JAM 2027 Biotechnology (BT)

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

Section 1: General Biology

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

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

Genetics: Mendelian inheritance; Exception to Mendelian law of independent assortment; Genetic interactions, linkage, recombination and chromosome mapping, Chromosomal mutations; Genetic disorders; Population Genetics

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 and differential gene expression in multicellular eukaryotes.

Evolution and Ecology: Darwinian view – natural selection, fossil record and descent with modification; Different types of speciation; Phylogenetic classification; Origin of life – abiotic synthesis of biological macromolecules, protocell, dating fossils and origin of multicellularity; Climate patterns; Terrestrial and aquatic biomes; Environmental constraints on species distribution; Factors affecting population density; Interactions among communities; Ecosystems; Ecological remediation.

Section 2. Microbial, Plant and Animal Biotechnology

Microbiology: Microbial genetics - transformation, conjugation and transduction; Structural features of viruses, bacteria, fungi and protozoa; Pathogenic microorganisms; Nutrition-based classification of microbes; Microbial metabolism; Isolation and Cultivation of microorganisms; Growth kinetics; Microbial control and sterilization; Microbial fermentation – batch, fed-batch and continuous; Bioreactor and its components; Introduction to downstream processing - product recovery and purification; Effluent treatment.

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; Plant growth regulators; Photobiology; Plant Tissue Culture – Cellular totipotency and microporopagation; Transgenic plants; 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, immunoglobulins and major histocompatibility complexes; Animal development – Fertilization, embryonic pattern formation, cleavage, gastrulation, cellular differentiation and morphogenesis; Mammalian cell culture, animal cloning; Transgenic animals.

Section 3: Biotechniques

Biochemical and Microscopy Techniques: Chromatography; Centrifugation; Electrophoresis; ELISA, Western blotting and immunostaining; Principles of light, fluorescence and electron microscopy.

Molecular Biology Techniques: DNA cloning – plasmid vectors, and restriction enzymes; Polymerase Chain Reaction; Expression of cloned eukaryotic genes in bacteria; Hybridization techniques; DNA sequencing; Recombinant DNA technology in medicine, agriculture and forensic sciences.

Computational Biology: Bioinformatics; Sequence and structure databases; DNA, RNA and protein sequence analysis; Secondary structure and 3D structure prediction; Biochemical databases.

Instrumental Techniques – Spectroscopy: fundamentals of molecular spectroscopy, emission and absorption spectroscopy, UV-Vis, circular dichroism, FTIR and 1-D proton NMR spectroscopy, basics of mass spectrometry; Basics of calorimetry; Basic concepts of crystallography; Flowcytometry.

Section 4: 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.

Section 5: Mathematics (10+2 level)

General mathematics: Sets; Relations and Functions; 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; 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.

Probability & Statistics: Mean, median, mode and standard deviation; Random variables; Poisson, normal and binomial distributions; Correlation and regression analysis.

Section 6: Physics (10+2 level)

General physics: 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.

JAM 2027
Chemistry (CY)

Section 1: Basic Mathematical Concepts (10+2 Level):

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

Section 2: Physical Chemistry:

2.1: Atomic and Molecular Structure: Planck's black body radiation, Photoelectric effect, Bohr's theory, de Broglie postulate, Heisenberg's Uncertainty Principle; Schr¨odinger'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.

2.2: 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.

2.3: 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.

2.4: 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.

2.5: 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.

2.6: 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.

2.7: Electrochemistry: Conductivity, equivalent and molar conductivity and their properties; Kohlrausch law; DebyeH¨uckel-Onsager equation; Ionic velocities, mobilities, transfer ence 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.

2.8: 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.

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

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

Section 3: Organic Chemistry

3.1: 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.

3.2: Organic Reaction Mechanism and Synthetic Applications: Chemistry of reactive intermediates (carbocations, carbanions, free radicals, carbenes, nitrenes, benzynes); 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-Villeger 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.

3.3: Qualitative Organic Analysis: Identification of functional groups by chemical tests; elementary UV, IR and ^{1}H NMR spectroscopic techniques as tools for structural elucidation of simple organic molecules.

3.4: Natural Products Chemistry: Chemistry of alkaloids, steroids, terpenes, carbohydrates, amino acids, peptides and nucleic acids.

3.5: Aromatic and Heterocyclic Chemistry: Monocyclic, bicyclic and tricyclic aromatic hydrocarbons, and monocyclic compounds with one hetero atom: synthesis, reactivity and properties, aromaticity; Electrophilic and nucleophilic aromatic substitution reactions.

Section 4: Inorganic Chemistry

4.1: Periodic Table: Periodic classification of elements, Aufbau's principle, periodicity; Variations of orbital energy, effective nuclear charge, atomic, covalent, and ionic radii, ionization enthalpy, electron gain enthalpy, and electronegativity with atomic number, electronic configuration of diatomic molecules (first and second row elements).

4.2: Extractions of Metals: General methods of isolation and purification of elements; Principles and applications of Ellingham diagram.

A. **4.3: Chemical Bonding and shapes of molecules:** Ionic bond: Packing of ions in crystals, radius ratio rule, Born-Landé equation, Kapustinskii expression, Madelung constant, Born-Haber cycle, solvation energy, polarizing power and polarizability; Fajan's rules; Covalent bond: Lewis

structure, valence bond theory. Hybridization, molecular orbital theory, molecular orbital diagrams of

diatomic and simple polyatomic molecules and ions; Multiple bonding (σ and π bond approach) and bond lengths; van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, instantaneous dipole- induced dipole interactions, hydrogen bonding; Effect of intermolecular forces on melting and boiling points, solubility energetics of dissolution process; Bond dipole, dipole moment, and molecular polarizabilities; VSEPR theory and shapes of molecules; ionic solids.

4.4: Main Group Elements (s and p blocks): Reactions of alkali and alkaline earth metals with oxygen, hydrogen and water; Alkali and alkaline earth metals in liquid ammonia; Gradation in properties of main group element in a group; Inert pair effect; Synthesis, structure and properties of diborane, ammonia, silane, phosphine and hydrogen sulphide; Allotropes of carbon; Oxides of nitrogen, phosphorus and sulphur; Oxoacids of phosphorus, sulphur and chlorine; Halides of silicon and phosphorus; Synthesis and properties of borazine, silicone and phosphazene; Synthesis and reactions of xenon fluorides.

4.5: Transition Metals (d block): Characteristics of d-block elements; oxide, hydroxide and salts of first row metals; coordination complexes: structure, isomerism, reaction mechanism and electronic spectra; VB, MO and crystal field theoretical approaches for structure, color and magnetic properties of metal complexes; Organometallic compounds with metal-ligand single and multiple bonds (such as metal carbonyls, metal nitrosyls and metallocenes); Homogenous catalysis involving Wilkinson's catalyst.

4.6: Bioinorganic Chemistry: Essentials and trace elements of life; basic reactions in the biological systems and the role of metal ions, especially Fe^{2+}, and Zn^{2+}; structure and function of myoglobin, hemoglobin and carbonic anhydrase.

4.7: Instrumental Methods of Analysis: Basic principles; instrumentations and simple applications of conductometry, potentiometry and UV-vis spectrophotometry; analyses of water, air and soil samples.

4.8: Analytical Chemistry: Principles of qualitative and quantitative analysis; Acidbase, oxidation-reduction and complexometric titrations using EDTA; Precipitation reactions; Use and types of indicators; Use of organic reagents in inorganic analysis; Radioactivity, nuclear reactions, applications of isotopes; Mathematical treatment in error analysis, elementary statistics and probability theory.

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JAM 2027
Economics (EN)

1. Mathematics for Economics

Preliminaries and functions: Set theory and number systems; monotonicity and inverse functions; elementary functions: quadratic, polynomial, power, exponential, logarithmic; logarithms and elasticities (log-derivative interpretation); functions of several variables; graphs and level curves; convex set; concavity and quasi-concavity of function; convexity and quasi-convexity of functions; sequences and series: convergence, algebraic properties and applications (including geometric series and basic limits of sequences).

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; Hessian; 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 ordinary equations with applications; steady state/equilibrium and basic stability (including simple phase-diagram intuition where relevant).

Linear algebra: Matrix representations and elementary operations; systems of linear equations: properties of their solution; linear independence and dependence; rank; determinants; matrix inverse and conditions for invertibility; eigenvectors and eigenvalues of square matrices (primarily 2x2); basic diagonalization idea (simple cases); symmetric matrices and quadratic forms; definiteness and semidefiniteness of quadratic forms and interpretation stability.

Optimization: Local and global optima: geometric and calculus-based characterisations and applications; multivariate optimization; use of quadratic forms, Hessians in optimization; constrained optimization (equality constraints) and method of Lagrange multiplier; constrained optimization with inequality constraints: Karush-Kuhn–Tucker (KKT) conditions and complementary slackness (basic form and applications); second order conditions of optima; definiteness and optimality; properties of value function: envelope theorem and applications; linear programming: graphical solution, matrix formulation, duality, economic interpretation.

2. Statistics for Economics

Descriptive Statistics: Different types of Charts and diagrams; Frequency Distribution; Measures of Central Tendency; Measures of Dispersion; Moments, Skewness, Kurtosis; Index Numbers.

Probability Theory: Random experiment, events, and sample space; Classical and axiomatic definitions of probability; Theorems of probability; Repeated trials and drawing with and without replacement; Conditional probability, independent events, and Bayes' theorem; Random variable and its probability distribution; Markov's inequality; Chebyshev's inequality; Expectation, variance, and other higher order moments of a random variable; Moment Generating Function; Bernoulli trials; Binomial, Poisson, Hypergeometric, Uniform, and Normal distributions with concepts of probability mass and probability density functions; Chi-square, Student's t-, and F-distributions, with their relation with Normal distribution; Joint distribution of random variables, conditional distributions, and their properties.

Mathematical Statistics: Random sampling and its different types; Concept of sampling distribution; Method of Estimation with the concepts of estimator and estimate; Confidence intervals vs. point and interval estimations; Properties of Estimators: Unbiasedness, Efficiency, and Consistency; Law of Large Numbers and Central Limit Theorem.

Hypothesis Testing: Concepts of Parameter vs. statistic; Null and Alternative Hypotheses; Concepts of test statistic and its distribution; Concept of p-value; Type I and Type II errors and computation of their probabilities; Size and Power of a test; Comparing two population characteristics on the basis of randomly drawn samples from them.

Correlation and Regression: Correlation and types of correlation; Nature of regression analysis; Method of Ordinary Least Squares (OLS) vis-à-vis Method of Moments vis-à-vis Maximum Likelihood estimations; CLRM assumptions, statistical properties of OLS estimators and hypothesis testing; Gauss-Markov Theorem and concept of Best Linear Unbiased Estimator (BLUE); Goodness of fit.

3. Microeconomics

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

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

Perfect competition and partial equilibrium: Profit maximization; individual and market supply; market equilibrium; consumer and producer surplus; government intervention in perfectly competitive markets: commodity taxes, subsidies, MSP, price ceilings and floors.

General equilibrium and welfare: Equilibrium and efficiency under pure exchange and production; the two theorems of welfare economics.

Introductory Game theory: Strategic-form games; dominant and dominated strategies; iterated elimination of dominated strategies; best response; pure and mixed strategy Nash equilibrium; sequential-move games (finite horizon); backward induction; subgame perfect equilibrium.

Imperfect competition and market structure: Monopoly; pricing with market power; price discrimination (first, second and third degrees); monopolistic competition; oligopoly models—Cournot, Bertrand and Stackelberg.

Market failure and government policy: Externalities (Pigouvian taxes and subsidies); public goods (Samuelson condition, Lindahl pricing); asymmetric information: adverse selection and moral hazard (basic notions).

4. Macroeconomics

National income accounting: Key concepts and measurement; circular flow of income (closed and open economy); nominal vs real GDP; GDP deflator; GDP and welfare.

Consumption and saving: Keynesian consumption (short run and long run); absolute income, permanent income and life-cycle hypotheses; two-period model of consumption.

Production Function: Cobb-Douglas Production Function, Total Factor Productivity, Technological Progress, Return to Scale, Cost Functions.

Labour Demand, Labour Supply, Investment: Profit Maximization under Perfect Competition, Labour Demand, Capital Demand and Investment, Labour Supply through Consumption-Leisure Framework, Structural, Frictional and Search Unemployment, Unemployment Rate, Aggregate Supply/Lucas Supply Curve.

Unemployment and Inflation: CPI/Cost of Living Index, Inflation Rate, Causes and Costs of Inflation, Aggregate Supply/Lucas Supply Curve and Phillips Curve.

Money Supply and Money Demand: Definition and roles of money; monetary Base; fiat vs. commodity money, fractional reserve banking, balance Sheet of Central Bank and commercial banks, money supply, deposit creation, money multiplier, monetary policy Tools (open market operations, reserve requirements, discount rate); quantity theory of money, Keynesian liquidity preference theory, Baumol-Tobin Model, Tobin's speculative demand for money; seigniorage; optimal monetary policy (rules vs. discretion).

Asset Pricing: Bonds, and Stock Pricing, Gordon Growth Model of Stocks Price, Tobin's q and Investment, Risk Structure and Term Structure of Interest Rate, Yield Curve.

Fiscal policy (based on two-period models): Government budget constraint; revenues, expenditures and deficits; distortionary vs non-distortionary taxes; Laffer curve; Ricardian equivalence.

Income determination and policy in the short run: Goods and money market equilibrium; IS–LM; classical vs Keynesian models; aggregate demand; fiscal and monetary multipliers; liquidity trap/zero lower bound; Fisher equation and real interest rate; Taylor rule and principle; simple dynamic AD–AS and stability.

Long-run growth: Stylized facts, Kaldor facts; Harrod–Domar model; Solow model with population and technology growth; convergence (conditional/absolute); golden rule; dynamic inefficiency of Solow model; growth accounting and Solow residual; endogenous growth (AK model); poverty trap.

Open economy macroeconomics: GNP; Balance of payments (trade balance, current account, financial account); current account in an intertemporal (two-period) framework; nominal and real exchange rates; fixed, flexible and dirty floating exchange rates; interest parity and capital market integration; impossible trinity; purchasing power parity, Big Mac index, PPP-adjusted exchange rate; Mundell–Fleming model.

5. Indian Economy

Introduction and features: Changing structure of the Indian economy. Changing paradigms of Development Strategies and Economic Reforms.

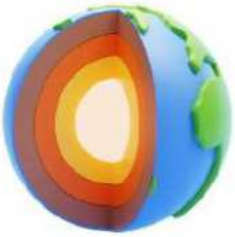
Poverty, Inequality, Inflation and Unemployment: Various concepts and estimates of poverty; Income inequality; Problem of unemployment; Interface between growth, poverty and employment; Inclusive growth and Human Development; Sustainable Development Goals—Targets for Decent Employment, reduction in Poverty, and Inequality. Inflation targeting and use of monetary and fiscal policy.

Demographic Issues: Demographic trends, size and structure of population; Health and Education; Skill challenges and demographic dividends; Sustainable Development Goals—Targets for Greater Wellbeing and Better Human Capital.

Perspectives in Agriculture, Industry and Services: Agricultural growth performance and food security, Industrial investment and growth, Service sector in India's growth process.

External Sector and Issues in Indian Public Finance: Foreign trade and trade policy; Foreign Exchange Reserves and exchange rate, Indian Union Budget and fiscal policy.

JAM 2027
Geology (GG)



The Planet Earth: Origin of the Solar System and the Earth; Internal structure, composition, and age of the Earth; Pressure-temperature-density variations within the Earth; Principles of radiometric dating (Rb-Sr, Sm-Nd, ^{14}C); Volcanism and volcanic landforms; Earthquakes; Earth's magnetism and gravity, Isostasy; Concepts of Plate Tectonics and orogeny.

Geomorphology: Weathering, erosion, deposition; Endogenous and exogenous processes of landform development; Soil formation; River and drainage basin/drainage pattern, network characteristics; Fluvial, aeolian, marine, glacial and karst landforms.

Structural Geology: Concept of dip, strike, rake and plunge; Contour lines; Rule of 'V's and outcrop patterns; Interpretation of geological maps; Cross-section construction; Classification and origin of folds, faults, joints, unconformities, foliations and lineations; Stereographic and equal-area projections of planes and lines; Quantitative interpretation of structures, outcrops, and bore-hole data.

Palaeontology: Major stages in the evolution of life forms; Fossils and their mode of preservation; Application of macrofossils in age determination and pale environmental interpretations; Morphology, major evolutionary trends and ages of important groups of invertebrates – Brachiopoda, Mollusca, Trilobita, Echinodermata; Gondwana plant fossils; Vertebrate fossils (Equidae, Proboscidea) in India.

Stratigraphy: Principles of stratigraphy; Litho-, chrono - and bio-stratigraphic 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, Cenozonic sequences of Assam, Bengal and Siwaliks.

Mineralogy: Symmetry and forms in common crystal classes; Miller indices; Twinning and twinning laws; Isomorphism, polymorphism, solid solution and exsolution; Elements of Optical Mineralogy; Classification, structure, chemistry, physical, and optical properties of common rock-forming minerals.

Petrology: Igneous rocks – classification and texture; Forms of igneous bodies; Evolution and diversification of magma; Use of binary systems to understand melting and crystallization behaviour of rocks and magmas; Genesis of common igneous rocks and associations.

Sedimentary rocks – classification, texture, and structure; Petrology of sandstone and limestone; Basics 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; Processes of formations of ore mineral deposits - magmatic concentration, hydrothermal processes, oxidation and supergene sulphide enrichment, residual and mechanical concentration; Mode of occurrence and distribution of metallic and non-metallic mineral deposits in India; Ore grade and reserve estimation; Coal and hydrocarbon geology and their Indian occurrences.

Applied Geology: Basics of groundwater geology; Types of aquifers, porosity and permeability; Groundwater flow; Principles of engineering geology; Geological considerations in construction of dams and tunnels; Basics of remote sensing.

JAM 2027

Mathematics (MA)

Section 1: 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.

Section 2: 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.

Section 3: Linear Algebra and Algebra

Basic algebra: Permutations and Combinations, Binomial Theorem

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.

JAM 2027
Mathematical Statistics (MS)

The Mathematical Statistics (MS) Test Paper comprises the following topics of Mathematics (Sections 1-3, about 25% weight) and Statistics (Sections 4-12, about 75% weight).

Mathematics (Sections 1-3)

Section 1; 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. Limit superior and limit inferior of 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^{th} 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.

Section 2; Differential Calculus of one and two real variables, and Integral Calculus

Differential Calculus of one variable: 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, Lebnitz'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.

Differential calculus of two variables: 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. Lebnitz'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). Lebnitz'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.

Section 3; Matrices and Determinants: $\mathbb{R}^n$ and $\mathbb{C}^n$ as vector spaces over real field. Span of a set. Linear dependence and independence. Dimension and basis. Null space. 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 and nullity 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. Consistent and inconsistent systems of linear equations. Properties of solutions of system of linear equations. Use of determinants in solving the system of linear equations. Cramer's rule. Characteristic roots and Characteristic vectors. Properties of characteristic roots and vectors. Cayley- Hamilton theorem. Quadratic forms, positive definite, positive semi-definite, negative definite, and negative semi-definite matrices, and their simple properties.

Statistics (Sections 4 - 12)

Section 4; Descriptive Statistics and Probability:

Descriptive Statistics: Concepts of sample and population. Different types of data. Tabular and graphical representation of data. Measures of central tendency (arithmetic mean, geometric mean, harmonic mean, median, mode). Measures of dispersion (range, inter quartile range, mean deviation about a point, standard deviation, variance, coefficient of variation). Moments, central moments, skewness and kurtosis. Bivariate data: Scatter diagram, covariance, simple, partial and multiple correlations (3 variables only), Spearman's rank correlation.

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.

Section 5; 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, 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.

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.

Section 6; 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. 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.

Section 7; Limit Theorems: Convergence in probability, convergence in mean square, almost sure convergence, convergence in distribution, and their inter-relations. Weak law of large numbers, Strong law of large numbers, and Central Limit Theorem (i.i.d. and finite variance case).

Section 8; 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 (χ^2) : 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 t - distribution: Definition and derivation of p.d.f. of Central t -distribution with n d.f., Properties and limiting form of central t -distribution. Central F -distribution: Definition and derivation of p.d.f. of 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.

Section 9; 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.

Section 10; 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 one-parameter parametric families. Likelihood ratio tests for parameters of univariate normal distribution.

Section 11; Nonparametric Methods: Tests of randomness based on total number of runs. Empirical distribution function. Kolmogorov-Smirnov one sample test. One and two sample sign tests. Mann-Whitney test.

Section 12; Stochastic Processes: Discrete time Markov chain: transition probability matrix, higher order transition probabilities, Markov chain as a graph, Chapman-Kolmogorov equation, classification of states and chains, stability of Markov chain (stationary and limiting distributions). Poisson process and its properties, interarrival and waiting times.

JAM 2027
Physics (PH)

Section 1: 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, Complex numbers, Error analysis of Experimental Data: Significant digits and rounding of numbers, Types of errors, mean, median, standard deviation

Section 2: 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 nonconservative 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.

Section 3: 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 oscillations, 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. 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.

Section 4: Electricity and Magnetism

Coulomb's law, Electric field and potential, Gauss's law, Electrostatic boundary conditions, Solution of Laplace's equation for simple cases – upto two dimensions

Conductors, capacitors, Linear dielectrics, dielectric polarization, volume and surface bound 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 vector, Poynting's theorem, Energy of Electromagnetic fields. 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.

Section 5: 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.

Section 6: 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.

Section 7: 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. OP-AMP 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.