

ANNEXURE I: SYLLABI FOR TEST PAPERS

BIOTECHNOLOGY (BT)

The Biotechnology (BT) Test Paper comprises Biology, Chemistry, Mathematics and Physics.

BIOLOGY (10+2+3 level)

Cell Biology: Structure of prokaryotic and eukaryotic cells; Membrane structure and function; Organelles and internal organization of the eukaryotic cell Protein trafficking in a eukaryotic cell; Cell communication – signalling pathways: endocrine and paracrine signalling; Extracellular matrix and apoptosis; Cell cycle – stages of mitosis and meiosis, and control of cell division cycle.

Biochemistry: Structure and function of biological macromolecules; Allostery; Enzymes – basic mechanisms of enzyme catalysis, Michaelis-Menten kinetics, enzyme inhibition, vitamins as coenzymes, and regulation; Bioenergetics – free-energy change, high-energy compounds, biological oxidation-reduction reactions and reduction potential; Metabolism – glycolysis, TCA cycle, oxidative phosphorylation, photosynthesis, nitrogen fixation, urea cycle, and regulation of glycolysis and TCA cycle.

Genetics: Mendel's laws; Inheritance patterns of polygenic traits; Mendelian inheritance patterns of human disorders; Pedigree analysis; Chromosomal basis of inheritance; Genetic recombination; Mapping genes on chromosomes based on linkage analysis; Plant breeding.

Molecular Biology: Landmark experiments that established DNA is the genetic material; DNA replication; Proof-reading and repair of DNA; DNA recombination; Transcription; RNA processing; Translation; Regulation of gene expression including operons bacteria and differential gene expression in multicellular eukaryotes.

Evolution: Darwinian view – natural selection, fossil record and descent with modification; Population genetics – sources of genetic variation, gene pools and allele frequencies, Hardy-Weinberg equation, genetic drift, gene flow and adaptive evolution; Different types of speciation; Phylogenetic classification; Origin of life – abiotic synthesis of biological macromolecules, protocell, dating fossils and origin of multicellularity.

Microbiology: Isolation; Cultivation; Structural features of viruses, bacteria, fungi and protozoa; Pathogenic microorganisms; Nutrition-based classification of microbes; Microbial metabolism; Growth kinetics; Submerged fermentation techniques; Microbial genetics.

Plant Biology: Types of tissues and organs; Primary and secondary growth; Morphogenesis; Transport in vascular plants; Plant nutrition; Development of flowering plants – gametophytic and sporophytic generations, different developmental phases, genetic control of flowering, gametogenesis, incompatibility, embryogenesis, dormancy, germination and environmental influence; Plant hormones; Photobiology; Plant response to biotic and abiotic stresses

Animal Biology: Digestive, circulatory, respiratory, excretory, nervous, reproductive and endocrine systems; Basics of immunology – Innate and adaptive immunity, Immune cells and Immunoglobulins; Animal development – Fertilization, embryonic pattern formation, cleavage, gastrulation, cellular differentiation and morphogenesis.

Ecology: Climate patterns; Terrestrial and aquatic biomes; Environmental constraints on species distribution; Factors affecting population density; Interactions among communities; Ecosystems; Ecological remediation.

Biotechnology: Plant tissue culture; Cloning of animals through somatic cell nuclear transfer; Applications of recombinant DNA technology in medicine, agriculture and forensic science.

Methods in Biology:

Cell Biology: Microscopy (light microscopy and electron microscopy); staining proteins with antibodies; Visualizations using the GFP reporter.

Biochemical techniques: UV spectrophotometry; Biomolecular chromatography; cell Fractionation by centrifugation; Electrophoresis; and Western blotting.

Molecular biology techniques: DNA cloning – plasmid vectors, and restriction enzymes; Polymerase Chain Reaction; Expression of cloned eukaryotic genes in bacteria; Hybridization techniques; DNA sequencing.

CHEMISTRY (10+2+3 level)

Structure and properties of Atoms: Bohr's theory; Periodicity in properties.

Bonding in molecules: Chemical bonding; Complex formation; Physical and chemical basis of molecular interactions.

Chemical kinetics, thermodynamics, and equilibrium: Chemical equilibrium; Chemical Thermodynamics (first and second law); and Chemical kinetics (zero and first order reactions).

Physical and chemical properties of compounds: Chemical catalysis; Acid-base concepts; Concepts of pH and buffer; Conjugative effects and resonance; Inductive effects; Electromeric effects; Photochemistry; and Electrochemistry.

Chemistry of organic compounds: Hydrocarbons; Alkyl halides; Alcohols; Aldehydes; Ketones; Carboxylic acids; Amines and their derivatives; Aromatic hydrocarbons, halides, nitro and amino compounds, phenols, diazonium salts, carboxylic and sulphonic acids; Soaps and detergents; Stereochemistry of carbon compounds.

Instrumental techniques - Spectroscopy: fundamentals of molecular spectroscopy, emission and absorption spectroscopy, UV-Vis, IR and 1-D proton NMR spectroscopy, basics of mass spectrometry; Basics of calorimetry; Basic concepts of crystallography.

MATHEMATICS (10+2 level)

Sets; Relations and Functions; Mathematical Induction; Logarithms; Complex numbers; Linear and Quadratic equations; Sequences and Series; Trigonometry; Cartesian System of Rectangular Coordinates; Straight lines and Family; Three Dimensional Geometry; Permutations and Combinations; Binomial Theorem; Vectors; Matrices and Determinants; Boolean Algebra; Functions; Limits and Continuity; Differentiation; Ordinary Differential Equations; Application of Derivatives; Integration as inverse process of differentiation; Definite and indefinite integrals; Methods of Integration; Integration by parts.

Statistics: Measures of dispersion; Mean Deviation for grouped and ungrouped data; Variance and Standard Deviation; and Analysis of Frequency Distribution.

Probability: Random Experiments; Event; Axiomatic Approach to Probability; Conditional Probability and its properties; Multiplication Theorem on Probability; Independent Events; Bayes' Theorem; Random Variables and its Probability Distributions; Bernoulli Trails and Binomial Distributions.

PHYSICS (10+2 level)

Units and measurements; Motion in one and two dimensions; Laws of motion; Work and kinetic energy; Conservation of energy; System of particles and rotational motion; Mechanical properties of solids and fluids; Thermal properties of matter; Heat and laws of thermodynamics; Kinetic theory of gases; Electric charge and field; Electric potential and capacitance; Current, resistance and simple circuits; Moving charges and magnetic field; Magnetism and matter; Electromagnetic induction; Electromagnetic waves; Alternating currents; Optics: Geometrical Optics – Reflection by spherical mirrors, Refraction at spherical surfaces and lenses, Total internal reflection and Optical instruments; Wave optics – Reflection and refraction of plane waves, Interference, Diffraction, Polarization, and Young's experiment: Dual nature of radiation and matter; Atoms, nuclei and nuclear physics; Semiconductor materials, devices and simple circuits.

CHEMISTRY (CY)

Basic Mathematical Concepts (10+2 Level):

Functions; maxima and minima; integrals; ordinary differential equations; vectors and matrices; determinants; elementary statistics.

Physical Chemistry

Atomic and Molecular Structure:

Planck's black body radiation, Photoelectric effect, Bohr's theory, de Broglie postulate, Heisenberg's Uncertainty Principle; Schrödinger's wave equation (including mathematical treatment), postulates of quantum mechanics, normalized and orthogonal wave functions, its complex conjugate (idea of complex numbers) and significance of Ψ^2 ; Operators; Particle in one- dimension box, radial and angular wave functions for hydrogen atom, radial probability distribution; Finding maxima of distribution functions (idea of maxima and minima), energy spectrum of hydrogen atom; Shapes of s, p, d and f orbitals; Pauli's Exclusion Principle; Hund's rule of maximum multiplicity.

Gaseous State:

Kinetic molecular model of a gas: collision frequency; collision diameter; mean free path and viscosity of gases; Maxwell-Boltzmann distribution: molecular velocities, law of equipartition of energy, molecular basis of heat capacities; Ideal gases, and deviations from ideal gas behaviour, van der Waals equation of state; critical state, law of corresponding states.

Liquid State:

Physical properties of Liquid, vapour pressure, surface tension and co-efficient of viscosity and their applications; effect of concentration of solutes on surface tension and viscosity; effect of temperature on viscosity of liquids.

Solid State:

Unit Cells, Miller indices, crystal systems and Bravais Lattices, elementary applications of vectors to crystal systems; X-ray diffraction, Bragg's Law, Structure of NaCl, CsCl, and KCl, diamond, and graphite; Close packing in metals and metal compounds, semiconductors, insulators; Defects in crystals, lattice energy; isomorphism; heat capacity of solids.

Chemical Thermodynamics:

Mathematical treatment: Exact and in-exact differentials, partial derivatives, Euler's reciprocity, cyclic rule; Reversible and irreversible processes; Laws of thermodynamics, thermochemistry, thermodynamic functions, such as enthalpy, entropy, and Gibbs free energy, their properties and applications; Partial molar quantities, dependence of thermodynamic parameters on composition, Gibbs Duhem equation, chemical potential and its applications.

Chemical and Phase Equilibria:

Law of mass action; K_p , K_c , K_x and K_n ; Effect of temperature on K; Le-Chatelier principle; Ionic equilibria in solutions; pH and buffer solutions; Salt hydrolysis; Solubility and solubility product; Acid – base titration curves; Indicators; Dilute solutions; Raoult's and Henry's Laws and their applications; Colligative properties; Gibbs phase rule; Phase equilibria; single and two- component phase diagrams.

Electrochemistry:

Conductivity, equivalent and molar conductivity and their properties; Kohlrausch law; Debye-Hückel-Onsager equation; Ionic velocities, mobilities, transference numbers; Applications of conductance measurement; Quantitative aspects of Faraday's laws of electrolysis, applications of electrolysis in metallurgy and industry; Electromotive force of a cell, Nernst equation; Standard electrode potential, Electrochemical series; Concentration cells with and without transference; Applications of EMF measurements including potentiometric titrations.

Chemical Kinetics:

Order and molecularity of a reaction, differential and integrated form of rate expressions; Kinetics of opposing, parallel, and consecutive reactions; Steady state approximation in reaction mechanisms; Chain reactions; Uni-molecular reaction (Lindemann mechanism); Temperature dependence of reaction rates, Arrhenius equation; activation energy; Collision theory of reaction rates; Types of catalysts, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; Enzyme catalysis (Michaelis-Menten mechanism, Double reciprocal plot), Acid-base catalysis.

Adsorption:

Gibbs adsorption equation; adsorption isotherm; types of adsorption; surface area of adsorbents; surface films on liquids.

Spectroscopy:

Beer-Lambert's law; fundamental concepts of rotational, vibrational, electronic and magnetic resonance spectroscopy.

Organic Chemistry

Basic Concepts in Organic Chemistry and Stereochemistry:

Electronic effects (resonance, inductive, hyperconjugation) and steric effects and its applications (acid/base property); optical isomerism in compounds with and without any stereocenters (allenes, biphenyls); conformation of acyclic systems (substituted ethane/n-propane/n-butane) and cyclic systems, substituted cyclohexanes, and polycyclic (*cis* and *trans* decalins) systems.

Organic Reaction Mechanism and Synthetic Applications:

Chemistry of reactive intermediates (carbocations, carbanions, free radicals, carbenes, nitrenes, benzyne); nucleophilic substitution, elimination reactions and mechanisms; Hofmann-Curtius-Lossen rearrangement, Wolff rearrangement, Simmons-Smith reaction, Reimer-Tiemann reaction, Michael reaction, Darzens reaction, Wittig reaction and McMurry reaction; Pinacolpinacolone, Favorskii, benzilic acid rearrangement, Baeyer-Villiger reaction; oxidation and reduction reactions in organic chemistry; Organometallic reagents in organic synthesis (Grignard, organolithium, organocopper and organozinc (Reformatsky only)); Diels-Alder, electrocyclic and sigmatropic reactions; functional group inter-conversions and structural problems using chemical reactions.

Economics (EN)

Microeconomics

Consumer theory: Preference, utility and representation theorem, budget constraint, choice, demand (ordinary and compensated), Slutsky equation, revealed preference axioms

Theory of production and cost: Production technology, isoquants, production function with one and more inputs, returns to scale, short run and long run costs, cost curves in the short run and long run

General equilibrium and welfare: Equilibrium and efficiency under pure exchange and production, welfare economics, theorems of welfare economics

Market structure: Perfect competition, monopoly, pricing with market power, price discrimination (first, second and third), monopolistic competition and oligopoly

Game theory: Strategic form games, iterated elimination of dominated strategies, Nash equilibrium, mixed extension and mixed strategy Nash equilibrium, examples: Cournot, Bertrand duopolies, Prisoner's dilemma

Public goods and market failure: Externalities, public goods and markets with asymmetric information (adverse selection and moral hazard)

Macroeconomics

National income accounting: Structure, key concepts, measurements, and circular flow of income - for closed and open economy, money, fiscal and foreign sector variables - concepts and measurements

Behavioural and technological functions: Consumption functions - absolute income hypothesis, life-cycle and permanent income hypothesis, random walk model of consumption, investment functions - Keynesian, money demand and supply functions, production function

Business cycles and economic models (closed economy): Business cycles-facts and features, the Classical model of the business cycle, the Keynesian model of the business cycle, simple Keynesian cross model of income and employment determination and the multiplier (in a closed economy), IS-LM Model, Hicks' IS-LM synthesis, role of monetary and fiscal policies

Business cycles and economic models (open economy): Open economy, Mundell- Fleming model, Keynesian flexible price (aggregate demand and aggregate supply) model, role of monetary and fiscal policies

Inflation and unemployment: Inflation - theories, measurement, causes, and effects, unemployment - types, measurement, causes, and effects

Growth models: Harrod-Domar, Solow and Neo-classical growth models (AK model, Romer model and Schumpeterian growth model)

Statistics for Economics

Probability theory: Sample space and events, axioms of probability and their properties, conditional probability and Bayes' rule, independent events, random variables and probability distributions, expectation, variance and higher order moments, functions of random variables, properties of commonly used discrete and continuous distributions, density and distribution functions for jointly distributed random variables, mean and variance of jointly distributed random variables, covariance and correlation coefficients

Mathematical statistics: Random sampling, types of sampling, point and interval estimation, estimation of population parameters using methods of moments and maximum likelihood procedures, properties of estimators, sampling distribution, confidence intervals, central limit theorem, law of large number

Hypothesis testing: distributions of test statistics, testing hypotheses related to population parameters, Type I and Type II errors, the power of a test, tests for comparing parameters from two samples

Correlation and regression: Correlation and types of correlation, the nature of regression analysis, method of Ordinary Least Squares (OLS), CLRM assumptions, properties of OLS, goodness of fit, variance and covariance of OLS estimator

Indian Economy

Indian economy before 1950: Transfer of tribute, deindustrialization of India

Planning and Indian development: Planning models, relation between agricultural and industrial growth, challenges faced by Indian planning

Indian economy after 1991: Balance of payments crisis in 1991, major aspects of economic reforms in India after 1991, reforms in trade and foreign investment

Banking, finance and macroeconomic policies: aspects of banking in India, CRR and SLR, financial sector reforms in India, fiscal and monetary policy, savings and investment rates in India

Inequalities in social development: India's achievements in health, education and other social sectors, disparities between Indian States in human development

Poverty: Methodology of poverty estimation, Issues in poverty estimation in India **India's labour**

market: unemployment, labour force participation rates

Mathematics for Economics

Preliminaries and functions: Set theory and number theory, elementary functions: quadratic, polynomial, power, exponential, logarithmic, functions of several variables, graphs and level curves, convex set, concavity and quasiconcavity of function, convexity and quasi-convexity of functions, sequences and series: convergence, algebraic properties and applications, complex numbers and its geometrical representation, De Moivre's theorem and its application

Differential calculus: Limits, continuity and differentiability, mean value theorems, Taylor's theorem, partial differentiation, gradient, chain rule, second and higher order derivatives: properties and applications, implicit function theorem, and application to comparative statics problems, homogeneous and homothetic functions: characterisations and applications

Integral calculus: Definite integrals, fundamental theorems, indefinite integrals and applications

Differential equations, and difference equations: First order difference equations, first order differential equations and applications

Linear algebra: Matrix representations and elementary operations, systems of linear equations: properties of their solution, linear independence and dependence, rank, determinants, eigenvectors and eigenvalues of square matrices, symmetric matrices and quadratic forms, definiteness and semidefiniteness of quadratic forms

Optimization: Local and global optima: geometric and calculus-based characterisations, and applications, multivariate optimization, constrained optimization and method of Lagrange multiplier, second order condition of optima, definiteness and optimality, properties of value function: envelope theorem and applications, linear programming: graphical solution, matrix formulation, duality, economic interpretation.

GEOLOGY (GG)

The Planet Earth: Origin of the Solar System and the Earth; Geosphere and the composition of the Earth; Shape and size of the Earth; Earth-Moon system; Dating rocks and age of the Earth; Volcanism and volcanic landforms; Interior of the Earth; Earthquakes; Earth's magnetism and gravity, Isostasy; Basic elements of Plate Tectonics; Orogenic cycles.

Geomorphology: Weathering and erosion; Soil formation; Transportation and deposition by wind, ice, river, sea and resulting landforms.

Structural Geology: Orientation of planes and lines in space – concept of dip, strike, rake and plunge. Contour lines; Rule of 'V's and outcrop patterns; Interpretation of geological maps and cross-section construction; Classification and origin of folds, faults, joints, unconformities, foliations and lineations; Stereographic and equal-area projections of planes and lines; Numerical problems related to outcrop and bore-hole data.

Paleontology: Major steps in the evolution of life forms; Fossils, their mode of preservation and utility in age determination and paleoenvironmental interpretations; Morphology, major evolutionary trends and ages of important groups of animals – Brachiopoda, Mollusca, Trilobita, Graptolitoidea, Anthozoa, Echinodermata; Gondwana plant fossils; Elementary idea of vertebrate fossils in India.

Stratigraphy: Principles of stratigraphy; Litho-, Chrono- and biostratigraphic classification; Stratigraphic correlation techniques; Archaean cratons of Peninsular India (Dharwar, Singhbhum and Aravalli); Proterozoic mobile belts; Stratigraphy of Cuddapah and Vindhyan basins; Stratigraphy of Paleozoic – Mesozoic of Spiti and Kashmir, Gondwana Supergroup, Jurassic of Kutch, Cretaceous of Trichinopoly, Tertiary and Quaternary sequences of Assam, Bengal and Siwaliks.

Mineralogy: Symmetry and forms in common crystal classes; Physical properties of minerals; Isomorphism, polymorphism, solid solution and exsolution; Classification of minerals; Structure of silicates; Mineralogy of common rock-forming minerals; Elements of Optical Mineralogy, Optical properties of common rock-forming minerals.

Petrology: Definition and classification of rocks; Igneous rocks – forms of igneous bodies; Processes of evolution and diversification of magma; Classification, association, and genesis of common igneous rocks. Sedimentary rocks – classification, texture, and structure; Petrology of sandstone and limestone; Elements of sedimentary environments and facies. Metamorphic rocks – classification and texture; Types of metamorphism; Controls on metamorphism – pressure, temperature and fluids; Concept of projections – ACF, AKF and AFM diagrams; Phase Rule and its applications; Concepts of zones and facies, Characteristic mineral assemblages of pelites in the Barrovian zones and mafic rocks in common facies.

Economic Geology: Physical properties of common economic minerals; General processes of formation of mineral deposits; Mode of occurrence and distribution of metallic and non-metallic mineral deposits in India; Fundamentals of reserve calculation; Elements of coal and hydrocarbon geology, Coal and hydrocarbon occurrences in India.

Applied Geology: Groundwater and hydrological cycle, Types of aquifers, porosity and permeability; Principles of engineering geology; Geological considerations in construction of dams and tunnels.

MATHEMATICS (MA)

Real Analysis:

Sequences and Series of Real Numbers: convergence of sequences, bounded and monotone sequences, Cauchy sequences, Bolzano-Weierstrass theorem, absolute convergence, tests of convergence for series – comparison test, ratio test, root test; Power series (of one real variable), radius and interval of convergence, term-wise differentiation and integration of power series.

Functions of One Real Variable: limit, continuity, intermediate value property, differentiation, Rolle's Theorem, mean value theorem, L'Hospital rule, Taylor's theorem, Taylor's series, maxima and minima, Riemann integration (definite integrals and their properties), fundamental theorem of calculus.

Multivariable Calculus and Differential Equations:

Functions of Two or Three Real Variables: limit, continuity, partial derivatives, total derivative, Maxima and minima.

Integral Calculus: double and triple integrals, change of order of integration, calculating surface areas and volumes using double integrals, calculating volumes using triple integrals.

Differential Equations: Bernoulli's equation, exact differential equations, integrating factors, orthogonal trajectories, homogeneous differential equations, method of separation of variables, linear differential equations of second order with constant coefficients, method of variation of parameters, Cauchy-Euler equation.

Linear Algebra and Algebra:

Matrices: systems of linear equations, rank, nullity, rank-nullity theorem, inverse, determinant, eigenvalues, eigenvectors.

Finite Dimensional Vector Spaces: linear independence of vectors, basis, dimension, linear transformations, matrix representation, range space, null space, rank-nullity theorem.

Groups: cyclic groups, abelian groups, non-abelian groups, permutation groups, normal subgroups, quotient groups, Lagrange's theorem for finite groups, group homomorphisms.

MATHEMATICAL STATISTICS (MS)

The Mathematical Statistics (MS) Test Paper comprises following topics of Mathematics (about 30% weight) and Statistics (about 70% weight).

Mathematics

Sequences and Series of real numbers: Sequences of real numbers, their convergence, and limits. Cauchy sequences and their convergence. Monotonic sequences and their limits. Limits of standard sequences. Infinite series and its convergence, and divergence. Convergence of series with non-negative terms. Tests for convergence and divergence of a series. Comparison test, limit comparison test, D'Alembert's ratio test, Cauchy's n^t root test, Cauchy's condensation test and Integral test. Absolute convergence of series. Leibnitz's test for the convergence of alternating Series. Conditional convergence. Convergence of power series and radius of convergence.

Differential Calculus of one and two real variables: Limits of functions of one real variable. Continuity and differentiability of functions of one real variable. Properties of continuous and differentiable functions of one real variable. Rolle's Theorem and Lagrange's mean value theorems. Higher order derivatives, Leibnitz's rule and its applications. Taylor's theorem with Lagrange's and Cauchy's form of remainders. Taylor's and Maclaurin's series of standard functions. Indeterminate forms and L' Hospital's rule. Maxima and minima of functions of one real variable, critical points, local maxima and minima, global maxima and minima, and point of inflection. Limits of functions of two real variables. Continuity and differentiability of functions of two real variables. Properties of continuous and differentiable functions of two real variables. Partial differentiation and total differentiation. Leibnitz's rule for successive differentiation. Maxima and minima of functions of two real variables. Critical points, Hessian matrix, and saddle points. Constrained optimization techniques (with Lagrange multiplier).

Integral Calculus: Fundamental theorems of integral calculus (single integral). Leibnitz's rule and its applications. Differentiation under integral sign. Improper integrals. Beta and Gamma integrals: properties and relationship between them. Double integrals. Change of order of integration. Transformation of variables. Applications of definite integrals. Arc lengths, areas and volumes.

Matrices and Determinants: Vector spaces with real field. Subspaces and sum of subspaces. Span of a set. Linear dependence and independence. Dimension and basis. Algebra of matrices. Standard matrices (Symmetric and Skew Symmetric matrices, Hermitian and Skew Hermitian matrices, Orthogonal and Unitary matrices, Idempotent and Nilpotent matrices). Definition, properties and applications of determinants. Evaluation of determinants using transformations. Determinant of product of matrices. Singular and non-singular matrices and their properties. Trace of a matrix. Adjoint and inverse of a matrix and related properties. Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum and the product of two matrices. Row reduction and echelon forms. Partitioning of matrices and simple properties. Consistent and inconsistent system of linear equations. Properties of solutions of system of linear equations. Use of determinants in solution to the system of linear equations. Cramer's rule. Characteristic roots and Characteristic vectors. Properties of characteristic roots and vectors. Cayley Hamilton theorem.

Statistics

Probability: Random Experiments. Sample Space and Algebra of Events (Event space). Relative frequency and Axiomatic definitions of probability. Properties of probability function. Addition theorem of probability function (inclusion exclusion principle). Geometric probability. Boole's and Bonferroni's inequalities. Conditional probability and Multiplication rule. Theorem of total probability and Bayes' theorem. Pairwise and mutual independence of events.

Univariate Distributions: Definition of random variables. Cumulative distribution function (c.d.f.) of a random variable. Discrete and Continuous random variables. Probability mass function (p.m.f.) and Probability density function (p.d.f.) of a random variable. Distribution (c.d.f., p.m.f., p.d.f.) of a function of a random variable using transformation of variable and Jacobian method. Mathematical expectation and moments. Mean, Median, Mode, Variance, Standard deviation, Coefficient of variation, Quantiles, Quartiles, Coefficient of Variation, and measures of Skewness and Kurtosis of a probability distribution. Moment generating function (m.g.f.), its properties and uniqueness. Markov and Chebyshev inequalities and their applications.

Standard Univariate Distributions: Degenerate, Bernoulli, Binomial, Negative binomial, Geometric, Poisson, Hypergeometric, Uniform, Exponential, Double exponential, Gamma, Beta (of first and second type), Normal and Cauchy distributions, their properties, interrelations, and limiting (approximation) cases.

Multivariate Distributions: Definition of random vectors. Joint and marginal c.d.f.s of a random vector. Discrete and continuous type random vectors. Joint and marginal p.m.f., joint and marginal p.d.f. Conditional c.d.f., conditional p.m.f. and conditional p.d.f. Independence of random variables. Distribution of functions of random vectors using transformation of variables and Jacobian method. Mathematical expectation of functions of random vectors. Joint moments, Covariance and Correlation. Joint moment generating function and its properties. Uniqueness of joint m.g.f. and its applications. Conditional moments, conditional expectations and conditional variance. Additive properties of Binomial, Poisson, Negative Binomial, Gamma and Normal Distributions using their m.g.f.

Standard Multivariate Distributions: Multinomial distribution as a generalization of binomial distribution and its properties (moments, correlation, marginal distributions, additive property). Bivariate normal distribution, its marginal and conditional distributions and related properties.

Limit Theorems: Convergence in probability, convergence in distribution and their inter relations. Weak law of large numbers and Central Limit Theorem (i.i.d. case) and their applications.

Sampling Distributions: Definitions of random sample, parameter and statistic. Sampling distribution of a statistic. Order Statistics: Definition and distribution of the r th order statistic (d.f. and p.d.f. for i.i.d. case for continuous distributions). Distribution (c.d.f., p.m.f., p.d.f.) of smallest and largest order statistics (i.i.d. case for discrete as well as continuous distributions). Central Chi-square distribution: Definition and derivation of p.d.f. of central χ^2 distribution with n degrees of freedom (d.f.) using m.g.f.. Properties of central χ^2 distribution, additive property and limiting form of central χ^2 distribution. Central Student's t -distribution: Definition and derivation of p.d.f. of Central Student's t -distribution with n d.f., Properties and limiting form of central t -distribution. Snedecor's Central F -distribution: Definition and derivation of p.d.f. of Snedecor's Central F -distribution with (m, n) d.f.. Properties of Central F -distribution, distribution of the reciprocal of F -distribution. Relationship between t , F and χ^2 distributions.

Estimation: Unbiasedness. Sufficiency of a statistic. Factorization theorem. Complete statistic. Consistency and relative efficiency of estimators. Uniformly Minimum variance unbiased estimator (UMVUE). Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Cramer-Rao inequality and UMVUEs. **Methods of Estimation:** Method of moments, method of maximum likelihood, invariance of maximum likelihood estimators. Least squares estimation and its applications in simple linear regression models. Confidence intervals and confidence coefficient. Confidence intervals for the parameters of univariate normal, two independent normal, and exponential distributions.

Testing of Hypotheses: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors. Critical region. Level of significance, size and power of a test, p-value. Most powerful critical regions and most powerful (MP) tests. Uniformly most powerful (UMP) tests. Neyman Pearson Lemma (without proof) and its applications to construction of MP and UMP tests for parameter of single parameter parametric families. Likelihood ratio tests for parameters of univariate normal distribution.

PHYSICS (PH)

Mathematical Methods: Calculus of single and multiple variables, partial derivatives, Jacobian, imperfect and perfect differentials, Taylor expansion, Fourier series. Vector algebra, Vector Calculus, Multiple integrals, Divergence theorem, Green's theorem, Stokes' theorem. First order equations and linear second order differential equations with constant coefficients. Matrices and determinants, Algebra of complex numbers.

Mechanics and General Properties of Matter: Newton's laws of motion and applications, Velocity and acceleration in Cartesian, polar and cylindrical coordinate systems, uniformly rotating frame, centrifugal and Coriolis forces, Motion under a central force, Kepler's laws, Gravitational Law and field, Conservative and non-conservative forces. System of particles, Center of mass, equation of motion of the CM, conservation of linear and angular momentum, conservation of energy, variable mass systems. Elastic and inelastic collisions. Rigid body motion, fixed axis rotations, rotation and translation, moments of Inertia and products of Inertia, parallel and perpendicular axes theorem. Principal moments and axes. Kinematics of moving fluids, equation of continuity, Euler's equation, Bernoulli's theorem.

Oscillations, Waves and Optics: Differential equation for simple harmonic oscillator and its general solution. Superposition of two or more simple harmonic oscillators. Lissajous figures. Damped and forced oscillators, resonance. Wave equation, traveling and standing waves in one-dimension. Energy density and energy transmission in waves. Group velocity and phase velocity. Sound waves in media. Doppler Effect. Fermat's Principle. General theory of image formation. Thick lens, thin lens and lens combinations. Interference of light, optical path retardation. Fraunhofer diffraction. Rayleigh criterion and resolving power. Diffraction gratings. Polarization: linear, circular and elliptic polarization. Double refraction and optical rotation.

Electricity and Magnetism: Coulomb's law, Gauss's law. Electric field and potential. Electrostatic boundary conditions, Solution of Laplace's equation for simple cases. Conductors, capacitors, dielectrics, dielectric polarization, volume and surface charges, electrostatic energy. Biot-Savart law, Ampere's law, Faraday's law of electromagnetic induction, self and mutual inductance. Alternating currents. Simple DC and AC circuits with R, L and C components. Displacement current, Maxwell's equations and plane electromagnetic waves, Poynting's theorem, reflection and refraction at a dielectric interface, transmission and reflection coefficients (normal incidence only). Lorentz Force and motion of charged particles in electric and magnetic fields.

Kinetic Theory, Thermodynamics: Elements of Kinetic theory of gases. Velocity distribution and Equipartition of energy. Specific heat of Mono-, di- and tri-atomic gases. Ideal gas, van-der-Waals gas and equation of state. Mean free path. Laws of thermodynamics. Zeroth law and concept of thermal equilibrium. First law and its consequences. Isothermal and adiabatic processes. Reversible, irreversible and quasi-static processes. Second law and entropy. Carnot cycle. Maxwell's thermodynamic relations and simple applications. Thermodynamic potentials and their applications. Phase transitions and Clausius-Clapeyron equation. Ideas of ensembles, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein distributions.

Modern Physics: Inertial frames and Galilean invariance. Postulates of special relativity. Lorentz transformations. Length contraction, time dilation. Relativistic velocity addition theorem, mass energy equivalence. Blackbody radiation, photoelectric effect, Compton Effect, Bohr's atomic model, X-rays. Wave-particle duality, Uncertainty principle, the superposition principle, calculation of expectation values, Schrödinger equation and its solution for one, two and three dimensional boxes. Solution of Schrödinger equation for the one dimensional harmonic oscillator. Reflection and transmission at a step potential, Pauli Exclusion Principle. Structure of atomic nucleus, mass and binding energy. Radioactivity and its applications. Laws of radioactive decay

Solid State Physics, Devices and Electronics: Crystal structure, Bravais lattices and basis. Miller indices. X-ray diffraction and Bragg's law; Intrinsic and extrinsic semiconductors, variation of resistivity with temperature. Fermi level. p-n junction diode, I-V characteristics, Zener diode and its applications, BJT: characteristics in CB, CE, CC modes. Single stage amplifier, two stage R-C coupled amplifiers. Simple Oscillators: Barkhausen condition, sinusoidal oscillators. OPAMP and applications: Inverting and non-inverting amplifier. Boolean algebra: Binary number systems; conversion from one system to another system; binary addition and subtraction. Logic Gates AND, OR, NOT, NAND, NOR exclusive OR; Truth tables; combination of gates; de Morgan's theorem.

JAM 2025