of Components on Monolithic ICs. Examples of Linear and Digital ICs.

Operational Amplifiers (Use Black Box approach) :- Basic Characteristics of Op-Amps. Characteristics of an Ideal Op-Amp. Feedback in Amplifiers . Open-loop and Closed-loop Gain. Frequency Response. CMRR. Virtual ground.

Applications of Op-Amps : (1) Inverting and Non-inverting Amplifiers, (2) Adder, (3) Subtractor, (4) Unity follower, (5) Differentiator, (6) Integrator, (7) Zero Crossing Detector.

Timers (Use Black Box approach):- 555 Timer and its Applications : Astable and Monostable Multivibrator.

Digital Circuits

Difference Between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. AND, OR and NOT Gates (Realization using Diodes and Transistor). NAND AND NOR Gates. Exclusive OR and Exclusive NOR Gates.

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

Data processing circuits :- Basic Idea of Multiplexers, De-multiplexers, Decoders, Encoders, Parity Checkers.

Memories:- Read-only memories (ROM), PROM, EPROM.

Arithmetic Circuits:- Binary Addition. Binary Subtraction using 2's Complement Method). Half Adders and Full Adders and Subtractors (only up to Eight Bits).

Sequential Circuits:- RS, D, and JK Flip-Flops. Level Clocked and Edge Triggered Flip-Flops. Preset and Clear Operations. Race-around Conditions in JK Flip-Flops. Master-Slave JK Flip-Flop (As Building Block of Sequential Circuits).

Shift Registers: - Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out, and Parallel-in-Parallel-out Shift Registers (only upto 4 bits).

Counters: - Asynchronous and Synchronous Counters. Ring Counters. Decade Counter.

D/A and A/D conversion: - D/A converter – Resistive network. Accuracy and Resolution.

Second Year: Semester-3

Mathematical Physics-III

Complex Variables

Importance of Complex Numbers and their Graphical Representation. De-Moivre's Theorem. Roots of Complex Numbers. Euler's Formula. Functions of Complex Variables. Examples. Cauchy-Riemann Conditions. Analytic Functions. Singularities. Differentiation and Integral Formula. Morera's Theorem, Cauchy's Inequality. Liouville's Theorem. Fundamental Theorem of Algebra. Multiple Valued Functions. Simple Ideas of Branch Points and Riemann Surfaces.

Power Series of a Complex Variable. Taylor and Laurent Series.

Residue and Residue Theorem. Contour Integration and its Applications to Evaluation of Integrals.

Second Order Differential Equations and Special Functions

Series Solution of Linear Second Order Ordinary Differential Equations : Singular Points of Second Order Differential Equations and their Importance. Series Methods (Frobenius). Legendre, Bessel, Hermite and Laguerre Differential Equations.

Legendre, Hermite and Laguerre Polynomials : Rodrigues' Formulae, Generating Functions, Recurrence Relations, Orthogonality. Series Expansion of a Function in terms of a Complete Set of Legendre Functions. Bessel Functions: First and Second Kind, Generating Function, Recurrence Formulas, Zeros of Bessel Functions and Orthogonality.

Thermal Physics

Thermodynamics

Zeroth and First Law of Thermodynamics :- Thermodynamical Equilibrium. Zeroth Law of Thermodynamics and Concept of Temperature. Work and Heat Energy. State Functions. First Law of Thermodynamics. Differential form of First Law. Internal Energy. First Law and Various Processes. Applications of First Law : General Relation between Cp and Cv. Work Done during Isothermal and Adiabatic Processes. Compressibility and Expansion Coefficient. Atmosphere and Adiabatic Lapse Rate.

Second Law of Thermodynamics:- Reversible and Irreversible Changes. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot Cycle. Carnot Engine and its Efficiency. Refrigerator and its Efficiency. Second Law of Thermodynamics : Kelvin-Planck and Clausius Statements and their Equivalence. Carnot Theorem. Applications of Second Law of Thermodynamics : Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

Entropy:-. Change in Entropy. Entropy of a State. Clausius Theorem. Clausius Inequality. Second Law of Thermodynamics in terms of Entropy. Entropy of a Perfect Gas. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Impossibility of Attainability of Absolute Zero : Third Law of Thermodynamics. Temperature-Entropy Diagrams. First and second order Phase Transitions.

Thermodynamic Potentials:- Extensive and Intensive Thermodynamic Variables. Thermodynamic Potentials U, H, F and G : Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work. Cooling due to Adiabatic Memagnetization. Approach to Absolute Zero.

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

Kinetic Theory of Gases

Distribution of Velocities:- Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's

Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific Heats of Gases.

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

Real Gases: Behavior of Real Gases:- Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. p-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling.

Second Year: Semester-4

Mathematical Physics-IV

Linear Vector Spaces

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

Matrices

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

Eigen-values and Eigenvectors. Cayley- Hamiliton Theorem. Diagonalization of Matrices. Solutions of Coupled Linear Ordinary Differential Equations. Bilinear and Quadratic Forms. Functions of a Matrix.

Partial Differential Equations

General Solution of Wave Equation in 1 Dimension. Transverse Vibrations of Stretched Strings. Oscillations of Hanging Chain. Wave Equation in 2 and 3 Dimensions. Vibrations of Rectangular and Circular Membranes.

Heat Flow in One, Two, and Three Dimensions. Heat Flow in Rectangular Systems of Finite Boundaries. Temperature inside Circular Plate. Laplace Equation in Cartesian, Cylindrical and Spherical Coordinate Systems. Problems of Steady Flow of Heat in Rectangular and Circular Plate.

Optics

Geometrical Optics

Fermat's Principle:- Optical Path. Fermat's Principle of Least Time or Extremum Path. Examples of Fermat's Principle:- (1) Reflection and (2) Refraction.

Lenses:- Transverse Magnification of a Spherically Refracting Surface. Lagrange and Helmholtz Laws of Magnification. Cardinal Points of a Coaxial Optical System. Graphical Construction of Image using Cardinal Points. Deviation produced by a Thin Lens. Equivalent Focal Length of Two Thin Lenses separated by a distance. Cardinal Points of a Coaxial System of Two Thin Lenses. Thick Lenses. Focal Length of a Thick Lens. Variation of Focal Length of a Convex Lens with Thickness. Cardinal Points of a Thick Lens.

Wave Optics

Nature of Light:- Theories of Light. Electromagnetic Nature of Light Definition of a Wave Front. Propagation of a Wave Front. Huygens Principle of Secondary Wavelets.

Interference

Interference: Division of Amplitude and Division of Wavefront. Young's Double Slit Experiment. Lloyd's Mirror and Fresnel's Biprism. Phase Change on Reflection : Stoke's treatment.. Interference in Thin Films : Parallel and Wedge-shaped Films. Fringes of Equal Inclination (Haidinger Fringes) and Fringes of Equal Thickness (Fizeau Fringes). Newton's Rings : Measurement of Wavelength and Refractive Index.

Michelson's Interferometer:- (1) Idea of form of fringes (No Theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, (5) Standardization of Meter and (6) Visibility of Fringes.

Coherence:- Temporal and Spatial Coherence. Theory of Partial Coherence. Coherence Time and Coherence Length. Purity of a Spectrum Line.

Diffraction

Fresnel diffraction:- Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Comparison of a Zone plate with a Convex lens. Diffraction due to (1) a Straight Edge and (2) a Rectangular Aperture (Slit), (3) a Small Circular Aperture and (4) an Oopaque Circular Disc. Fresnel's Integrals, Cornu's Spiral: Fresnel Diffraction Pattern due to (1) a Straight Edge, (2) a Slit, and (3) a Wire (Qualitatively using Cornu's Spiral).

Fraunhofer diffraction: Diffraction due to (1) a Single Slit, (2) a Double Slit and (3) a Plane Transmission Grating. Rayleigh's criterion of resolution. Resolving Power and Dispersive Power of a Plane Diffraction Grating.

Holography: Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves.

Third Year: Semester-5

Mathematical Physics-V

Integral Transforms

Fourier Transforms (FTs):- Fourier Integral Theorem. Sine and Cosine Transforms. Properties of FTs: (1) FTs of Derivatives of Functions, (2) Change of Scale Theorem, (3) FTs of Complex Conjugates of Functions, (4) Shifting Theorem, (5) Modulation Theorem, (6) Convolution Theorems, and (7) Parseval's Identity.

Laplace Transforms (LTs) :- Existence Theorem. LTs of Elementary Functions. Properties of LTs : (1) Change of Scale Theorem, (2) Shifting Theorem, (3) LTs of Derivatives and Integrals of Functions, (4) Derivatives and Integrals of LTs, (5) LT of Unit Step function, (6) LTs of Periodic Functions, and (6) Convolution Theorem. Inverse LT (Bromwich Integral).

Applications of Laplace Transforms :- (1) Solution of First and Second Order ODEs, (2) Solution of Simultaneous First Order ODEs, (3) Solution of One-Dimensional PDEs : Wave and Diffusion Equations, (4) Evaluation of Definite Integrals.

Dirac Delta Function

Definition, Representation and Properties of Dirac Delta Function. Fourier and Laplace Transforms.

Cartesian Tensors

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

General Tensors

Transformation of Co-ordinates. Contravariant and Covariant Vectors. Contravariant, Covariant and Mixed Tensors. Kronecker Delta and Permutation Tensors. Algebra of Tensors. Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Metric Tensor. Reciprocal Tensors. Associated Tensors. Christoffel Symbols of First and Second Kind and their Transformation Laws. Covariant Derivative. Tensor Form of Gradient, Divergence and Curl.

Quantum Mechanics

Particles and Waves

Inadequacies in Classical Physics. Blackbody Radiation : Quantum Theory of Light. Photoelectric Effect. Compton Effect. Franck-Hertz experiment. Wave Nature of Matter : De Broglie Hypothesis. Wave-Particle Duality. 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.

Heisenberg's Uncertainty Principle (Uncertainty Relations involving Canonical Pair of Variables): Derivation from Wave Packets. γ-ray Microscope.

Quantum Mechanics

Basic Postulates and Formalism :- Energy, Momentum and Hamiltonian Operators. Time-independent Schrodinger Wave Equation for Stationary States. Properties of Wave Function. Interpretation of Wave Function. Probability Density and Probability. Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Expectation Values. Wave Function of a Free Particle.

Applications of Schrödinger Wave Equation:

Eigen Functions and Eigenvalues for a Particle in a One Dimensional Box.

Bound State Problems :- General Features of a Bound Particle System, (1) One Dimensional Simple Harmonic Oscillator : Energy Levels and Wave Functions. Zero Point Energy, (2) Quantum Theory of Hydrogen Atom : Particle in a Spherically Symmetric Potential. Schrodinger Equation. Separation of Variables. Radial Solutions and Principal Quantum Number, Orbital and Magnetic Quantum Numbers. Quantization of Energy and Angular Momentum. Space Quantization. Electron Probability Density. Radiative Transitions. Selection Rules.

Scattering Problems in One Dimension :- (1) Finite Potential Step : Reflection and Transmission. Stationary Solutions. Probability Current. Attractive and Repulsive Potential Barriers. (2) Quantum Phenomenon of Tunneling : Tunnel Effect. Tunnel Diode (Qualitative Description). (3) Finite Potential Well (Square Well).

Atomic and Molecular Physics

Determination of e/m of the Electron. Thermionic Emission. Isotopes and Isobars.

X-rays :- Ionizing Power, X-ray Diffraction, Bragg's Law. Bohr Atomic Model, Critical Potentials, X-rays-Spectra: Continuous and Characteristic X-rays, Moseley Law.

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

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

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

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

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

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.

Electronic Devices

Circuit Analysis:- Kirchhoff's Laws, Mesh and Node Analysis of dc and ac Circuits, Duality in Networks, Equivalent Star (T) and delta (π) Networks of a Given Network, Star to Delta and Delta to Star Conversion. Wheatstone Bridge and its Applications to Wein Bridge and Anderson Bridge.

Semiconductor Diodes :– p and n Type Semiconductors. Energy Level Diagram. Conductivity and Mobility. pn Junction Fabrication (Simple Idea). Barrier Formation in pn

Junction Diode. Current Flow Mechanism in Forward and Reverse Biased Diode (Recombination, Drift and Saturation of Drift Velocity). Derivation of Mathematical Equations for Barrier Potential, Barrier Width and Current for Step Junction. pn junction and its characteristics. Static and Dynamic Resistance. Diode Equivalent Circuit. Ideal Diode. Load Line Analysis of Diodes. Load Line and Q-point.

Two-terminal Devices and their Applications :- (1) Rectifier Diode. Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification Efficiency. Qualitative idea of C, L and π - Filters. (2) Zener Diode and Voltage Regulation. (3) Photo Diode, (4) Tunnel Diode, (5) LED (6) Varactor Diode.

Bipolar Junction transistors :- n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Current gains α, β and γ and Relations between them. Load Line Analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff, and Saturation Regions. Transistor in Active Region and Equivalent Circuit.

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

Coupled Amplifiers :- RC-Coupled Amplifier and its Frequency Response of Voltage Gain.

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

Sinusoidal Oscillators:- Barkhauson's Criterion for Self-sustained Oscillations. RC Phase Shift Oscillator, Determination of Frequency. Hartley Oscillator. Colpitts Oscillator.

Non-Sinusoidal Oscillators – Astable and Monostable Multivibrators.

Three-terminal Devices (UJT and FETs) :- (1) UJT : Its Chararacteristics and Equivalent Circuit. Relaxation Oscillator, (2) JEFT : Its Characteristics and Equivalent Circuit. Advantages of JFET. MOSFET (Qualtiative Discussion only).

Modulation and Demodulation:- Types of Modulation. Amplitude Modulation. Modulation Index. Analysis of Amplitude Modulated Wave. Sideband Frequencies in AM Wave. CE Amplitude Modulator. Demodulation of AM Wave using Diode Detector. Idea of Frequency, Phase, and Digital Modulation.

Third Year: Semester-6

Electromagnetic Theory

Maxwell's Equations

Maxwell 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 Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density.

Reflection and Refraction of Electromagnetic Waves

Reflection and Refraction of a Plane Wave at a Plane Interface between Dielectics. Fresnel Formulae. Total Internal Reflection. Brewster's Angle. Waves in Conducting Media. Metallic Reflection (Normal Incidence). Skin Depth. Maxwell's Equations in Microscopic Media (Plasma). Characteristic Plasma Frequency. Refractive Index. Conductivity of an Ionized Gas. Propagation of e.m. Waves in Ionosphere.

Polarization of Electromagnetic Waves

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

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

Wave Guides

Planar Optical Wave Guides. Planar Dielectric Wave Guide. Condition of Continuity at Interface. Phae Shift on Total Reflection. Einenvalue Equations. Phase and Group Velocity of the Guided Waves. Field Energy and Power Transmission.

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

Statistical Physics

Classical Statistics

Entropy and Thermodynamic Probability. Maxwell-Boltzmann Distribution Law. Ensemble Concept. Partition Function. Thermodynamic Functions of Finite Number of Energy Levels. Negative Temperature. Thermodynamic Functions of an Ideal Gas. Classical Entropy Expression, Gibbs Paradox. Law of Equipartition of Energy – Applications to Specific Heat and its Limitations.

Classical Theory of Radiation

Properties of Thermal Radiation. Blackbody Radiation. Pure Temperature Dependence. Kirchhoff's Law. Stefan-Boltzmann Law and Wien's Displacement law. Saha's Ionization Formula.

Quantum Theory of Radiation

Radiation:- Stefan-Boltzmann Law: Thermodynamic Proof. Radiation Pressure. Spectral Distribution of Black Body Radiation. Wien's Distribution Law and Displacement Law. Rayleigh-Jean's Law. Ultraviolet Catastrophe. 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 and (4) Wien's Displacement Law from Planck's Law.

Bose-Einstein Statistics

B-E distribution law. Thermodynamic functions of a Completely Degenerate Bose Gas. Bose-Einstein condensation, properties of liquid He (qualitative description). Radiation as photon gas. Bose's derivation of Planck's law.

Fermi-Dirac Statistics

Fermi-Dirac Distribution Law. Thermodynamic functions of an ideal Completely Degenerate Fermi Gas. Fermi Energy. Electron gas in a Metal. Specific Heat of Metals. White Dwarf Stars. Chandrasekhar Mass Limit.

Solid State Physics

Crystal Structure

Solids :- Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis – Central and Non-Central Elements. Unit Cell. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Types of Bonds. Ionic Bond. Covalent Bond. Van der Waals Bond. Diffraction of x-rays by Crystals. Bragg's Law.

Elementary Lattice Dynamics

Lattice Vibrations and Phonons :- Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Einstein and Debye Theories of Specific Heat of Solids. $T3$ Law.

Magnetic Properties of Matter

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

Dielectric Properties of Materials

Polarization. Local Electric Field at an Atom. Depolarization Field. Dielectric Constant. Electric Susceptibility. Polarizability. Classical Theory of Electric Polarizability. Clausius-Mosotti Equation. Normal and Anomalous Dispersion. Complex Dielectric Constant.

Electrical Properties of Materials

Elementary Band Theory of Solids. Bloch Theorm. Kronig-Penney Model. Effective Mass of Electron. Concept of Holes. Band Gaps. Energy Band Diagram and Classification of Solids. Law of Mass Action. Insulators, and Semiconductors. Direct and Indirect Band Gap. Intrinsic and Extrinsic Semiconductors. p- and n- Type Semiconductors. Conductivity in Semiconductors. Hall Effect in Semiconductors (Qualitative Discussion Only)

Superconductivity

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth.

Isotope effect. Idea of BCS theory (No derivation): Cooper Pair and Coherence length. Variation of Superconducting Energy Gap with Temperature. Experimental Evidence of Phonons. Josephson Effect.

Nuclear and Particle Physics

Structure of nuclei:- Basic Properties of Nuclei: (1) Mass, (2) Radii, (3) Charge, (4) Angular Momentum, (5) Spin, (5) Magnetic Moment (μ), (6) Stability and (7) Binding Energy.

Radioactivity:- Law of Radioactive Decay. Half-life, Theory of Successive Radioactive Transformations. Radioactive Series, Binding Energy, Mass Formula.

α-decay:- Range of α-particles, Geiger-Nuttal law and α-particle Spectra. Gamow Theory of Alpha Decay.

β-decay:- Energy Spectra and Neutrino Hypothesis.

γ-decay:- Origin of γ-rays, Nuclear Isomerism and Internal Conversion.

Nuclear Reactions :- Types of Reactions and Conservation Laws. Concept of Compound and Direct Reaction. Compound Nucleus. Scattering Problem in One Dimension : Reflection and Transmission by a Finite Potential Step. Stationary Solutions, Attractive and Repulsive Potential Barriers. Scattering Cross-section. Reaction Rate. Q-value of Reaction. Fission and Fusion.

Nuclear Models:- Liquid Drop Model. Mass formula. Shell Model. Meson Theory of Nuclear Forces and Discovery of Pion.

Accelerators:- Van de Graaff Generator, Linear Accelerator, Cyclotron, Betatron, and Light and Heavy Ion Synchro-Cyclotron. Idea of Large Hadron Collider.

Detectors of Nuclear Radiations:- Interaction of Energetic particles with matter. Ionization chamber. GM Counter. Cloud Chambers. Wilson Cloud Chamber. Bubble Chamber. Scintillatipn Detectors. Semiconductor Detectors (Qualitative Discussion Only). An Idea about Detectors used in Large Hadron Collider. Cosmic Rays:- Nature and Properties.

Elementary Particles (Qualitative Discussion Only):- Fundamental Interactions. Classification of Elementary Particles. Particles and Antiparticles. Baryons, Hyperons,

Leptons, and Mesons. Elementary Particle Quantum Numbers: Baryon Number, Lepton Number, Strangeness, Electric Charge, Hypercharge and Isospin. Eightfold way: Super-multiplets of Mesons and Baryons. Conservation Laws and Symmetry. Different Types of Quarks and Quark Contents of Spin. Baryons. Photons, Gravitons, Gluons, Charms and Intermediate Vector Bosons. Idea of Standard Model. Higg's Boson.