AE Aerospace Engineering

Important Note for Candidates: In each of the following subjects, the topics have been divided into two categories – Core Topics and Special Topics. The corresponding sections of the question paper will contain at least 90% of the questions on Core Topics and the remaining 10% at most on Special Topics.

Section 1: Engineering Mathematics

Core Topics:

Linear Algebra: Vector algebra, matrix algebra, systems of linear equations, rank of a matrix; Eigenvalues and eigenvectors.

Calculus: Functions of single variable, limits, continuity and differentiability, chain rule, maxima and minima, Integration; Functions of several variables, partial derivatives, gradient, divergence and curl, directional derivatives; Line, surface and volume integrals. Theorems of Stokes, Gauss and Green.

Differential Equations: First order linear ordinary differential equations; Higher order linear ODEs with constant coefficients; Classification of partial differential equations; solution to: wave equation, Laplace equation, heat equation using separation of variables methods.

Numerical Methods: Numerical solutions for linear and nonlinear algebraic equations by bisection, Newton-Raphson method; basic numerical differentiation; numerical integration by trapezoidal and Simpson's rules; linear regression and least squares method; linear interpolation.

Special Topics:

Fourier series; complex numbers, analytic functions and Cauchy-Riemann equations.

Basics of probability and statistics: Bayes theorem, mean, median, & mode; variance; binomial, normal and Poisson distribution.

Section 2: Flight Mechanics & Space Dynamics

Core Topics:

Atmosphere: Properties of standard atmosphere.

Classification of aircraft. Airplane (fixed wing aircraft) configuration and various parts; Pressure altitude; equivalent, calibrated, indicated air speeds;

Primary flight instruments: Altimeter, air speed indicator, vertical speed indicator, turn-bank indicator.

Aerodynamic forces and moments; angle of attack; sideslip;

High-lift devices; roll, pitch & yaw controls.

Airplane performance: C_L-alpha curve, drag polar; take-off and landing; steady climb and descent; absolute and service ceiling; range and endurance, load factor, turning flight, V-n diagram. Winds: head, tail and cross winds.

Static stability: stability and control derivatives; longitudinal stick fixed and free stability; horizontal tail position and size; directional stability, vertical tail position and size; lateral stability; wing dihedral, sweep & position; hinge moments, stick forces.

Linear momentum and angular momentum balance for rigid bodies.

Space Dynamics: central force motion, Keplerian orbits, Kepler's laws; escape velocity.

Special Topics:
Equations of motion; Euler angles; decoupling of longitudinal and lateral-directional dynamics; longitudinal modes; lateral-directional modes, Hohmann orbital transfers.

Section 3:	Aerodynamics

Core Topics:
Basic fluid mechanics: fluid kinematics, streamline, streakline, pathline; conservation laws: mass, linear momentum and energy (integral and differential form); dimensional analysis and dynamic similarity; incompressibility conditions; Newtonian fluids.

Elementary ideas of viscous flows: Hagen-Poiseulle flow, Couette flow, basic concepts in boundary layers, boundary layer thickness.

Two-dimensional potential flow theory: sources, sinks, doublets, point vortex and their superposition, Bernoulli's equation.

Airfoils and wings: airfoil nomenclature; aerodynamic coefficients: lift, drag and moment; Kutta-Joukoswki theorem; thin airfoil theory, Kutta condition, starting vortex; finite wing theory: induced drag, Prandtl lifting line theory; critical and drag divergence Mach numbers.

Compressible flows: basic concepts of compressibility, one-dimensional compressible flows, isentropic flows, normal and oblique shocks, Prandtl-Meyer flow; flow through nozzles and diffusers.

Special Topics:
Fanno flow; Rayleigh flow; pressure measurements using U-tube manometers and Pitot probe.

Section 4:	Structures

Core Topics:
Strength of materials: Stress and strain, stress-strain curves of steel and Aluminium; stresses and deflections in statically determinate and indeterminate linear elastic trusses, bars, beams, and shafts; two-dimensional transformations of stresses and strains, Mohr's circle, principal stresses and strains; combined loading, failure criteria: maximum stress, Tresca, von Mises; strain energy; Castigliano's principles; three-dimensional Hooke's law; plane stress and strain; Euler buckling of columns.

Flight vehicle structures: torsion, bending and shear of open and closed thin-walled sections: symmetric and unsymmetric cross-sections; loads on aircraft.

Structural Dynamics: free and forced vibrations of undamped and damped SDOF systems; free vibrations of undamped 2-DOF systems.

Special Topics:
Equilibrium and compatibility equations in two-dimensional elasticity.

Section 5:	Propulsion

Core Topics:
Basics of thermodynamics.
Aerothermodynamics of aircraft engines: thrust, efficiency, range. Brayton cycle.
Engine performance: ramjet, turbojet, turbofan, turboprop and turboshaft engines; after-burners.
Aerothermodynamics of non-rotating propulsion components such as intakes, nozzles.

Gas turbine combustor: types and configurations; combustion, stoichiometric fuel-to-air ratio.

Turbomachinery: Axial compressors: angular momentum, work and compression, characteristic performance of a single axial compressor stage, efficiency of the compressor and degree of reaction, multi-staging; Centrifugal compressor: stage dynamics, inducer, impeller and diffuser; Axial turbines: stage performance.

Rockets: thrust equation and specific impulse, rocket performance; multi-staging; chemical rockets; performance of solid and liquid propellant rockets.

Special Topics:
Turbine blade cooling, compressor-turbine matching.

AG Agricultural Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrices and determinants, linear and orthogonal transformations, Caley Hamilton theorem; Eigen values and Eigen vectors, solutions of linear equations.

Calculus: Limit, continuity and differentiability; partial derivatives; homogeneous function – Euler's theorem on homogeneous functions, total differentiation; maxima and minima of function with several independent variables; sequences and series – infinite series, tests for convergence; Fourier, Taylor and MacLaurin series.

Vector Calculus: Vector differentiation, scalar and vector point functions, vector differential operators – del, gradient; divergence and curl; physical interpretations-line, surface and volume integrals; Stokes, Gauss and Green's theorems.

Differential Equations: Linear and non-linear first order Ordinary Differential Equations (ODE); homogeneous differential equations, higher order linear ODEs with constant coefficients; Laplace transforms and their inverse; Partial Differential Equations - Laplace, heat and wave equations.

Probability and Statistics: Mean, median, mode and standard deviation; random variables; Poisson, normal and binomial distributions; correlation and regression analysis.

Numerical Methods: Solutions of linear and non-linear algebraic equations; numerical integration - trapezoidal and Simpson's rule; numerical solutions of ODEs.

Section 2: Farm Machinery

Machine Design: Design and selection of machine elements – gears, pulleys, chains and sprockets and belts; overload safety devices used in farm machinery; measurement of force, stress, torque, speed, displacement and acceleration on machine elements - shafts, couplings, keys, bearings and knuckle joints.

Farm Machinery: Soil tillage; forces acting on a tillage tool; hitch systems and hitching of tillage implements; functional requirements, principles of working, construction and operation of manual, animal, tractor and renewable energy operated equipment for tillage, sowing, planting, fertilizer application, inter-cultivation, spraying, mowing, chaff cutting, harvesting and threshing, calculation of performance parameters - field capacity, efficiency, performance index, application rate and losses; cost analysis of implements and tractors, equipment for precision agriculture.

Section 3: Farm Power

Sources of Power: Sources of power on the farm — human, animal, mechanical, electrical, wind, solar and biomass; bio-fuels and their use in farm mechanization.

Farm Power: Thermodynamic principles of I.C. engines; I.C. engine cycles; engine components; fuels and combustion; lubricants and their properties; I.C. engine systems – fuel, cooling, lubrication, ignition, electrical, intake and exhaust; selection, operation, maintenance and repair of I.C. engines; power efficiencies and measurement, engine performance curves; calculation of power, torque, fuel consumption, heat load and power losses;

Tractors and Power tillers: Type, selection, maintenance and repair of tractors and power tillers; tractor clutches and brakes; power transmission systems – gear trains, differential, final drives and power take-off;

mechanics of tractor chassis; traction theory; three point hitches - free link and restrained link operations; steering and hydraulic control systems used in tractors; tractor tests and performance; human engineering and safety considerations in design of tractor and agricultural implements.

Section 4:	Soil and Water Conservation Engineering

Fluid Mechanics: Ideal and real fluids, properties of fluids; hydrostatic pressure and its measurement; continuity equation, kinematics and dynamics of flow; Bernoulli's theorem; laminar and turbulent flow in pipes, Darcy- Weisbach and Hazen-Williams equations; flow through orifices, weirs and notches; flow in open channels, dimensional analysis – concepts of geometric dimensionless numbers.

Soil Mechanics: Engineering properties of soils; fundamental definitions and relationships; index properties of soils; permeability and seepage analysis; shear strength, Soil compaction and Proctor test, Mohr's circle of stress, active and passive earth pressures; stability of slopes, Terzaghi's one dimensional soil consolidation theory.

Hydrology: Hydrological cycle and measurement of its components; meteorological parameters and their measurement; analysis of precipitation data; runoff estimation; hydrograph analysis, unit hydrograph theory and application; stream flow measurement; flood routing, hydrological reservoir and channel routing, Infiltration – indices and equations, drought and its classification.

Surveying and Leveling: Measurement of distance and area; instruments for surveying and levelling; chain surveying, methods of traversing; measurement of angles and bearings, plane table surveying; types of levelling; the Theodolite traversing; contouring; total station, introduction to GPS survey, computation of areas and volume.

Soil and Water Erosion: Mechanics of soil erosion - wind and water erosion: soil erosion types, factors affecting erosion; soil loss estimation; biological and engineering measures to control erosion; terraces and bunds; vegetative waterways; gully control structures, drop, drop inlet and chute spillways; earthen dams.

Watershed Management: Watershed characterization and land use capability classification; water budgeting in watershed, rainwater harvesting, check dams and farm ponds.

Section 5:	Irrigation and Drainage Engineering

Soil-Water-Plant Relationship: Water requirement of crops; consumptive use and evapotranspiration; measurement of infiltration, soil moisture and irrigation water infiltration.

Irrigation Water Conveyance and Application Methods: Design of irrigation channels and underground pipelines; irrigation scheduling; surface, sprinkler and micro irrigation methods, design and evaluation of irrigation methods; irrigation efficiencies.

Agricultural Drainage: Drainage coefficient; planning, design and layout of surface and sub- surface drainage systems; leaching requirement and salinity control; irrigation and drainage water quality and reuse; non-conventional drainage system.

Groundwater Hydrology: Groundwater occurrence; ground water movement; Darcy's Law, steady and unsteady flow in confined and unconfined aquifers, groundwater exploration techniques; overview of groundwater recharge estimation and artificial recharge techniques.

Wells and Pumps: Types of wells, steady flow through wells; design and construction of water wells; classification of pumps; pump characteristics; pump selection and installation.

Section 6:	Agricultural Process Engineering

Engineering properties of agriculture produce: Physical, thermal, frictional, rheological and electrical properties.

Evaporation and Drying: Concentration and drying of liquid foods – evaporators, tray, drum and spray dryers; osmotic dehydration and freeze drying; hydrothermal treatments; drying and milling of cereals, pulses and oilseeds; drying kinetics; psychrometry – properties of air-water vapor mixture.

Size Reduction and Material Handling: Mechanics and energy requirement in size reduction of agriculture produce; particle size analysis for comminuted solids; size separation by screening; fluidization of granular solids-pneumatic, bucket, screw and belt conveying; cleaning and grading; effectiveness of separation; centrifugal separation of solids, liquids and gases; homogenization; filtration and membrane separation.

Processing of Agriculture Produce: Processing of seeds, spices, fruits and vegetables; value addition of agriculture produce.

Storage Systems: Controlled and modified atmosphere storage; perishable food storage, godowns, bins and grain silos, packaging material and machines.

Section 7:	Dairy and Food Engineering

Heat and Mass Transfer: Steady state heat transfer in conduction, convection and radiation; transient heat transfer in simple geometry; working principles of heat exchangers; diffusive and convective mass transfer; simultaneous heat and mass transfer in agricultural processing operations; material and energy balances in food processing systems; water activity, sorption and desorption isotherms.

Unit operations in Dairy and Food engineering: Blanching, homogenization, pasteurization, sterilization.

Preservation of Food: Kinetics of microbial death – pasteurization and sterilization of milk and other liquid foods; preservation of food by cooling and freezing; refrigeration and cold storage basics and applications.

AR Architecture and Planning

Part A: Common Section

Section A.1: Design and Graphics

Architectural Graphics; Visual composition in 20 and 30; Form; Surface development; Anthropometrics; Ergonomics, Ratio and proportion, Scales in design, Organization of space; Plans, elevations, and sections of buildings; Circulation- horizontal and vertical; Universal design; Building bye-laws; Codes and standards, Barrier-free environment; Engineering curves; Orthographic and Isometric projection; One-point and two-point perspectives; Light, shade and shadow;

Section A.2: Environmental Planning and Landscape

Natural and man-made ecosystem; Environmental, ecological, and sustainability principles; Environmental pollution- types, causes, controls and abatement strategies; Sustainable development goals and strategies; Climate change and built environment; Urban ecosystem approach; Ecological footprint and carrying capacity; Resource management; Life cycle analysis; Principles of circular economy; Environmental Impact Assessment; Carbon footprint; Carbon credits; Urban Heat Islands; Sustainable site planning; Contour and slope analysis; Landscape planning and design; Landscape suitability analysis; Plant characteristics and planting designs; Landscape conservation – principles and techniques; Social forestry; Historical gardens;

Section A.3: Urban Design and Conservation

Historical and modern examples of urban design; Elements of urban built environment – urban form, spaces, structure, pattern, fabric, texture, grain; Theories, principles, tools and techniques of urban design; Precincts, character, spatial qualities; Placemaking ; Form-based code; Urban design interventions for sustainable development and transportation; Development controls – FAR, densities and building byelaws; Urban renewal and conservation; Heritage conservation; Historical and contemporary public spaces;

Section A.4: Town Planning, Housing and Real Estate Development

Principles and concepts of town planning; Traditional and modern planned cities in India and abroad; Housing typologies; Concepts of housing need, demand, supply and shortage; Neighbourhood design; Residential densities; Affordable and incremental housing; Slums, squatters and informal housing; Standards for housing and community facilities; Housing for special areas and needs; Real estate valuation; Real estate feasibility studies and market analysis; Real Estate locational decisions and economic analysis; Project phasing and construction phasing;

Part B1: Architecture

Section B1.1 History and Theory of Architecture

World History of Architecture: Egyptian, Greco-Roman classical period, Byzantine, Gothic, Renaissance, Baroque-Rococo; Recent trends in Contemporary Architecture: Art nouveau, Art Deco, Eclecticism, International styles, Postmodernism, Deconstruction in architecture; Influence of Modern art and Design in Architecture; Indian Architecture; Oriental Architecture; Works of renowned national and international architects; Principles of art, design and Architecture;

Section B1.2 Climatology and Environmentally Responsive Design

Climatic factors and classification; Solar architecture; Micro and macro climatic considerations in design; Thermal comfort in built environments; Passive design principles and concepts; Building energy audit and management; Embodied and operational energy; Building energy performance simulation and evaluation; Alternate and renewable sources of energy for buildings; Building Performance Rating systems; Kinetic architecture; Sustainable building technologies;

Section B1.3	Building Construction, Materials, and Structural Systems

Building construction techniques, methods and details: foundation, plinth, masonry, bonds, fenestrations, arches, scaffolding, formwork, timber/RCC/Steel frame construction, roof and roof covering; Lightweight construction; Fire protection; Flooring systems; Principles of Modular Coordination; Prefabricated construction; Building materials characteristics & applications; Different types of building materials for walls, floor, roof, finishes, repair and retrofitting, acoustic & insulation materials, damp prevention; Alternative building materials; Building structural systems; Elastic and Limit State design; Structural systems; Design with steel and RCC; Principles of Prestressing; High Rise and Shell structures; Gravity and lateral load resisting systems; Space frames; Long span structures; Suspension structures; Catenary structures; Wind load & seismic considerations in high-rise structures; Disaster resistant structures; Temporary structures for rehabilitation;

Section B1.4	Building Services

Natural and mechanical ventilation; HVAC design principles; Air-Conditioning systems; Water supply and distribution system; Water harvesting systems; Water treatment, recycling and reuse; Storm water drainage; Sewage and waste disposal; Sanitary fittings and fixtures; Plumbing systems; Drainage system; Principles of electrification and illumination and special lighting for buildings; Acoustics in buildings; Vertical transport systems- standards and uses; Building automation systems; Firefighting Systems; Building Safety and Security systems; Building Management Systems; Services for specialised buildings like Hospitals, Indoor Sports Stadiums & High-rise buildings;

Section B1.5	Computer Applications in Architecture

Fundamental principles of computational methods; Logic-based understanding of pattern recognition, simulation, and data analytics; Computer applications in building design and performance analysis; Architectural visualization: 3d Modelling and BIM, Rendering, Virtual Reality, Augmented Reality; Computational design: parametric design, shape grammar and generative design; Visual communication; User Interface and User Experience Design; Digital design and fabrication methods: CNC mining and 3d printing; Artificial Intelligence for architecture.

Section B1.6	Project Management and Professional Practice

Construction planning and equipment; Construction project management techniques e.g. PERT, CPM; Professional practice and ethics; Estimation, costing and specification; Tendering; Arbitration; Role of Council of Architecture; Architecture journalism; Industrial architecture; Human Sociology; Building Economics; Interior design;

Part B2: Planning

Section B2.1	Planning History, Theory and Techniques

Origins of the city; Pre-industrial cities; Post-industrial cities; Garden City, City Beautiful, Broadacre, Radial City, Linear City; Concepts and theories of urban planning; Ekistics; Urban sociology; Theories of urban geography; Regional delineation; Settlement hierarchy; Urban growth models; Industrial location theories; Contemporary planning ideas and trends: Eco- City, Smart City; Network Cities, Global Cities etc.; Global North and South perspectives; Land use and land cover classification; Types, tools, and techniques of surveys; Sampling techniques; Demography – definition and variables; Techniques of population projections; Estimation and forecasting techniques in planning; Socio-economic analysis; Goal formulation and scenario analysis; Planning indicators, norms, and standards; Public perception and user behaviour;

Section B2.2	Planning Policy and Practice

Concepts, factors and trends of urbanization; International charters and mandates for planning; Constitutional and legal provision for planning; Planning as a state subject; Policies and programs for planning in India; Types and hierarchy of plans; Development norms, standards and guidelines such as URDPFI; Eminent domain; Land pooling and readjustment; Land acquisition; Laws governing land; Institutions of urban governance; Composition and functions of local self-governments and statutory institutions; Urban reforms and good governance; Participatory planning and use of technology; Municipal information systems, land

information systems, cadastral systems;

Section B2.3	Infrastructure, Services and Utilities

Water supply demand; Sources of water and intakes; Groundwater yield and recharge; Service Reservoir and Pumps; Water distribution system layout and network design; Water treatment; Water quality and testing; Water sensitive urban planning; Off-site and on-site sanitation; Decentralized sewerage system; Water carriage systems; Sewage quantity; Sewerage layout and network design; Sewer section and sewer design; Sewer appurtenances; Waste water treatment; Sewage disposal; Surface water runoff estimate, Discharge from streams and rivers; Flood protection measures; Layout and design of storm water drains; Rain water harvesting;

Solid waste management: collection, storage, transportation and disposal; Waste composition and characteristics; Recycling and Reuse of solid waste; Processing and treatment of solid wastes; Area requirements and location choice criteria for different facilities and infrastructure; Standards, rules and Codes; Fundamentals of power transmission & distribution; Transformers, Feeders, Substation;

Section B2.4	Urban Land Use and Transportation

Land Use-Transport-Urban form interaction; Urban structures and land use pattern; Economics concepts of land, rent, land use and land values; Land value capture; Transit Oriented Development, Urban regeneration and brown field redevelopment; Real estate pricing; Accessibility measures; Residence and employment location choice; Aggregate and disaggregate transport demand models and forecasting; Traffic and travel demand management and control in urban areas; Process and principles of traffic engineering; Design of roads, intersections, grade separators and parking areas; Hierarchy of roads and level of service; Modes of transportation; Pedestrian and non-motorized transport planning; Traffic survey methods, Traffic flow Analysis; Transport infrastructure and allied facilities planning; Intelligent transportation systems;

Section B2.5	Data Analysis, Remote Sensing and Geo-informatics

Types of data and sources of data for planning; Descriptive statistics; Tests of normality; Inferential statistics: linear and multiple regression, testing of hypothesis, testing of error, ANOVA etc.; Decision Problem Structuring: Analytical Hierarchical Process, Multi-Criteria Analysis etc.; Basic concepts in satellite remote sensing, satellites, sensors, and coverage; Principles of digital image processing; Satellite data products and their use; Aerial photography; Principles of photogrammetry; Application of remote sensing in urban and regional studies; G.l.S applications in planning; Georeferencing; Storage of spatial data; Processing tools; 2d(spatial), 3d(elevation) and 4d(temporal) data analysis and modeling; Database management systems; Structured query Language; Spatial queries; Application of Machine Learning in urban planning; Smart city loT applications; Python basics; Urban Analytics; Spatial Data Infrastructure;

Section B2.6	Project Implementation and Financing

Reforms in municipal finance; Municipal tax administration; Municipal budgeting; Fiscal indicators for finance; Municipal bonds/debentures; Loans and credit rating; Recovery mechanisms and pricing of services and infrastructure; Partnership approaches and types of contracts; Financial Viability & cost-benefit analysis; Project implementation, monitoring and evaluation; Asset management; Operation and maintenance; Institutional organizational structures and capacity building;

BM Biomedical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, Eigenvalues and Eigenvectors.

Calculus: Mean value theorems, theorems of integral calculus, partial derivatives, maxima and minima, multiple integrals, Fourier series, vector identities, line, surface and volume integrals, Stokes, Gauss and Green's theorems.

Differential equations: First order linear and nonlinear differential equations, higher order linear differential equations with constant coefficients, method of separation of variables, Cauchy's and Euler's equations, initial and boundary value problems, and solution of partial differential equations.

Analysis of complex variables: Analytic functions, Cauchy's integral theorem and integral formula, Taylor's and Laurent's series, residue theorem.

Probability and Statistics: Sampling theorems, conditional probability, mean, median, mode and standard deviation, random variables, discrete and continuous distributions: normal, Poisson and binomial distributions. Tests of Significance, statistical power analysis, and sample size estimation. Linear Regression and correlation analysis.

Numerical Methods: Matrix inversion, numerical solutions of nonlinear algebraic equations, iterative methods for solving differential equations, numerical integration.

Section 2: Electrical Circuits

Voltage and current sources - independent, dependent, ideal and practical; v-i relationships of resistor, inductor and capacitor; transient analysis of RLC circuits with dc excitation; Kirchoff's laws, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems; Peak, average and rms values of ac quantities; apparent, active and reactive powers; phasor analysis, impedance and admittance; series and parallel resonance, realization of basic filters with R, L and C elements, Bode plot.

Section 3: Signals and Systems

Continuous and Discrete Signal and Systems - Periodic, a periodic and impulse signals; Sampling theorem; Laplace and Fourier transforms; impulse response of systems; transfer function, frequency response of first and second order linear time invariant systems, convolution, correlation. Discrete time systems - impulse response, frequency response, DFT, Z - transform; basics of IIR and FIR filter.

Section 4: Analog and Digital Electronics

Basic characteristics and applications of diode, BJT and MOSFET; Characteristics and applications of operational amplifiers - difference amplifier, adder, subtractor, integrator, differentiator, instrumentation amplifier, buffer, filters and waveform generators. Number systems, Boolean algebra; combinational logic circuits - arithmetic circuits, comparators, Schmitt trigger, encoder/decoder, MUX/DEMUX, multi-vibrators; Principles of ADC and DAC; Microprocessor- architecture, interfacing memory and input- output devices.

Section 5: Measurements and Control Systems

SI units, systematic and random errors in measurement, expression of uncertainty - accuracy and precision index, propagation of errors; PMMC, MI and dynamometer type instruments; DC potentiometer; bridges for measurement of R, L and C, Q-meter. Basics of control system - transfer function.

Section 6: Sensors and Bioinstrumentation

Sensors - resistive, capacitive, inductive, piezoelectric, Hall effect, electro chemical, optical; Sensor signal conditioning circuits; application of LASER in sensing and therapy. Origin of bio potentials and their measurement techniques - ECG, EEG, EMG, ERG, EOG, GSR, PCG, Principles of measuring blood pressure, body temperature,

volume and flow in arteries, veins and tissues, respiratory measurements and cardiac output measurement. Operating principle of medical equipment-sphygmomanometer, ventilator, cardiac pacemaker, defibrillator, pulse oximeter, hemodialyzer Electrical Isolation (optical and electrical), Safety and Regulatory Aspects of Biomedical Instruments.	
Section 7:	**Mammalian Cell Biology, Human Anatomy and Physiology**
Basics of cell, types of tissues and organ systems; Homeostasis; Basics of organ systems & their physiological aspects - musculoskeletal, respiratory, circulatory, excretory, endocrine, nervous, and gastro-intestinal systems.	
Section 8:	**Medical Imaging Systems**
Instrumentation and image formation techniques in medical imaging modalities such as X-Ray, Computed Tomography, Single Photon Emission Computed Tomography, Positron Emission Tomography, Magnetic Resonance Imaging, Ultrasound.	
Section 9:	**Biomechanics**
Kinematics of muscles and joints - free-body diagrams and equilibrium, forces and stresses in joints, biomechanical analysis of joints, Gait analysis; Hard Tissues - Definition of Stress and Strain, Structure and mechanical properties of bone - cortical and cancellous bones; Soft Tissues - Structure, functions, material properties.	
Section 10:	**Biomaterials and Tissue Engineering**
Basic properties of biomaterials - Metallic, Ceramic, Polymeric, Carbon-based and Composite materials; Fundamental characteristics of implants - biocompatibility, bioactivity, biodegradability; Basics of tissue engineering. Biomaterial characterization techniques - Atomic Force Microscopy, Electron Microscopy, Fourier Transform Infrared Spectroscopy; Scaffold fabrication techniques– Electrospinning, 3D Printing and Bioprinting; Artificial Organs; Organoid; Organ-on-chip.	

BT	Biotechnology

Section 1:	Engineering Mathematics

Linear Algebra: Matrices and determinants; Systems of linear equations; Eigen values and Eigen vectors.

Calculus: Multivariable calculus (limits, continuity, and differentiability); Partial derivatives, maxima and minima; Sequences and series; Test for convergence. Multivariable calculus: Gradient, divergence, and curl (for applications in fluid mechanics, transport processes, etc.).

Differential Equations: Linear and nonlinear first order ODEs, higher order ODEs with constant coefficients; Cauchy's and Euler's equations; Laplace transforms.

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

Numerical Methods: Solution of linear and nonlinear algebraic equations; Integration by trapezoidal and Simpson's rule; Single step method for differential equations.

Section 2:	General Biology

Biochemistry: Biomolecules - structure and function; Biological membranes - structure, membrane channels and pumps, molecular motors, action potential and transport processes; Basic concepts and regulation of metabolism of carbohydrates, lipids, amino acids and nucleic acids; Metabolism: Regulation of metabolism of carbohydrates, lipids, amino acids, and nucleic acids; Detailed pathways like glycolysis, citric acid cycle, and fatty acid oxidation; Photosynthesis, respiration and electron transport chain; Enzymes - Classification, catalytic and regulatory strategies; Enzyme kinetics - Michaelis-Menten equation; Enzyme inhibition - competitive, non-competitive and uncompetitive inhibition.

Microbiology: History of Microbiology, Bacterial classification and diversity; Bacterial cell wall composition, Gram positive and Gram-negative bacteria, Archea, Methods in microbiology; Microbial growth and nutrition; Operon- Lac, Trp and Ara operon, Nitrogen fixation; Microbial diseases and host-pathogen interactions; Antibiotics and antimicrobial resistance, Two-component system (TCS), bacterial communication, Viruses - structure and classification.

Immunology: Primary and Secondary lymphoid organs; Innate immunity and Inflammation; Cytokines and Chemokines; Complement system; Effector responses: Cellular and Humoral Immunity; Molecular basis of Antibody diversity and function; Polyclonal and Monoclonal antibodies; T-cell and B-cell development; Memory responses; Major Histocompatibility complex (MHC); Antigen processing and presentation; Regulation of immune responses; Immune tolerance; Hypersensitivity; Autoimmunity and Immunodeficiency; Graft vs Host disease; Immunization and vaccines.

Section 3:	Genetics, Cellular and Molecular Biology

Genetics and Evolutionary Biology: Mendelian inheritance; Gene interaction; Complementation; Linkage, recombination and chromosome mapping; Extra chromosomal inheritance; Microbial genetics - transformation, transduction and conjugation; Bacterial gene mapping; Horizontal gene transfer and transposable elements; Chromosomal variation; Sex Determination; Genetic disorders; Population genetics; Epigenetics; Selection and inheritance; Adaptive and neutral evolution; Genetic drift; Species and speciation.

Cell Biology: Eukaryotic cell structure; Cell cycle and cell growth control; Cell-cell communication; Cell signalling and signal transduction; Non-cell autonomous cell signalling; Post-translational modifications; Protein trafficking; Cell death and autophagy; Extra-cellular matrix.

Molecular Biology: Molecular structure of genes and chromosomes; Mutations and mutagenesis;Regulation of gene expression; Nucleic acid - replication, transcription, splicing, translation and their regulatory mechanisms; Non-coding and micro RNA; RNA interference; DNA damage and repair.

Section 4:	Fundamentals of Biological Engineering

Bioreaction Engineering: Rate law, zero and first order kinetics; (More advanced kinetic models, including **Michaelis-Menten kinetics** for enzyme reactions. **Inhibition kinetics**: Competitive, non-competitive, and uncompetitive inhibition in enzyme catalysis); Ideal reactors - batch, mixed flow and plug flow; Enzyme immobilization, diffusion effects - Thiele modulus, effectiveness factor, Damkoehler number; Kinetics of cell growth, substrate utilization and product formation; Structured and unstructured models; Batch, fed-batch and continuous processes; Microbial and enzyme reactors; Optimization and scale up (Design and operation of microbial reactors (e.g., fermentation reactors) and enzyme reactors (e.g., immobilized enzyme systems); Case studies on the use of microbial reactors in large-scale production (e.g., antibiotics, biofuels).

Upstream and Downstream Processing: Media formulation and optimization; Sterilization of air and media; Filtration - membrane filtration, ultra filtration; Centrifugation - high speed and ultra; Cell disruption; Principles of chromatography - ion exchange, gel filtration, hydrophobic interaction, affinity, GC, HPLC and FPLC; Extraction, adsorption and drying; Measurement devices;Valves; First order and second order systems; Feedback and feed forward control; Types of controllers – proportional, derivative and integral control; Tuning of controllers.

Section 5:	Plant, Animal and Microbial Biotechnology

Plants: Totipotency; Cell fate transition, direct and indirect organogenesis, regeneration of plants; Plant growth regulators and elicitors; Tissue culture and cell suspension culture system - methodology, kinetics of growth and nutrient optimization; Production of secondary metabolites; Hairy root culture; Plant products of industrial importance; Artificial seeds; Somaclonal variation; Protoplast, protoplast fusion - somatic hybrid and cybrid; Transgenic plants - direct and indirect methods of gene transfer techniques; Selection marker and reporter gene; Plastid transformation.

Animals: Culture media composition and growth conditions; Animal cell and tissue preservation;Anchorage and non-anchorage dependent cell culture; Kinetics of cell growth; Micro & macro- carrier culture; Hybridoma technology; Stem cell technology; Animal cloning; Transgenic animals; Knock-out and knock-in animals.

Microbes: Production of biomass and primary/secondary metabolites - Biofuels, bioplastics, industrial enzymes, antibiotics; Large scale production and purification of recombinant proteins and metabolites; Clinical-, food- and industrial- microbiology; Screening strategies for new products.

Section 6:	Recombinant DNA technology and Other Tools in Biotechnology

Recombinant DNA technology: Restriction and modification enzymes; Vectors - plasmids, bacteriophage and other viral vectors, cosmids, Ti plasmid, bacterial and yeast artificial chromosomes; Expression vectors; cDNA and genomic DNA library Gene isolation and cloning, strategies for production of recombinant proteins; Transposons and gene targeting, Recombination-based gene cloning.

Molecular tools: Polymerase chain reaction; DNA/RNA labelling and Sangers and next generation sequencing; Southern and northern blotting; In-situ hybridization; DNA fingerprinting, RAPD, RFLP; Site-directed mutagenesis; CRISPR-Cas; Biosensing and biosensors; DNA-protein and protein-protein interaction tools; Genomics and proteomics-based approaches.

Analytical tools: Principles of microscopy - light, electron, fluorescence and confocal; Principles ofspectroscopy-UV, visible, fluorescence, CD, IR, FT-IR, MS, NMR; Electrophoresis; Micro- arrays; Enzymatic assays; Immunoassays - ELISA, RIA, immunohistochemistry; Immunoblotting; Flow cytometry; Whole genome and ChIP sequencing.

Computational tools: Bioinformatics resources and search tools; Sequence and structure databases; Sequence analysis - sequence file formats, scoring matrices, alignment, phylogeny; Genomics, proteomics, metabolomics; Gene prediction; Functional annotation; Secondary structure and 3D structure prediction; Knowledge discovery in biochemical databases; Metagenomics; Metabolic engineering and systems biology.

CE Civil Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra; Systems of linear equations; eigenvalues and eigenvectors.

Calculus: Functions of single variable; Limit, continuity and differentiability; Mean value theorems, local maxima and minima; Taylor series; Evaluation of definite and indefinite integrals, application of definite integral to obtain area and volume; Partial derivatives; Total derivative; Gradient, Divergence and Curl, Vector identities; Directional derivatives; Line, Surface and Volume integrals.

Ordinary Differential Equation (ODE): First order (linear and non-linear) equations; higher order linear equations with constant coefficients; Euler-Cauchy equations; initial and boundary value problems.

Partial Differential Equation (PDE): Fourier series; Separation of variables; solutions of one-dimensional diffusion equation; first and second order one-dimensional wave equation and two-dimensional Laplace equation.

Probability and Statistics: Basic concepts of probability – axioms and theorems, statistical independence; Conditional probability; Descriptive statistics – Mean, median, mode and standard deviation; Random Variables – Probability mass function, probability density function, cumulative distribution function; Poisson and Normal Distribution; Linear regression.

Numerical Methods: Error analysis. Numerical solutions of linear and nonlinear algebraic equations; Newton's and Lagrange polynomials; numerical differentiation; Integration by trapezoidal and Simpson's rule; Single and multi-step methods for first order differential equations.

Section 2: Structural Engineering

Engineering Mechanics: System of forces, free-body diagrams, equilibrium equations; Internal forces in structures; Frictions and its applications; Centre of mass.

Solid Mechanics: Bending moment and shear force in statically determinate beams; Transformation of stress (Mohr's circle); Simple stress and strain relationships; Simple bending theory, flexural and shear stresses, shear centre; Uniform torsion; Combined stresses; Column buckling.

Structural Analysis: Principle of superposition; Work and energy methods: Principle of virtual work, Castigliano's second theorem; Deflections of statically determinate beams, frames, and trusses; Analysis of statically indeterminate structures by force and displacement methods (method of consistent deformations, slope-deflection method, moment distribution method); Influence lines and moving loads; Stiffness matrix method; Analysis of determinate arches and cables.

Concrete Structures: Working stress and limit state design concepts; Design and detailing of beams, slabs, columns, and isolated footings; Bond and development length.

Steel Structures: Working stress and limit state design concepts; Design of tension and compression members, beams and beam-columns, column bases; Connections – simple and eccentric, beam-column connections; Concept of plastic analysis – beams and portal frames.

Section 3: Geotechnical Engineering

Three-phase system and phase relationships, index properties; Unified and Indian standard soil classification system; Permeability – one dimensional flow, Seepage through soils – two-dimensional flow, flow nets, uplift pressure, piping, capillarity, seepage force; Principle of effective stress and quicksand condition; Compaction

of soils; One-dimensional consolidation, time rate of consolidation; Shear Strength, Mohr's circle, effective and total shear strength parameters; Stress-strain characteristics of clays and sand; Stress paths.

Sub-surface investigations – Drilling bore holes, sampling, plate load test, standard penetration and cone penetration tests; Earth pressure theories – Rankine and Coulomb; Stability of slopes – Finite and infinite slopes, Bishop's method; Sheet Piles; Stress distribution in soils – Boussinesq's theory; Pressure bulbs; Shallow foundations – Terzaghi's and Meyerhof's bearing capacity theories, effect of water table; Combined footing and raft foundation; Contact pressure; Settlement analysis in sands and clays; Deep foundations – static formulae, axial load capacity of piles in sands and clays, pile load test, pile under lateral loading, pile group efficiency, negative skin friction; Ground improvement techniques.

Section 4: Water Resources Engineering

Fluid Mechanics: Properties of fluids, fluid statics; Continuity, momentum and energy equations and their applications; Potential flow, Laminar and turbulent flow; Flow in pipes, pipe networks; Concept of boundary layer and its growth; Concept of lift and drag.

Hydraulics: Forces on immersed bodies; Flow measurement in channels and pipes; Dimensional analysis and hydraulic similitude; Channel Hydraulics – Energy-depth relationships, specific energy, critical flow, hydraulic jump, uniform flow, gradually varied flow and water surface profiles; Prismatic and mobile channels, steady and unsteady flows, rapidly varied flow and hydraulic jump; Flow past sharp crested weirs.

Hydrology: Hydrologic cycle, precipitation, evaporation, evapo-transpiration, watershed, infiltration; Streamflow measurements, unit hydrographs, hydrograph analysis, reservoir capacity, flood estimation and routing, surface runoff models, ground water hydrology – steady state well hydraulics and aquifers; Application of Darcy's Law.

Irrigation: Types of irrigation systems and methods; Crop water requirements – Duty, delta, evapo-transpiration; Gravity dams and spillways; Lined and unlined canals, Design of weirs on permeable foundation; cross drainage structures; River training structures; Earthen dams; Seepage through dams; Well irrigation.

Section 5: Environmental Engineering

Water and Waste Water Quality and Treatment: Basics of water quality standards – Physical, chemical and biological parameters; Water quality index; Unit processes and operations; Water requirement; Water distribution system; Drinking water treatment.

Sewerage system design, quantity of domestic wastewater, primary, secondary and tertiary treatment. Effluent discharge standards; Sludge treatment and disposal; Reuse of treated sewage for different applications.

Air Pollution: Types of pollutants, their sources and impacts, air pollution control, air quality standards, Air quality index and limits.

Municipal Solid Wastes: Characteristics, generation, collection and transportation of solid wastes, engineered systems for solid waste management (reuse/recycle, energy recovery, treatment and disposal); Basics of landfill design and operation.

Section 6: Transportation Engineering

Transportation Infrastructure: Geometric design of roadways using IRC codes – crosssectional elements, sight distances, classifications of roadways, design vehicle, horizontal and vertical alignments.

Geometric design of railway Track – Speed and cant.

Concept of airport runway length, calculations and corrections; taxiway and exit taxiway design.

Highway Pavements: Highway materials – desirable properties and tests; Desirable properties of bituminous paving mixes; Design factors for flexible and rigid pavements; Design of flexible and rigid pavement using IRC codes.

Traffic Engineering: Traffic studies on flow and speed, peak hour factor, accident study, statistical analysis of traffic data; Microscopic and macroscopic parameters of traffic flow, fundamental relationships; Traffic signs; Signal design by Webster's method; Types of intersections and interchanges; Highway capacity and level of service.

Transportation Planning: Four step travel demand modelling – trip generation, trip distribution, mode choice, traffic assignment and its applications.

Section 7:	Geomatics Engineering

Principles of surveying; Plane and geodetic surveying, GNSS surveying, errors and their adjustment; Maps – Scale, coordinate system; Distance and angle measurement – Levelling and trigonometric levelling; Traversing and triangulation survey; Total station; Principles of topographic, cadastral, engineering; Introduction to cartography, map projections.

Photogrammetry – Introduction to photogrammetry, digital photogrammetry, photographic scale, flying height; Space resection, parallax equations, elevations by parallax differences, camera calibration.

Section 8:	Construction Materials and Management

Construction Materials: Steel – Composition, material properties and behaviour; Cement – composition, hydration and microstructure, chemical and mineral admixtures; Concrete – Constituents, mix design, short-term and long-term properties.

Construction Management: Types of construction projects; Estimation and costing – Quantity estimation using long wall and short wall method, center line method, analysis of rates; Project planning and scheduling: AOA and AON network analysis – PERT and CPM; Project updating and monitoring; Construction equipment – Equipment for earthwork, concreting, hoisting and transportation of materials; Types of contracts.

CH Chemical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra; Systems of linear equations; Eigenvalues and eigenvectors.

Calculus: Functions of single variable; Limit, continuity and differentiability; Taylor series; Mean value theorem; Evaluation of definite and improper integrals; Partial derivatives; Total derivative; Maxima and minima; Gradient, divergence, and curl; Vector identities; Directional derivatives; Line, surface, and volume integrals; Stokes, Gauss, and Green's theorems.

Differential Equations: First order equations (linear and nonlinear); Higher order linear differential equations with constant coefficients; Cauchy's and Euler's equations; Initial and boundary value problems; Laplace transforms; Solutions of one-dimensional heat equation, wave equation, and Laplace equation.

Complex Variables: Complex number; polar form of complex number.

Probability and Statistics: Definitions of probability and sampling theorems; Conditional probability; Mean, median, mode, and standard deviation; Random variables; Poisson, Normal, and Binomial distributions.

Fundamentals of AI/ML: Linear Regression; Principal Component Analysis (PCA).

Numerical Methods: Numerical solutions of linear and non-linear algebraic equations; Integration by trapezoidal and Simpson's rule; Single and multi-step methods for numerical solution of ordinary differential equations; Finite-difference method for partial differential equations.

Section 2: Process Calculations

Steady and unsteady state mass and energy balances including multiphase, multi-component, reacting and non-reacting systems; Use of tie components; Recycle, bypass and purge calculations; Gibbs phase rule and degree of freedom analysis.

Section 3: Thermodynamics

Laws of thermodynamics; Open and closed systems; Entropy and chemical potential; Thermodynamic properties of pure substances: equations of state and residual properties; Thermodynamic properties of mixtures: partial molar properties, fugacity, excess properties, and activity coefficients; Phase equilibria: predicting VLE of systems; Chemical reaction equilibrium.

Section 4: Fluid Mechanics and Mechanical Operations

Newtonian and non-Newtonian fluids; Fluid statics; Surface Tension; Fluid kinematics; Equation of continuity, Equation of motion, Equation of mechanical energy; Macroscopic friction factors; Dimensional analysis and similitude; Inviscid flows: Euler equation; Flow through pipes: velocity profile, pressure drop, Bernoulli equation, flow meters; Pumps; Turbulent flow: fluctuating velocity, universal velocity profile, pressure drop; Elementary boundary layer theory; Flow past immersed bodies including packed and fluidized beds.

Particle size and shape; Particle size distribution; Size reduction and classification of solid particles; Free and hindered settling; Centrifuge and cyclones; Thickening and clarification; Filtration, agitation and mixing.

Section 5:	Heat Transfer
Equation of energy; Steady and unsteady heat conduction, convection, and radiation; Thermal boundary layer and heat transfer coefficients; Boiling, condensation, and evaporation; Types of heat exchangers and evaporators and their process calculations; Design of double pipe, shell and tube heat exchangers, and single and multiple effect evaporators.	
Section 6:	**Mass Transfer**
Fick's laws; Molecular diffusion in fluids; Mass transfer coefficients; Film, penetration and surface renewal theories; Momentum, heat and mass transfer analogies; Stage-wise and continuous contacting and stage efficiencies; HTU & NTU concepts. Fundamentals concepts and design of mass transfer operations: distillation, absorption, leaching, liquid-liquid extraction, drying, humidification, dehumidification and adsorption, membrane separations.	
Section 7:	**Chemical Reaction Engineering**
Theories of reaction rates; Kinetics of homogeneous reactions; Interpretation of kinetic data; Single and multiple reactions in ideal reactors; Kinetics of enzyme reactions (Michaelis-Menten and Monod models); Non-ideal reactors: residence time distribution, single parameter model; Non-isothermal reactors; Kinetics of heterogeneous catalytic reactions; Diffusion effects in catalysis; Catalyst deactivation.	
Section 8:	**Instrumentation and Process Control**
Measurement of process variables; Sensors and transducers; P&ID equipment symbols; Process modeling and linearization; State-space models; Transfer functions and dynamic responses of various systems; Systems with inverse response; Process reaction curve; Controller modes (P, PI, and PID); Control valves; Analysis of closed loop systems including stability, frequency response, controller tuning, cascade and feed forward control.	
Section 9:	**Plant Design and Economics**
Principles of process economics and cost estimation including depreciation and total annualized cost, cost indices, rate of return, payback period, discounted cash flow; Optimization in process design and sizing of chemical engineering equipment such as heat exchangers and multistage contactors; Batch plant scheduling.	
Section 10:	**Chemical Technology**
Overview of raw materials, unit operations, and processes involved in inorganic chemical industries (synthesis gas, sulfuric acid, phosphoric acid, chlor-alkali industry), fertilizers (ammonia, urea), natural products industries (pulp and paper, sugar and ethanol), petroleum refining and petrochemicals (ethyl benzene, styrene, ethylene oxide), polymerization industries (polyethylene and polyester).	

CS Computer Science and Information Technology

Section 1: Engineering Mathematics

Discrete Mathematics: Propositional and first order logic. Sets, relations, functions, partial orders and lattices. Monoids, Groups. Graphs: connectivity, matching, colouring. Combinatorics: counting, recurrence relations, generating functions.

Linear Algebra: Matrices, determinants, system of linear equations, eigenvalues and eigenvectors, LU decomposition.

Calculus: Limits, continuity and differentiability, Maxima and minima, Mean value theorem, Integration.

Probability and Statistics: Random variables, Uniform, normal, exponential, Poisson and binomial distributions. Mean, median, mode and standard deviation. Conditional probability and Bayes theorem.

Section 2: Digital Logic

Boolean algebra and minimization – algebraic technique, Karnaugh map, tabular method. Design of combinational and sequential circuits. Number representation and arithmetic (fixed and floating point).

Section 3: Computer Organization and Architecture

Instruction set and addressing modes. Design of arithmetic and logic unit (ALU). Design of control unit – hardwired and microprogrammed. Memory interfacing and hierarchy: performance, cache memory mapping. I/O interface (interrupt and DMA). Instruction pipelining, pipeline hazards.

Section 4: Programming and Data Structures

Programming in C. Recursion. Arrays, stacks, queues, linked lists, trees, binary search trees, binary heaps, graphs.

Section 5: Algorithms

Searching, sorting, hashing. Asymptotic worst case time and space complexity. Algorithm design techniques: greedy, dynamic programming and divide-and-conquer. Graph traversals, minimum spanning trees, shortest paths.

Section 6: Theory of Computation

Regular expressions and finite automata. Context-free grammars and push-down automata. Regular and context-free languages, pumping lemma. Turing machines and undecidability.

Section 7: Compiler Design

Lexical analysis, parsing, syntax-directed translation. Runtime environments. Intermediate code generation. Local optimisation, Data flow analyses: constant propagation, liveness analysis, common sub expression elimination.

Section 8: Operating System

System calls, processes, threads, inter-process communication, concurrency and synchronization. Deadlock. CPU and I/O scheduling. Memory management and virtual memory. File systems.

Section 9:	Databases

ER-model. Relational model: relational algebra, tuple calculus, SQL. Integrity constraints, normal forms. File organization, indexing (e.g., B and B+ trees). Transactions and concurrency control.

Section 10:	Computer Networks

Principles of Layering; Basics of switching (circuit, packet and virtual circuit) and performance metrics;

Data link layer: error detection, Medium Access Control, Ethernet; Distance vector and link state routing; IPv4 - Fragmentation, CIDR Notation, Network Address Translation; TCP- flow control and congestion control, socket API; DNS and HTTP.

CY Chemistry

Section 1: Physical Chemistry

Structure: Postulates of quantum mechanics. Operators. Commutation relations and expectations values; the role of the wave function and its absolute squares, time dependent and time independent Schrödinger equations. Born interpretation. Dirac bra-ket notation. Examples of model solvable quantum mechanical systems.

Particle in a Box: Solutions and interpretations for finite length and infinite potential barrier; concept of tunnelling; particle in 1D, 2D and 3D-boxes; applications.

Harmonic Oscillator: Exact solutions of wave functions, properties of Hermite polynomials. eigenvalues in one dimension. Calculation of expectation values for potential and kinetic energy, harmonic and anharmonic potentials.
Rotational Motion: Angular momentum operators (orbital and spin), spherical harmonics and their properties.

Hydrogen and Hydrogen-like Atoms: Atomic orbitals; radial and angular distribution functions and their probabilities; Atomic units, Multi-electron atoms: Orbital approximation; electron spin; Pauli exclusion principle; Slater determinants. Variational method and secular determinants; first order non-degenerate perturbation techniques.

Molecular Structure and Chemical Bonding: Born-Oppenheimer approximation; Valence bond theory treatment for hydrogen molecule and linear combination of atomic orbitals – molecular orbitals (LCAO-MO) theory. Concept of hybridization and hybrid orbitals. Applications of LCAO-MO theory to H_2^+, H_2; Molecular orbital theory (MOT) of homo- and heteronuclear diatomic molecules. Hückel theory, applications to simple molecules, small conjugated π-electron systems.

Group Theory: Symmetry elements and symmetry operations. Basic postulates of groups and group multiplication tables. Classes, reducible and irreducible representations of symmetry elements. Classification and labelling of molecular point groups. Symmetry based selection rules and their application to electronic and vibrational spectroscopy. Internal coordinates and symmetry labelling of vibrational modes; symmetry adapted linear combination of atomic orbitals (LCAO-MO); construction of hybrid orbitals using molecular point group symmetry.

Spectroscopy: Atomic spectroscopy; Russell-Saunders coupling; Term symbols and spectral details; origin of selection rules. Rotational, Vibrational, Electronic and Raman spectroscopy of diatomic and simple polyatomic molecules. Line broadening and line widths; simple properties of Gaussian and Lorentzian line shapes. Molecular spectroscopy: Absorbance, Beer- Lambert's law, Einstein's coefficient, Jablonski diagram. Relationship of transition moment integral with molar extinction coefficient and oscillator strength. Basic principles of Nuclear Magnetic Resonance: Gyromagnetic ratio; Chemical shift, nuclear coupling.

Equilibrium: Laws of thermodynamics. Standard states. Thermochemistry. Thermodynamic functions and their relationships: Gibbs-Helmholtz and Maxwell relations, Gibbs-Duhem equation, Van't Hoff equation. Criteria of spontaneity and equilibrium. Absolute entropy. Partial molar quantities. Thermodynamics of mixing. Chemical potential. Fugacity, Activity and Activity coefficient. Chemical equilibria. Dependence of equilibrium constant on temperature and pressure.

Solutions: Ideal and non-ideal solutions, Raoult's Law and Henry's Law.

Electrochemistry: Standard electrode potential and electrochemical cells. Nernst Equation and its application, relationship between electrode potential and thermodynamic quantities, Potentiometric and conductometric titrations. Ionic mobility and conductivity. Kohlrausch's law, Debye-Hückel limiting law. Debye-Hückel-Onsager equation.

Phase Equilibria: Phase rule. Clausius- Clapeyron equation. Phase diagram of one component system: CO_2, H_2O, S; two component systems: liquid-vapor, liquid-liquid and solid-liquid systems. Fractional distillation. Azeotropes and Eutectics.

Statistical Thermodynamics: Micro-canonical, Canonical and Grand canonical ensembles, Boltzmann distribution, Partition functions and thermodynamic properties. Statistical mechanics of non-interacting systems, ideal monoatomic, diatomic gases, translational, rotational, vibrational and electronic partition functions.

Kinetics and Reaction Dynamics: Elementary, parallel, opposing, and consecutive reactions. Steady state approximation. Mechanism of complex reactions. Unimolecular reactions. Potential energy surface and classical trajectories, Concept of saddle points, Transition state theory: Eyring equation, thermodynamic aspects. Kinetics of polymerization. Catalysis concepts and enzyme catalysis. Kinetic isotope effects. Fast reaction kinetics: relaxation and flow methods. Diffusion controlled reactions. Kinetics of unimolecular and bimolecular photophysical processes, Quantum yield calculation, static and dynamic quenching.

Surfaces and Interfaces: Physisorption and chemisorption. Langmuir, Freundlich and Brunauer-Emmett-Teller (BET) isotherms. Surface catalysis: Langmuir-Hinshelwood mechanism. Surface tension, viscosity, Self-assembly/ physical chemistry of colloids, micelles and macromolecules.

Section 2: Inorganic Chemistry

Main Group Elements: Shapes and structures of molecules using VSEPR postulates, Hydrides, halides, oxides, oxoacids, nitrides, sulfides - shapes and reactivity. Structure and bonding of boranes, carboranes, silicones, silicates, boron nitride, borazine and phosphazenes: electron counting in polyhedral boranes, isolobal analogy. Allotropes of carbon, phosphorus and sulfur. Industrial synthesis of compounds of main group elements such as NH_3, H_2SO_4 and HNO_3. Chemistry of noble gases and interhalogen compounds. Acid-base concepts and principles (Lewis, Brønsted, HSAB and acid-base catalysis).

Transition Metals: Coordination chemistry – structure and isomerism, theories of bonding (VBT, CFT, and MOT). Metal-metal multiple bonds. Energy level diagrams in various crystal fields, CFSE, applications of CFT, Jahn-Teller distortion. Electronic spectra of transition metal complexes: spectroscopic term symbols, selection rules, Orgel and Tanabe-Sugano diagrams, nephelauxetic effect and Racah parameter, charge-transfer spectra. Magnetic properties of transition metal complexes. Ray-Dutt and Bailar twists, Reaction mechanisms: kinetic and thermodynamic stability, associative, dissociative substitution and redox reactions.

Lanthanides and Actinides: Recovery. Periodic properties, spectral and magnetic properties.

Organometallics: 18-Electron rule; metal-alkyl, metal-carbonyl, metal-olefin and metal-carbene complexes and metallocenes. Fluxionality in organometallic complexes. Types of organometallic reactions. Homogeneous catalysis – Hydrogenation, hydroformylation, methanol to acetic acid process, olefin metathesis and Wacker oxidation. Heterogeneous catalysis – Fischer-Tropsch reaction, Ziegler-Natta polymerization.

Bioinorganic Chemistry: Ion (Na^+ and K^+) transport, oxygen binding, transport and utilization, electron transfer reactions, nitrogen fixation, metalloenzymes containing magnesium, molybdenum, iron, cobalt, copper and zinc.

Solids: Crystal systems and lattices, Miller planes, crystal packing, crystal defects, Bragg's law, ionic crystals, structure of AX, AX_2, ABX_3 type compounds, spinels, band theory, metals and semiconductors, Zeolites and their applications.

Instrumental Methods of Analysis: UV-visible, fluorescence and FT-IR spectrophotometry, NMR and ESR spectroscopy, mass spectrometry, atomic absorption spectroscopy, Mössbauer spectroscopy (Fe and Sn) and X-ray crystallography. Electroanalytical methods – cyclic voltammetry, ion-selective electrodes. Thermo-analytical methods: TGA, DTA and DSC.

Section 3: Organic Chemistry

General Concepts: Structure dependence on properties such as basicity and acidity. Role of aromatic stability on physical properties of organic compounds.

Stereochemistry: Chirality and symmetry of organic molecules with or without chiral centres and determination of their absolute configurations and optical purity. Relative stereochemistry in compounds having more than one stereogenic centre. Homotopic, enantiotopic and diastereotopic atoms, groups and faces. Conformational

analysis of acyclic and cyclic compounds. Geometrical isomerism and optical isomerism. Configurational and conformational effects, atropisomerism, and neighbouring group participation on reactivity and selectivity/specificity. Stereoselective and stereospecific synthesis. Enantiomeric excess.

Reaction Mechanisms: Basic mechanistic concepts and energy profile diagrams - kinetics versus thermodynamic control, Hammond's postulate and Curtin-Hammett principle. Methods of determining reaction mechanisms through kinetics, identification of products, intermediates and isotopic labelling. Solvent effects in substitution and elimination reactions. Linear free-energy relationship – Hammett and Taft equations.

Types of Reactions: Nucleophilic and electrophilic substitution reactions (both aromatic and aliphatic). Addition reactions to carbon-carbon and carbon-heteroatom (N and O) multiple bonds. Elimination reactions. Reactive intermediates – carbocation, carbanion, carbenes, nitrenes, arynes and free radicals. Molecular rearrangements. Barton decarboxylation and Barton-McCombie reaction, Hunsdiecker reaction.

Organic Synthesis: Synthesis, reactions, mechanisms and selectivity involving the following classes of compounds – alkenes, alkynes, arenes, alcohols, phenols, aldehydes, ketones, carboxylic acids, esters, nitriles, halides, nitro compounds, amines and amides. Uses of Mg, Li, Cu, B, Zn, P, S, Sn and Si based reagents in organic synthesis. Carbon-carbon bond formation through coupling reactions – Heck, Suzuki, Stille, Sonogashira, Negishi, Kumada, Hiyama, Tsuji-Trost reactions; olefin metathesis, McMurry coupling and Buchwald-Hartwig amination reactions. Baylis-Hillman, Henry, Ritter, Sakurai, Tebbe olefination, Pauson-Khand and Nazarov cyclization reactions. Concepts of multistep synthesis – retrosynthetic analysis, strategic disconnections, synthons and synthetic equivalents. Atom economy and green chemistry, Umpolung reactivity – formyl and acyl anion equivalents. Selectivity in organic synthesis – chemo-, regio- and stereoselectivity. Protection and deprotection of functional groups. Concepts of asymmetric synthesis – resolution (including enzymatic), desymmetrization and use of chiral auxiliaries, organocatalysis. Carbon-carbon and carbonheteroatom bond forming reactions through enolates (including boron enolates), enamines and silyl enol ethers. Stereoselective addition to C=O groups (Cram, Prelog and Felkin-Anh models). Asymmetric aldol reactions – Evans reaction and proline catalyzed reaction.

Oxidation: Oxidation of alcohols involving metal and non-metal-based (chromium, manganese, DMSO, and hypervalent iodine) reagents. Peracid oxidation of alkenes and carbonyls. Alkenes to diols (manganese and osmium-based reagents), alkenes to carbonyls with bond cleavage (ozonolysis), and alkenes to alcohols/carbonyls without bond cleavage (hydroboration-oxidation). Asymmetric epoxidations (Sharpless and Jacobsen) and Sharpless asymmetric hydroxylation.

Reduction: Catalytic homogeneous and heterogeneous hydrogenation. Metal based reductions using Li/Na in liquid ammonia, magnesium, zinc, titanium, and samarium. Hydride transfer reagents: $NaBH_4$, L-selectride, K-selectride, Luche reduction, $LiAlH_4$ and DIBAL-H.

Pericyclic Reactions and Photochemistry: Electrocyclic, cycloaddition and sigmatropic reactions. Diels-Alder reaction, Claisen and Cope rearrangements and their applications in organic synthesis. FMO method of analysis. Woodward-Hoffmann rules. Photochemistry of alkenes, arenes and carbonyl compounds. Photo-oxidation and photo-reduction. Di-π-methane rearrangements, Norrish type-I and II reactions. Paternó-Büchi reaction, Photo-Curtius and Wolff rearrangements. Barton and Hofmann-Löffler-Freytag reactions.

Heterocyclic Compounds: Nomenclature of mono- and bicyclic, as well as mono- and di-heteroatomic compounds, Structure, preparation, properties and reactions of furan, pyrrole, thiophene, pyridine, indole, quinoline and isoquinoline.

Biomolecules: Structure, properties and reactions of mono- and di-saccharides, physicochemical properties of amino acids, chemical synthesis of peptides, chemical structure determination of peptides and proteins, structural features of proteins, nucleic acids, lipids, steroids, terpenoids, carotenoids, and alkaloids.

Experimental Techniques in Organic Chemistry: Optical rotation (polarimetry). Application of various chromatographic techniques such as thin-layer, column, HPLC and GC. Applications of UV-visible, IR, NMR spectroscopy and Mass spectrometry in the structural determination of organic molecules.

DA Data Science and Artificial Intelligence

Section 1: Probability and Statistics

Counting (permutation and combinations), probability axioms, Sample space, events, independent events, mutually exclusive events, marginal, conditional and joint probability, Bayes Theorem, conditional expectation and variance, mean, median, mode and standard deviation, correlation, and covariance, random variables, discrete random variables and probability mass functions, uniform, Bernoulli, binomial distribution, Continuous random variables and probability distribution function, uniform, exponential, Poisson, normal, standard normal, t-distribution, chi-squared distributions, cumulative distribution function, Conditional PDF, Central limit theorem, confidence interval, z-test, t-test, chi-squared test.

Section 2: Linear Algebra

Vector space, subspaces, linear dependence and independence of vectors, matrices, projection matrix, orthogonal matrix, idempotent matrix, partition matrix and their properties, quadratic forms, systems of linear equations and solutions; Gaussian elimination, eigenvalues and eigenvectors, determinant, rank, nullity, projections, LU decomposition, singular value decomposition.

Section 3: Calculus and Optimization

Functions of a single variable, limit, continuity and differentiability, Taylor series, maxima and minima, optimization involving a single variable.

Section 4: Programming, Data Structures and Algorithms

Programming in Python, basic data structures: stacks, queues, linked lists, trees, hash tables; Search algorithms: linear search and binary search, basic sorting algorithms: selection sort, bubble sort and insertion sort; divide and conquer: mergesort, quicksort; introduction to graph theory; basic graph algorithms: traversals and shortest path.

Section 5: Database Management and Warehousing

ER-model, relational model: relational algebra, tuple calculus, SQL, integrity constraints, normal form, file organization, indexing, data types, data transformation such as normalization, discretization, sampling, compression; data warehouse modelling: schema for multidimensional data models, concept hierarchies, measures: categorization and computations.

Section 6: Machine Learning

Supervised Learning: regression and classification problems, simple linear regression, multiple linear regression, ridge regression, logistic regression, k-nearest neighbour, naive Bayes classifier, linear discriminant analysis, support vector machine, decision trees, bias-variance trade-off, cross-validation methods such as leave-one-out (LOO) cross-validation, k-folds cross-validation, multi-layer perceptron, feed-forward neural network;

Unsupervised Learning: clustering algorithms, k-means/k-medoid, hierarchical clustering, top-down, bottom-up: single-linkage, multiple-linkage, dimensionality reduction, principal component analysis.

Section 7: AI

Search: informed, uninformed, adversarial; logic, propositional, predicate; reasoning under uncertainty topics — conditional independence representation, exact inference through variable elimination, and approximate inference through sampling.

EC Electronics and Communication Engineering

Section 1: Engineering Mathematics

Linear Algebra: Vector space, basis, linear dependence and independence, matrix algebra, eigen values and eigen vectors, rank, solution of linear equations - existence and uniqueness.

Calculus: Mean value theorems, theorems of integral calculus, evaluation of definite and improper integrals, partial derivatives, maxima and minima, multiple integrals, line, surface and volume integrals, Taylor series.

Differential Equations: Linear differential equations, Euler-Cauchy equation, Nonhomogeneous equations, methods of solution using variation of parameters, complementary function and particular integral, partial differential equations, variable separable method, initial and boundary value problems.

Vector Analysis: Vectors in plane and space, vector operations, gradient, divergence and curl, Gauss's, Green's and Stokes' theorems.

Complex Analysis: Analytic functions, Cauchy's integral theorem, Cauchy's integral formula, sequences, series, convergence tests, Taylor and Laurent series, residue theorem.

Probability and Statistics: Mean, median, mode, standard deviation, combinatorial probability, probability distributions, binomial distribution, Poisson distribution, exponential distribution, normal distribution, joint and conditional probability, correlation and regression analysis.

Section 2: Networks, Signals and Systems

Circuit Analysis: Node and mesh analysis, superposition, Thevenin's theorem, Norton's theorem, reciprocity. Sinusoidal steady state analysis: phasors, complex power, maximum power transfer.

Time and frequency domain analysis of linear circuits: RL, RC and RLC circuits, solution of network equations using Laplace transform. Linear 2-port network parameters, wye-delta transformation.

LTI systems: definition and properties, causality, stability, impulse response, convolution, poles and zeroes, frequency response, group delay, phase delay.

Continuous-time Signals: Fourier series and Fourier transform, Nyquist sampling theorem, sampling and reconstruction.
Discrete-time Signals: DTFT, DFT, z-transform, FIR and IIR filter design.

Section 3: Electronic Devices

Formation of energy bands in solids, energy bands in intrinsic and extrinsic semiconductors, equilibrium carrier concentration, direct and indirect band-gap semiconductors.

Carrier Transport: Diffusion current, drift current, mobility and resistivity, generation and recombination of carriers, Poisson and continuity equations.

P-N junction, Zener diode, BJT, MOS capacitor, MOSFET, scaling in MOSFETs, LED, photo diode and solar cell.

Section 4: Analog Circuits

Diode Circuits: Clipping, clamping and rectifiers.
BJT and MOSFET Amplifiers: Biasing, AC coupling, small signal analysis, frequency response. Current mirrors and differential amplifiers.

Op-amp Circuits: Amplifiers, summers, differentiators, integrators, active filters, Schmitt trigger and oscillators, dominant-pole (Miller) compensation, phase margin.

Section 5:	Digital Circuits

Number Representations: Binary, integer and floating-point- numbers. Combinatorial circuits: Boolean algebra, minimization of functions using Boolean identities and Karnaugh map, logic gates and their static CMOS implementations, arithmetic circuits, code converters, multiplexers, decoders.

Sequential Circuits: Latches and flip-flops, counters, shift-registers, finite state machines, propagation delay, setup and hold time, critical path delay.
Data Converters: Sample and hold circuits, ADCs and DACs.
Semiconductor Memories: ROM, SRAM, DRAM.
Computer Organization: Machine instructions and addressing modes, ALU, data-path and control unit, instruction pipelining.

Section 6:	Control Systems

Basic control system components; Feedback principle; Transfer function; Block diagram representation; Signal flow graph; Transient and steady-state analysis of LTI systems; Frequency response; Routh-Hurwitz and Nyquist stability criteria; Bode and root-locus plots; compensators, PID controller; State variable model and solution of state equation of LTI systems.

Section 7:	Communications

Random Processes: Autocorrelation and power spectral density, properties of white noise, filtering of random signals through LTI systems.

Analog Communications: Amplitude modulation and demodulation, angle modulation and demodulation, spectra of AM and FM, super heterodyne receivers.

Information Theory: Entropy, source coding, mutual information and channel capacity theorem.

Digital Communications: PCM, DPCM, digital modulation schemes (ASK, PSK, FSK, QAM), bandwidth, inter-symbol interference, MAP, ML detection, matched filter receiver, SNR and BER. Fundamentals of error correction, Hamming codes, CRC.

Section 8:	Electromagnetics

Maxwell's Equations: Differential and integral forms and their interpretation, boundary conditions, wave equation, Poynting vector.

Plane Waves and Properties: Reflection and refraction, polarization, phase and group velocity, propagation through various media, skin depth.

Transmission Lines: Equations, characteristic impedance, impedance matching, impedance transformation, Sparameters, Smith chart. Rectangular and circular waveguides, light propagation in optical fibers, dipole and monopole antennas, linear antenna arrays.

EE Electrical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix Algebra, Systems of linear equations, Eigen values, Eigen vectors.

Calculus: Mean value theorems, Theorems of integral calculus, Evaluation of definite and improper integrals, Partial Derivatives, Maxima and minima, Multiple integrals, Fourier series, Vector identities, Directional derivatives, Line integral, Surface integral, Volume integral, Stokes's theorem, Gauss's theorem, Divergence theorem, Green's theorem.

Differential Equations: First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Method of variation of parameters, Cauchy's equation, Euler's equation, Initial and boundary value problems, Partial Differential Equations, Method of separation of variables.

Complex Variables: Analytic functions, Cauchy's integral theorem, Cauchy's integral formula, Taylor series, Laurent series, Residue theorem, Solution integrals.

Probability and Statistics: Sampling theorems, Conditional probability, Mean, Median, Mode, Standard Deviation, Random variables, Discrete and Continuous distributions, Poisson distribution, Normal distribution, Binomial distribution, Correlation analysis, Regression analysis.

Section 2: Electric circuits

Network Elements: Ideal voltage and current sources, dependent sources, R, L, C, M elements; Network solution methods: KCL, KVL, Node and Mesh analysis; Network Theorems: Thevenin's, Norton's, Superposition and Maximum Power Transfer theorem; Transient response of DC and AC networks, sinusoidal steady-state analysis, resonance, two port networks, balanced three phase circuits, star-delta transformation, complex power and power factor in AC circuits.

Section 3: Electromagnetic Fields

Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits, Self and Mutual inductance of simple configurations.

Section 4: Signals and Systems

Representation of continuous and discrete time signals, shifting and scaling properties, linear time invariant and causal systems, Fourier series representation of continuous and discrete time periodic signals, sampling theorem, Applications of Fourier Transform for continuous and discrete time signals, Laplace Transform and Z transform. R.M.S. value, average value calculation for any general periodic waveform.

Section 5: Electrical Machines

Single phase transformer: equivalent circuit, phasor diagram, open circuit and short circuit tests, regulation and efficiency; Three-phase transformers: connections, vector groups, parallel operation; Auto-transformer, Electromechanical energy conversion principles; DC machines: separately excited, series and shunt, motoring and generating mode of operation and their characteristics, speed control of dc motors; Three-phase induction machines: principle of operation, types, performance, torque-speed characteristics, no-load and blocked-rotor tests, equivalent circuit, starting and speed control; Operating principle of single-phase induction motors; Synchronous machines: cylindrical and salient pole machines, performance and characteristics, regulation and parallel operation of generators, starting of synchronous motors; Types of losses and efficiency calculations of electric machines.

Section 6:	Power Systems
Basic concepts of electrical power generation, AC and DC transmission concepts, Models and performance of transmission lines and cables, Economic Load Dispatch (with and without considering transmission losses), Series and shunt compensation, Electric field distribution and insulators, Distribution systems, Per-unit quantities, Bus admittance matrix, Gauss- Seidel and Newton-Raphson load flow methods, Voltage and Frequency control, Power factor correction, Symmetrical components, Symmetrical and unsymmetrical fault analysis, Principles of over-current, differential, directional and distance protection; Circuit breakers, System stability concepts, Equal area criterion.	
Section 7:	**Control Systems**
Mathematical modelling and representation of systems, Feedback principle, transfer function, Block diagrams and Signal flow graphs, Transient and Steady-state analysis of linear time invariant systems, Stability analysis using Routh-Hurwitz and Nyquist criteria, Bode plots, Root loci, Lag, Lead and Lead-Lag compensators; P, PI and PID controllers; State space model, Solution of state equations of LTI systems.	
Section 8:	**Electrical and Electronic Measurements**
Bridges and Potentiometers, Measurement of voltage, current, power, energy and power factor; Instrument transformers, Digital voltmeters and multi-meters, Phase, Time and Frequency measurement; Oscilloscopes, Error analysis.	
Section 9:	**Analog and Digital Electronics**
Simple diode circuits: clipping, clamping, rectifiers; Amplifiers: biasing, equivalent circuit and frequency response; oscillators and feedback amplifiers; operational amplifiers: characteristics and applications; single stage active filters, Active Filters: Sallen Key, Butterworth, VCOs and timers, combinatorial and sequential logic circuits, multiplexers, demultiplexers, Schmitt triggers, sample and hold circuits, A/D and D/A converters.	
Section 10:	**Power Electronics**
Static V-I characteristics and firing/gating circuits for Thyristor, MOSFET, IGBT; DC to DC conversion: Buck, Boost and Buck-Boost Converters; Single and three-phase configuration of uncontrolled rectifiers; Voltage and Current commutated Thyristor based converters; Bidirectional ac to dc voltage source converters; Magnitude and Phase of line current harmonics for uncontrolled and thyristor based converters; Power factor and Distortion Factor of AC to DC converters; Single-phase and three-phase voltage and current source inverters, sinusoidal pulse width modulation.	

ES Environmental Science and Engineering

Section 1: Mathematics Foundation

Linear Algebra: Determinants and matrices, Systems of linear equations, Eigenvalues and eigenvectors.

Calculus: Functions, Limit, Continuity, Differentiability, Local maxima and minima, Taylor series, Tests for convergence, Definite and indefinite integrals, Application of definite integral to obtain area and volume, Partial and total derivatives, Linear and non-linear first order ordinary differential equations (ODE).

Numerical Methods: Approximation, errors, accuracy and precision in numerical methods; Numerical solutions (roots) of linear and non-linear algebraic equations; Interpolation and curve fitting - Least square approximation, Newton's and Lagrange polynomials; Numerical differentiation and integration - trapezoidal and Simpson's rule; Numerical solution of ordinary differential equations - single and multi-step methods.

Probability and Statistics: Descriptive statistics, Measurement of central tendency, Dispersion, Skewness and kurtosis, Probability concepts, Conditional probability, Bayes theorem, Risk and reliability, Probability distributions, Correlation, Single and multiple regression models, Hypothesis testing (t-test, F-test, chi-square test).

Section 2: Environmental Chemistry

Fundamentals of Environmental Chemistry: Covalent and ionic bonding; Chemical equations, concentration and activity; Structure and chemistry of organic molecules; Chemical equilibria; Thermodynamics and kinetics of chemical reactions.

Principles of Water Chemistry: Water quality parameters and their measurement; Acid-base equilibria; Buffer solution; Carbonate equilibrium; Solubility of gases in water; Complexation, precipitation, and redox reactions; Inorganic and organic contaminants.

Soil Chemistry: Organic matter, nitrogen, phosphorous, potassium, cation exchange capacity, base saturation, and sodium absorption ratio.

Atmospheric Chemistry: Composition of the atmosphere; Reactivity of trace substances in the atmosphere; Chemistry of ozone formation.

Section 3: Environmental Microbiology

Prokaryotic and Eukaryotic Microorganisms: Characteristics of diverse groups of microorganisms; Classification of microorganisms; Microbial diversity; Role of microorganisms in wastewater treatment, bioremediation and biogeochemical cycling.

Cell Chemistry and Cell Biology: Structure of proteins, nucleic acid (DNA & RNA), lipids and polysaccharides; Structure of cell; Structure and function of cytoplasmic membrane, cell wall, outer membrane, glycocalyx; antimicrobial resistance, quorum sensing.

Microbial Metabolism: Anabolism and catabolism; Phosphorylation; Glycolysis; TCA cycle; Electron transport chain; Fermentation; Anaerobic respiration; Energy balances; Enzymes and Enzyme kinetics.

Growth and Control of Microorganisms: Bacterial nutrition and growth; Specific growth rate and doubling time; Monod's model; Types of culture media; Batch and continuous culture; Effects of environmental factors on growth; Control of microbes using physical and chemical methods.

Microbiology and Health: Pathogens and modes of transmission; Indicator organisms; Quantification of coliforms using MPN and membrane filtration techniques.

Section 4:	Water Resources and Environmental Hydraulics

Global Water Resources: Structure, properties and distribution of water; Threats to water resources; Water conservation.

Surface Water Resources: Hydrological cycle and water balance - precipitation, infiltration, evapotranspiration, runoff; Flow hydrographs; Unit hydrographs; Stage-discharge relationship; Reservoir capacity; Surface water management; Rain water harvesting and storage.

Groundwater Resources: Geologic formations as aquifers; Vadose and saturated zones; Confined and unconfined aquifers and their parameters - porosity, permeability, transmissivity and storage coefficient; Darcy's law and applications; Steady state well hydraulics.

Environmental Hydraulics: Concepts of mechanics; Properties of fluids; Pressure measurement; Hydrostatic force on surfaces; Buoyancy and flotation; Laminar and turbulent flow; Flow through pipes; Pipe networks; Forces on immersed bodies; Flow measurement in channels and pipes; Kinematics of flow; Continuity, momentum and energy equations; Channel hydraulics - specific energy, critical flow, hydraulic jump, rapid and gradually varied flow; Design of lined channels.

Section 5:	Water & Wastewater Treatment and Management

Water and wastewater quality parameters; Eutrophication and thermal stratification in lakes; River pollution - Oxygen sag curve.

Water treatment methods — screening, sedimentation with and without coagulation, filtration, desalination, disinfection; Water distribution and storage.

Point and non-point sources of wastewater; Population forecasting methods; Design of sewer and storm water sewers; Sewer appurtenances; Preliminary, primary, secondary and tertiary sewage treatment; Sludge generation, processing and disposal methods; Sewage farming.

Sources and characteristics of industrial effluents; Concept of Common Effluent Treatment Plants (CETP); Wastewater recycling and zero liquid discharge.

Kinetics and reactor design: Mass and energy balance, Order and rate of reactions, Batch reactors, Completely mixed flow reactors, Plug flow reactors.

Section 6:	Air and Noise Pollution

Structure and composition of the atmosphere; sources (natural and anthropogenic); Atmospheric processes (emission, transformation, transport, removal); Indoor air pollution; Effects on health and environment; Air pollution: gases and particulate matter; Air quality standards; Primary and secondary pollutants; Criteria pollutants; primary and secondary pollutants; ambient and emission standards; air quality indices; visibility and radiative effects.

Particulate Pollutants: Measurement and control methods; Control of particulate air pollutants using gravitational settling chambers, cyclone separators, wet scrubbers, fabric filters (Baghouse filter), electrostatic precipitators (ESP).

Gaseous Pollutants: Measurement and control methods; Control of gaseous contaminants: absorption, adsorption, condensation and combustion; Control of sulphur oxides, nitrogen oxides, carbon monoxide, and hydrocarbons; Diffusion, Fick's law and interfacial mass transfer. Vehicular emission control systems, including diesel particulate filters (DPFs), catalytic converters, and fuel standards.

Air Quality Management: Point, line and area sources; Inventory; Meteorology and dispersion; atmospheric stability and inversion, mixing height, wind rose diagrams, Gaussian plume dispersion modelling, and topographic influences.

Noise Pollution: Sources; Health effects; Standards; Measurement parameters (sound pressure level, equivalent continuous sound level *Leq*, day-night level *Ldn*); frequency analysis; and control and mitigation methods.

Section 7:	**Solid and Hazardous Waste Management**

Integrated solid waste management; Waste hierarchy; Rules and regulations for solid waste management in India.

Municipal solid waste management: Sources, generation, characteristics, collection, segregation, and transportation, waste processing and disposal (including reuse options, biological methods, energy recovery processes and landfilling), waste-to-energy technologies, circular economy principles, life-cycle energy analysis, decentralized renewable systems, and urban metabolism.

Hazardous waste management: Characteristics, generation, fate of materials in the environment, treatment and disposal. Soil contamination and leaching of contaminants into groundwater.

Management of biomedical waste, plastic waste, waste from energy sector (solar/wind/batteries etc), C&D waste and E-waste: Sources, generation and characteristics; Waste management practices including storage, collection and transfer.

Section 8:	**Global and Regional Environmental Issues**

Global effects of air pollution: Greenhouse gases, radiative forcing and global warming potential (GWP), climate change, urban heat islands, acid rain, ozone hole.

Ecology and various ecosystems; Biodiversity; Factors influencing increase in population, energy consumption, and environmental degradation.

Section 9:	**Environmental Management and Sustainable Development**

Environmental Management Systems; ISO14000 series; Environmental Auditing: Environmental Impact Assessment; Life cycle assessment; Human health risk assessment; Occupational Health and Hygiene, Physical & Chemical Hazards.

Environmental Law and Policy: Objectives; Polluter pays principle, Precautionary principle; The Water and Air Acts with amendments; The Environment (Protection) Act (EPA) 1986; National Green Tribunal Act, 2010; National Environment Policy; Principles of International Law and International treaties.

Energy and Environment: Energy Sources: Overview of resources and reserves; Renewable and non-renewable energy sources; Energy-Environment nexus.

Sustainable Development: Definition and concepts of sustainable development; Sustainable development goals; Hurdles to sustainability; Environment and economics; carbon pricing, emission trading, Environmental, Social, and Governance (ESG) frameworks.

EY Ecology and Evolution

Section 1: Ecology

Fundamental Concepts: Abiotic and biotic components of ecosystems; Levels of biological organization (individuals, population, species, community, ecosystems, biomes); Niches; Habitats; Functional traits; Ecophysiology (e.g. physiological adaptations, homeostasis, acclimation).

Population Ecology: Population dynamics and growth (density dependent/independent); Meta-population ecology; Age-structured populations.

Interactions: Types of interactions (mutualism, symbiosis, commensalism, competition, parasitism, predation, etc.); Two species population models (Lotka-Voltera equations); Trophic levels and their direct and indirect interactions.

Community Ecology: Community assembly, structure and succession; Role of dispersal and habitat/environmental filtering; levels of diversity (alpha, beta, gamma); Species richness, Evenness and diversity indices; Relative abundance; Species-area relationships; Diversity gradients (e.g. latitudinal and altitudinal gradients); Theory of island biogeography.

Ecosystem Structure and Function: Primary and secondary productivity; Food web, energy flow, and biogeochemical cycles (e.g. carbon and nitrogen); Ecosystem properties (e.g. stability, resilience); Global biomes and biogeographic zones; Flora and fauna of India; Biogeography of India.

Section 2: Evolution

Fundamentals: Lamarckism; Darwinism; Modern Synthesis; Variation; Heritability; Natural selection; Fitness and adaptation; Types of selection (e.g. stabilizing, directional, disruptive).

Diversity of Life: Origin and history of life on earth; Paleobiological evidence; Diversity and classification of life; Classical taxonomy vs systematics (cladistics).

Life History Theory: Allocation of resources; Tradeoffs; r/K selection; Strategies (e.g. semelparity and iteroparity).

Interactions: Co-evolution (e.g. mutualism, arms race, co-speciation); Prey-predator interactions (e.g. mimicry, crypsis); Host-parasite interactions

Population and Quantitative Genetics: Origins of genetic variation; Mendelian genetics; Hardy-Weinberg equilibrium; Drift; Selection (one-locus two-alleles model); Population genetic structure (panmixia, gene flow, FST); Polygenic traits; Gene-environment interactions (phenotypic plasticity); Heritability; Epistasis and epigenetic inheritance.

Molecular Evolution and Phylogenetics: Mutation rates; Molecular clocks; Neutral processes; Rates of evolution; Chromosomal and genome evolution (e.g. hybridization, ploidy, introgression); Phylogenetic methods (parsimony; maximum likelihood, Bayesian, etc); Phylogeography

Macroevolution: Species concepts; Speciation and extinction; Adaptive radiation; Convergence; Biogeographic processes; Continental drift.

Section 3:	Mathematics and Quantitative Ecology

Mathematics and Statistics in Ecology: Simple functions (linear, quadratic, exponential, logarithmic, etc); Concept of derivatives and slope of a function; Permutations and combinations; Basic probability (probability of random events; Sequences of events, conditional probability, etc); Probability distributions (e.g. binomial, normal, Poisson); Descriptive statistics (mean, variance, coefficient of variation, confidence intervals, etc.).

Study design and Statistical methods: Statistical hypothesis testing; Concept of p-value; Type I and Type II error, Statistical tests (e.g. t- test, Chi-square test); Correlation, linear regression and ANOVA.

Section 4:	Behavioural Ecology

Classical Ethology and Sensory Ecology: Proximate and ultimate explanations for behaviour; Innate and learnt behavior; Basic mechanisms (e.g., neuroethology, behavioural endocrinology); Modes of communication (chemical, visual, etc); Movement (e.g. navigation).

Foraging and Reproduction: Optimal foraging theory; Space use (e.g. territoriality); Mating systems; Sexual selection and sexual conflict (runaway selection, good-genes, handicap principle, etc); Parental care.

Social Behaviour: Costs and benefits of group-living; Intraspecific competition (e.g. scramble and contest); Kin selection; Altruism.

Section 5:	Applied Ecology & Evolution

Biodiversity and Conservation: Biodiversity-ecosystem function relationships; Ecosystem services; Conservation (endemism, biodiversity hotspots, protected areas); Global conservation initiatives (e.g. COP, IUCN, CBD, CITES); Conservation genetics and methods (genetic diversity, inbreeding depression, DNA fingerprinting and DNA barcoding).

Disease Ecology and Evolution: Epidemiology; Zoonotic diseases; Antibiotic resistance.

Global Change: Causes, consequences, adaptation and mitigation of climate change; Threats to biodiversity (e.g. pollution, habitat loss and change); Invasive species.

GA	General Aptitude

Section 1:	Verbal Aptitude
Basic English grammar: tenses, articles, adjectives, prepositions, conjunctions, verb-noun agreement, and other parts of speech. Basic vocabulary: words, idioms, and phrases in context. Reading and comprehension, Narrative sequencing.	

Section 2:	Quantitative Aptitude
Data interpretation: data graphs (bar graphs, pie charts, and other graphs representing data), 2-and 3-dimensional plots, maps, and tables. Numerical computation and estimation: ratios, percentages, powers, exponents and logarithms, permutations and combinations, and series. Mensuration and geometry, Elementary statistics and probability.	

Section 3:	Analytical Aptitude
Logic: deduction and induction, Analogy, Numerical relations and reasoning.	

Section 4:	Spatial Aptitude
Transformation of shapes: translation, rotation, scaling, mirroring, assembling, and grouping paper folding, cutting, and patterns in 2 and 3 dimensions.	

GE Geomatics Engineering

Part A: Common Section

Engineering Mathematics: Surveying measurements, Accuracy, Precision, Most probable value, Errors and their adjustments, Regression analysis, Correlation coefficient, Least squares adjustment, Statistical significant value, Chi-square test.

Remote Sensing: Basic concept, Physical Principles of Remote Sensing, Spectral signature, Resolutions: Spectral. Spatial, Temporal, Radiometric, Platforms and Sensors, Remote Sensing Data Products- PAN, Multispectral, Microwave, Thermal, Hyperspectral data; Visual and digital interpretation methods.

GNSS: Principle used, Components of GNSS, Data collection methods, DGPS, Errors in observations and corrections.

GIS: Introduction, Data Sources, Data Models and Data Structures, DBMS, Creation of Databases (spatial and non-spatial), Basic Spatial analysis: Interpolation, Buffer, Overlay, Terrain Modeling and Network analysis.

Part B1: Surveying and Mapping

Maps: Importance of maps to engineering projects, Types of maps, Scales, and uses, Plotting accuracy, Map sheet numbering, Coordinate systems- Cartesian and geographical, Map projections, Map datum – MSL, Geoid, spheroid, WGS-84.

Land Surveying: Levelling instruments, Levelling methods, Compass, Theodolite, Total Station and COGO functions, Tachometer, Trigonometric levelling, Traversing, Triangulation and Trilateration.

Aerial Photogrammetry: Types of photographs, Flying height and scale, Relief (height) displacement, Stereoscopy, Height determination using Parallax Bar, Digital Elevation Model (DEM).

Part B2: Image Processing and Analysis

Data Quantization and Processing: Sampling and quantization theory Principle of Linear System, Convolution.

Digital Image Processing: Digital image characteristics: image histogram and scattergram and their significance, Variance-Covariance and Correlation matrix and their significance.

Basic Radiometric and Geometric Corrections: Registration and Resampling techniques.

Image Enhancement: Spatial Enhancement: Noise and Spatial filters, Contrast Enhancement: Linear and Non-linear methods.

Image Transformation: Principal Component Analysis (PCA), Discriminant Analysis, Color transformations (RGB - IHS, CMYK), Indices (Ratios, NDVI, NDWI).

Basic Image Classification and Segmentation: Supervised and unsupervised techniques, accuracy analysis.

GG Geology and Geophysics

Part A: Common Section

This section includes various introductory topics related to geology and geophysics.

Introduction to Earth and planetary systems: Terrestrial planets and moons of the solar system; Concept of isostasy, Internal structure of Earth – elasticity, body and surface waves, propagation of body waves in the Earth's interior; Heat flow within the Earth; Gravitational field of the Earth; Continental and oceanic crust – composition, structure and thickness.

Plate Tectonics: Type of plate boundaries; Plate motions and driving mechanisms; Processes at plate boundaries - volcanism, seismicity, orogenesis, sea-floor spreading and magnetic anomalies and paleomagnetism, formation of back-arc basins; Continental rifting, mantle plumes, hotspots; Numerical problems related to plate motions.

Earth surface processes: Landforms created by hillslopes, rivers, wind, glaciers, oceans, and volcanoes.

Basic structural geology: Mohr's circle, stress, strain, and material response; Brittle and ductile deformation; Nomenclature and classification of folds and faults.

Mineralogy: Silicate crystal structure, physical and chemical properties of common rock-forming minerals.

Common Igneous: Sedimentary, and metamorphic-rocks: composition, structure, and formation processes.

Stratigraphy and Geological time scale: Relative and absolute time, Half-life, decay constant, radioactive equilibrium, stratigraphic principles, and major stratigraphic divisions of India; Major metallic ores, coal and petroleum resources of India.

Introduction to remote sensing: Energy sources and radiation principles, atmospheric absorption, interaction of energy with Earth's surface; Engineering properties of rocks and soils; Natural hazards (landslide, volcanic, seismogenic, coastal) and mitigation; Principles of climate change;

Elements of hydrogeology: Principles and applications of gravity, magnetic, electrical, electromagnetic, seismic, and radiometric methods of prospecting for oil, mineral, and groundwater.

Part B1: Advanced topics in Geology

Geomorphology: Basic geomorphic concepts, Geomorphic processes, and agents; Development and evolution of landforms in continental and oceanic settings; Landscape evolution in response to tectonics, climate, and base-level change. Quaternary geomorphology.

Structural Geology: Stress and strain analysis, deformation mechanisms, primary and secondary structures; Geometry and genesis of planar and linear structures (bedding, cleavage, schistosity, lineation); Folds, faults, joints, and unconformities; Shear zones, thrusts, and superposed folding; Geological maps-interpretation, measurements, and numerical analysis; Stereographic projection.

Crystallography and Mineralogy: Elements of crystal symmetry, form, and twinning; Crystallographic projections; Classification of minerals, physical and optical properties of rock-forming minerals; Mineral nucleation; Mineral chemistry (major, trace, and rare earth elements), cation re-calculations.

Geochemistry: Nucleosynthesis and cosmic abundance of elements; Classification and components of meteorites; Geochemical affinities and distribution of major, minor and trace elements in crust, mantle, and core; Planetary differentiation and geochemical evolution of the earth; Radiogenic (long-lived) isotopic evolution (Rb-Sr, Sm-Nd, U-Th-Pb) of the crust and the mantle, mantle reservoirs; Stable isotope geochemistry (H, O, C), isotope fractionation; geochemical cycles; Elements of high-temperature and low-temperature geochemical thermodynamics; Geochemical and isotopic (C-O, Sr isotopes) composition of river water, groundwater and seawater, residence time, and water-rock interaction; Principles of environmental geochemistry (pH, Salinity,

TDS, BOD, COD).

Igneous Petrology: Classification and textures of common igneous rocks; Mantle melting; Magmatic differentiation; Role of major, trace, and rare earth elements in igneous petrogenesis; Magma evolution, modeling crystallization and melting processes, plate margin volcanism; Intra-plate volcanism and large igneous provinces.

Thermodynamics: Equilibrium, Gibbs free energy; enthalpy, entropy, energy, Clapeyron Equation, Mineral stability and Phase equilibria, Schreinmakers rules; Phase rule; Phase diagrams, Activity-composition; Mineral solid solutions; Enthalpy and entropy of magma crystallization, Binary and ternary phase diagrams in igneous systems; Chemical speciation and equilibrium in natural waters, solubility and precipitation of minerals - saturation index calculations, Eh-pH diagrams and redox equilibria.

Sedimentology: Texture, structure, sedimentary processes, physical principles related to fluid flow; Statistical analysis in sedimentology; Petrology of common sedimentary rocks; Sedimentary facies and environments, cyclicities in sedimentary succession; Provenance and basin analysis.

Metamorphic Petrology: Structures and textures of metamorphic rocks; Extreme metamorphism; Metamorphic facies and grades; Paired metamorphic belts; Mineral reactions and chemographic projections; Metamorphism of pelitic, mafic and impure carbonate rocks; role of bulk compositions and fluids in metamorphism; Thermobarometry; Timing of metamorphism.

Paleontology: Diversity of life through time, mass extinctions- causes and effects; Taphonomy - processes of fossilization. functional morphology of invertebrates (bivalves, brachiopods, gastropods, echinoids, ammonites) and microfossils - (foraminifera, Ostracoda, conodonts, bryozoa); Statistical analysis of morphology; Vertebrate paleontology. Basic concepts of paleoecology; Fossils and paleoenvironments.

Stratigraphy: Principles of stratigraphy, concepts of correlation and their applications in Indian stratigraphy; Quantitative Lithostratigraphy, biostratigraphy, and chronostratigraphy - statistical and probabilistic approaches; Isotope stratigraphy; Principles of sequence stratigraphy and applications; Boundary problems in Indian stratigraphy.

Resource Geology: Ore-mineralogy; Ore forming processes - magmatic, hydrothermal, sedimentary, supergene, and metamorphogenic ores; Fluid inclusions in ore genesis; Coal and petroleum geology; Marine mineral resources; Prospecting and exploration of economic mineral deposits - sampling, ore reserve estimation, geostatistics, and mining methods; Distribution of strategic, essential, and critical minerals and fossil fuel deposits in India.

Engineering Geology: Physico-mechanical properties of rocks and soils; rock index tests; Rock failure criteria (Mohr-Coulomb, Griffith, and Hoek-Brown criteria); Shear strength of rock discontinuities; Rock mass classifications (RMR and Q Systems); in-situ stresses; Geological factors in the construction of engineering structures including dams, tunnels, and excavation sites; Analysis of slope stability.

Hydrogeology: Porosity and permeability; Groundwater storage and aquifer properties; Darcy's law; Hydraulic conductivity and groundwater flow dynamics; Groundwater exploration, well hydraulics.

Remote Sensing: EM spectrum, multispectral remote sensing in visible, infrared, thermal IR and microwave regions including hyperspectral; Digital processing of satellite images. GIS – basic concepts, raster and vector mode operations; Applications of remote sensing tools and techniques in geology.

Part B2: Advanced topics in Geophysics

Heat flow: Elements of conduction and convection within the mantle and the core, Half-space cooling, calculation of simple geotherms, geothermal gradient, equilibrium geotherms, thermal models in plate tectonics, adiabat, and melting in the mantle.

Geodesy: Gravitational Field of the Earth; Clairaut's theorem, size and shape of Earth; Geoid; Ellipsoid; Geodetic Reference Systems; Datum; GPS.

Seismology and Interior of the Earth: Variation of density, velocity, pressure, temperature, electrical and magnetic properties of the Earth; Conservation laws, Newton's law of viscosity, elements of laminar and turbulent flow; Elements of elasticity theory- stress and strain tensors, Generalized Hooke's Law; Body and Surface Waves; Rotational, dilatational, irrotational, and equivoluminal waves; Reflection and refraction of elastic waves; Inhomogeneous and evanescent waves and bounded waves; Eikonal Equation and Ray theory; Wave propagation in elastic media, Seismic Tomography.

Earthquake Seismology: Earthquakes-causes and measurements, magnitude and intensity, focal mechanisms; Earthquake quantification, source characteristics, seismotectonics and seismic hazards; Digital seismographs, Earthquake statistics, quantifying earthquake source from seismological data; Uniqueness Theorem, Representation Theorems of correlation and convolution type, Reciprocity.

Potential and Time Varying Fields: Scalar and vector potential fields; Laplace, Maxwell and Helmholtz equations for solution of different types of boundary value problems in Cartesian, cylindrical, and spherical polar coordinates; Green's theorem; Image theory; integral equations in potential and time-varying field theory.

Gravity: The earth as a planet; Absolute and relative gravity measurements; The various corrections for gravity data reduction – free air, Bouguer and isostatic anomalies; density estimates of rocks; Regional and residual gravity separation; Principle of equivalent stratum; Upward and downward continuation; Wavelength filtering; Gravity anomalies and their interpretation – anomalies due to geometrical and irregular shaped bodies, depth rules, calculation of mass.

Magnetic Methods: Geomagnetic field, paleomagnetism; Inclination, declination; Magnetic induction equation – convection, diffusion, Ohm's law for a moving conductor, frozen flux theorem, magnetic fields of planets in the Solar System, Geodynamo and origin of Earth's Magnetic field, magnetic susceptibility of rocks and measurements; Various corrections applied to magnetic data, IGRF, Poisson's relation of gravity and magnetic potential field, upward and downward continuation, magnetic anomalies due to geometrical and irregular shaped bodies; Interpretation of processed magnetic anomaly data; Derivative, analytic signal and Euler Depth Solutions.

Electrical Methods: Conduction of electricity through rocks, electrical conductivities of metals, non-metals, rock-forming minerals and different rocks, concepts of D.C. resistivity measurement and depth of investigation; Apparent Resistivity and Apparent Chargeability, Theory of Reciprocity, Sounding and Profiling, Various electrode arrangements, application of linear filter theory, Sounding curves over multi-layered earth, interpretation of resistivity field data, Principles of equivalence and suppression.

Electromagnetic Methods: Geo-electromagnetic spectrum; Biot Savart's Law; Maxwell's Equation, Helmholtz Equation, Basic concept of EM induction in the earth, Skin-depth, elliptic polarization, in-phase and quadrature components, phasor diagrams; Response function and response parameters; Measurements in different source receiver configurations; Earth's natural electromagnetic methods- tellurics, geomagnetic depth sounding and magnetotellurics; Electromagnetic profiling and Sounding, Time domain EM method; EM scale modelling, processing of EM data and interpretation; Ground Penetrating Radar (GPR) Methods; Effect of conducting overburden.

Seismic Methods: Elastic properties of earth materials; Reflection, refraction, generation, and propagation of elastic waves, velocity – depth models, seismic noise and noise profile analysis, processing, and interpretation; CDP stacking charts, binning, filtering, static and dynamic corrections, Digital seismic data processing, seismic deconvolution and migration methods, attribute analysis, bright and dim spots, seismic stratigraphy, high-resolution seismics, VSP, AVO, multi-component seismics, and seismic interferometry; Kirchhoff migration, Time Reversal, Time-Reversal imaging, Reverse-Time Migration; Representation theorem of cross-correlation and convolution type.

Reservoir Geophysics: Rock Physics and Petrophysics, Failure Criteria, stress concentration, Linear elasticity fracture mechanics, Elastic-Plastic Fracture mechanics; Griffith's criterion, dynamic fracture mechanics; Lithology and Porosity Estimation; Saturation and Permeability Estimation; application of borehole geophysics in groundwater, mineral, and oil exploration.

Geophysical Signal Processing: Sampling theorem, Nyquist frequency, aliasing, Fourier series, periodic waveform, Fourier and Hilbert transform, Z-transform and wavelet transform; power spectrum, delta function, auto-correlation, cross-correlation, convolution, deconvolution, principles of digital filters, windows, poles, and zeros, Basics of Time-frequency analysis.

Geophysical Well Logging: Principles and techniques of geophysical well-logging, SP, resistivity, induction, gamma ray, neutron, density, sonic, temperature, dip meter, caliper, nuclear magnetic resonance- longitudinal and transverse relaxation, CPMG sequence, porosity characterization, cement bond logging, micro-logs, Quantitative evaluation of formations from well logs.

Geophysical Inversion: Basic concepts of forward and inverse problems, Ill-posedness of inverse problems, condition number, non-uniqueness and stability of solutions; L1, L2, and Lp norms, overdetermined, underdetermined and mixed determined inverse problems, quasi-linear and non-linear methods including Tikhonov's regularization method, Singular Value Decomposition, Backus-Gilbert method, simulated annealing, genetic algorithms, swarm intelligence, Statistics of misfit and likelihood, Random Variables and Processes, Probability distribution functions - Gaussian, Poissonian, log-normal; Spatial analysis, Hypothesis testing; Bayesian construction of posterior probabilities, sparsity promoting L1 optimization; Ambiguity and uncertainty in geophysical interpretation; PDE constrained optimization, Adjoint-state method.

IN Instrumentation Engineering

Section 1 Engineering Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, consistency and rank, eigenvalues and eigenvectors, tensors.

Calculus: Functions, limits, continuity; differentiation, differentiability, partial derivatives, maxima and minima, integration, multiple integrals, vector algebra, line, surface and volume integrals, Stokes, Gauss and Green's theorems.

Differential Equations: Ordinary differential equations, first order linear differential equations, second order linear differential equations with constant coefficients, method of variation of parameters, Cauchy's and Euler's equations, initial and boundary value problems, solution of partial differential equations: variable separable method.

Analysis of Complex Variables: Analytic functions, Cauchy's integral theorem and integral formula, Taylor's and Laurent's series, residue theorem, solution of integrals.

Probability and Statistics: Random variables, discrete and continuous distributions: normal, Poisson and Binomial distributions. Sampling from distributions, conditional probability and Bayes' theorem, mean, median, mode, standard deviation and variance.

Numerical Methods: Solution of matrix equations, solutions of non-linear algebraic equations, iterative methods for solving differential equations, numerical integration, regression and correlation analysis, backpropagation for neural networks.

Section 2 Electricity and Magnetism

Coulomb's law, electric field intensity, electric flux density, Gauss' law, electric field and potential due to point, line, plane and spherical charge distributions, effect of dielectric medium, permittivity, capacitance, magnetic field intensity, magnetic flux density, Biot-Savart's law, Ampere's law, Faraday's law, Lorentz force, permeability, self and mutual inductance, electrical and magnetic dipoles, electromagnetic induction, magnetomotive force, reluctance, magnetic circuits, B-H curve, Maxwell's equations: vector, differential and integral forms.

Section 3 Electrical Circuits and Machines

Electrical Circuits: Independent, dependent, ideal and practical sources; V-I characteristics of practical current and voltage sources, battery, solar cell, resistor, inductor, coupled inductor, capacitor; transient analysis of RC, RL, LC, RLC circuits; power and energy consumption, power rating of components, efficiency and losses.

Kirchhoff's laws, mesh and nodal analysis, star-delta transformation, superposition, Thevenin's, Norton's, Miller's, maximum power transfer and reciprocity theorems.

Peak, average and rms values of AC quantities; apparent, active and reactive powers, power factor; phasor analysis, impedance and admittance; series and parallel resonance, locus diagrams, realization of basic filters with R, L, and C elements; transient analysis of RLC circuits with AC excitation.

Analysis of one-port and two-port networks with controlled voltage and current sources, driving point impedance and admittance, open and short circuit parameters.

Electrical Machines: Single phase transformers, permanent magnet synchronous machines; buck and boost converters, rectifiers, single phase inverters; rotor position and speed sensing, current sensing, pulse width modulation (PWM) control.

Section 4	Signals and Systems

Periodic, aperiodic and impulse signals; sampling; Fourier series, Laplace, Fourier and z-transforms, DFT and FFT; continuous-time and discrete-time systems, transfer function, linear time invariant systems, impulse response, frequency response, pulse transfer function; convolution, correlation; basics of IIR and FIR filters.

Section 5	Control Systems

Feedback principles, role of sensing in feedback, signal flow graphs, transient response, steady state error, Bode plot, phase and gain margins, Routh and Nyquist criteria, root loci, state-space representation of systems; time-delay systems.

Actuators for control system: control valves, servo valves, servo motors, stepper motors; on-off, P, PI, PID, cascade, feed forward, and ratio controllers, tuning of PID controllers; design of lead, lag and lead-lag compensators; basic concept of supervisory control, basics of distributed control system (DCS) and programmable logic controller (PLC).

Section 6	Analog Electronics

Types of diode and their applications; BJT and MOSFET circuits, biasing, power dissipation, DC analysis, small signal analysis, frequency response of transistor circuits, feedback, amplifier design. Characteristics of ideal and practical operational amplifiers; applications of opamps: adder, subtractor, integrator, differentiator, difference amplifier, instrumentation amplifier, precision rectifier, active filters, comparators, Schmitt trigger, multivibrators, oscillators, signal generators, voltage-controlled oscillators and phase-locked loop.

Sources and effects of noise and interference in electronic circuits; conductively, capacitively, inductively coupled interference; noise generated by electronic components, thermal noise, shot noise, flicker noise; shielding and grounding. Basic principles of component selection based on specifications, circuit board realization and testing.

Section 7:	Digital Electronics

Basics of number systems. Combinational logic circuits, multiplexer and demultiplexer, truth table, minimization of Boolean functions; IC families: ECL, TTL and CMOS, CMOS implementation of logic gates; arithmetic circuits, sequential circuits, finite state machines, flipflops, shift registers, timers and counters.

Analog front end: analog multiplexer, programmable gain amplifier, sample-and-hold circuit; analog-to-digital converters (ADC) (successive approximation, integrating, flash and sigma-delta) and digital-to-analog converters (DAC) (weighted R, R-2R ladder and current steering logic); characteristics and specifications of ADC and DAC (dynamic range, resolution, quantization, significant bits, conversion/settling time, INL, DNL, ENOB); embedded systems: common microprocessors and microcontrollers, memory and input-output interfacing, embedded systems programming; basics of data acquisition systems, virtual instrumentation, IoT; basic AI applications in instrumentation (sensor linearization, system calibration and tuning, signal classification).

Section 8:	Measurements

SI units, standards of basic electrical quantities (R, L, C, voltage, current and frequency), systematic and random errors in measurement, expression of uncertainty, accuracy and precision, propagation of errors, linear and weighted regression; bridges: Wheatstone, Kelvin, Maxwell, Anderson, Schering and Wien bridges for measurement of R, L, C and frequency, typical applications of bridges, Q-meter; megohm measurement; measurement of voltage, current and power in DC, single and three phase AC circuits; contact and noncontact type AC and DC current and voltage probes; true rms meters, voltage and current scaling, instrument transformers, timer/counter, time, phase and frequency measurements, digital voltmeter, digital multimeter, digital energy meter, digital storage oscilloscope, spectrum analyzer.

Section 9:	Sensors and Industrial Instrumentation
Resistive, capacitive, inductive, piezoelectric, electromagnetic and Hall effect sensors and associated signal conditioning circuits; transducers for industrial instrumentation: displacement, velocity, acceleration (linear and angular), force, torque, vibration, shock, pressure (including low and high pressure), flow (variable head, variable area, electromagnetic, ultrasonic, turbine flowmeters), temperature (thermocouple, bolometer, 2, 3, 4 wire RTD, thermistor, pyrometer and semiconductor sensor), liquid level, pH, conductivity and viscosity measurement.	
Section 10	**Communication and Optical Instrumentation**
Amplitude and frequency modulation and demodulation, pulse code modulation, frequency and time division multiplexing; amplitude, phase, frequency, quadrature amplitude, pulse shift keying for digital modulation and demodulation; functional architectures of transmitters and receivers; instrument and sensor networks, 4–20 mA two-wire transmitter. Optical sources and detectors: LED, laser, photo-diode, light dependent resistor, square law detectors and their characteristics; interferometer: applications in metrology; basics of fiber optic sensing. Near-infrared (NIR) sensing, Ultraviolet-Visible (UV-VIS) spectrophotometers, mass spectrometer.	

MA Mathematics

Section 1: Calculus

Functions of two or more variables, continuity, directional derivatives, partial derivatives, total derivative, Taylor's theorem, maxima and minima, saddle point, method of Lagrange's multipliers; Double and Triple integrals, Jacobians and Change of variables, Applications to area, volume and surface area;

Vector Calculus: gradient, divergence and curl, Line integrals and Surface integrals, Green's theorem, Stokes' theorem, and Gauss divergence theorem.

Section 2: Linear Algebra

Finite dimensional vector spaces over real or complex fields; Linear transformations and their matrix representations, rank and nullity; systems of linear equations, characteristic polynomial, eigenvalues and eigen-vectors, diagonalization, minimal polynomial, Cayley-Hamilton Theorem, Finite dimensional inner product spaces, Gram-Schmidt orthonormalization process, symmetric, skew-symmetric, Hermitian, skew-Hermitian, normal, orthogonal and unitary matrices; diagonalization by a unitary matrix, Jordan canonical form; bilinear and quadratic forms.

Section 3: Real Analysis

Metric spaces, Baire category theorem, connectedness, compactness, completeness; Continuity and Uniform continuity of functions; Sequences and series of functions, uniform convergence, Ascoli-Arzela theorem; Weierstrass approximation theorem; contraction mapping principle, Power series; Differentiation of functions of several variables, Inverse and Implicit function theorems; Lebesgue measure on the real line, measurable functions; Lebesgue integral, Fatou's lemma, monotone convergence theorem, dominated convergence theorem, L^p spaces.

Section 4: Complex Analysis

Functions of a complex variable: continuity, differentiability, analytic functions, harmonic functions;

Complex integration: Cauchy's integral theorem and formula; Liouville's theorem, maximum modulus principle, Morera's theorem; zeros and singularities; Power series, radius of convergence, Taylor's series and Laurent's series; Residue theorem and applications for evaluating real integrals; Rouche's theorem, Argument principle, Schwarz lemma; Conformal mappings, Mobius transformations.

Section 5: Ordinary Differential Equations

First order ordinary differential equations, existence and uniqueness theorems for initial value problems, linear ordinary differential equations of higher order with constant coefficients; Second order linear ordinary differential equations with variable coefficients; Cauchy-Euler equation; Definition and basic properties of Laplace transforms, Applications of Lapalce transform for solving ordinary differential equations, series solutions (power series, Frobenius method); Legendre and Bessel functions and their orthogonal properties; Systems of linear first order ordinary differential equations, Sturm's oscillation and separation theorems, Sturm-Liouville eigenvalue problems, Planar autonomous systems of ordinary differential equations: Stability of stationary points for linear systems with constant coefficients, Linearized stability, Lyapunov functions.

Section 6: Algebra

Groups, subgroups, normal subgroups, quotient groups, homomorphisms, automorphisms; cyclic groups, permutation groups, Group action, Finite Abelian groups, Sylow's theorems and their applications; Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domains, Principle ideal domains, Euclidean domains, polynomial rings, Eisenstein's irreducibility criterion; Fields, finite fields, field extensions, algebraic extensions, algebraically closed fields.

Section 7:	Functional Analysis

Normed linear spaces, Bounded linear operators and compact linear operators, Banach spaces, Separability, Dual spaces, Hahn-Banach theorem, open mapping and closed graph theorems, principle of uniform boundedness; Inner-product spaces, Hilbert spaces, orthonormal bases, projection theorem, Riesz representation theorem, spectral theorem for compact self-adjoint operators.

Section 8:	Numerical Analysis

Systems of linear equations: Direct methods (Gaussian elimination, LU decomposition, Cholesky factorization), Iterative methods (Gauss-Seidel and Jacobi) and their convergence for diagonally dominant coefficient matrices;

Numerical solutions of nonlinear equations: bisection method, secant method, Newton-Raphson method, fixed point iteration;

Interpolation: Lagrange and Newton forms of interpolating polynomial, Error in polynomial interpolation of a function;

Numerical differentiation and error, Numerical integration: Trapezoidal and Simpson rules, Newton-Cotes integration formulas, composite rules, mathematical errors involved in numerical integration formulae;

Numerical solution of initial value problems for ordinary differential equations: Methods of Euler, Runge-Kutta method of order 2.

Section 9:	Partial Differential Equations

Method of characteristics for first order linear and quasilinear partial differential equations; Second order partial differential equations in two independent variables: classification and canonical forms, method of separation of variables for Laplace equation in Cartesian and polar coordinates, Maximum Principle; heat and wave equations in one space variable; Wave equation: Cauchy problem and d'Alembert formula, domains of dependence and influence, non-homogeneous wave equation; Heat equation: Cauchy problem; Laplace and Fourier transform methods.

Section 10:	Topology

Basic concepts of topology, bases, subbases, subspace topology, order topology, product topology, quotient topology, metric topology, connectedness, path connectedness, compactness, sequentially compact, limit point compact, Tychonoff theorem, countability and separation axioms, Urysohn's Lemma, Tietze extension theorem.

Section 11:	Linear Programming

Linear programming models, convex sets, extreme points; Basic feasible solution, graphical method, simplex method, two phase methods, revised simplex method ; Infeasible and unbounded linear programming models, alternate optima; Duality theory, weak duality and strong duality; Balanced and unbalanced transportation problems, Initial basic feasible solution of balanced transportation problems (least cost method, north-west corner rule, Vogel's approximation method); Optimal solution, modified distribution method; Solving assignment problems, Hungarian method.

ME Mechanical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, eigen values and eigen vectors.

Calculus: Functions of single variable, limit, continuity and differentiability, mean value theorems, indeterminate forms; evaluation of definite and improper integrals; double and triple integrals; partial derivatives, total derivative, Taylor series (in one and two variables), maxima and minima, Fourier series; gradient, divergence and curl, vector identities, directional derivatives, line, surface and volume integrals, applications of Gauss, Stokes and Green's theorems.

Differential Equations: First order equations (linear and nonlinear); higher order linear differential equations with constant coefficients; Euler-Cauchy equation; initial and boundary value problems; Laplace transforms; solutions of heat, wave and Laplace's equations.

Complex Variables: Analytic functions; Cauchy-Riemann equations; Cauchy's integral theorem and contour
integral formula; Taylor and Laurent series.

Probability and Statistics: Definitions of probability, sampling theorems, conditional probability; mean, median, mode and standard deviation; random variables, binomial, Poisson and normal distributions.

Numerical Methods: Numerical solutions of linear and non-linear algebraic equations; integration by trapezoidal and Simpson's rules; single and multi-step methods for ordinary differential equations.

Section 2: Applied Mechanics and Design

Engineering Mechanics: Free-body diagrams and equilibrium; friction and its applications including rolling resistance, belt-pulley, brakes, clutches, screw jack, wedge, vehicles, etc.; plane trusses and frames; virtual work; kinematics and dynamics of rigid bodies in plane motion; impulse and momentum (linear and angular) and energy formulations.

Mechanics of Materials: Stress and strain, elastic constants and their relationships; stress and strain components transformations in 2D; Mohr's circle for plane stress and plane strain; thin-walled pressure vessels; shear force and bending moment diagrams; bending and shear stresses; concept of shear centre; deflection of beams; torsion of circular shafts; Euler's theory of columns; energy methods; thermal stresses; strain gauges and rosettes; Mechanical properties of materials, toughness, hardness, impact strength.

Theory of Machines: Displacement, velocity and acceleration analysis of plane mechanisms; dynamic analysis of linkages; cams; gears and gear trains; flywheels and governors; balancing of reciprocating androtating masses; gyroscope.

Vibrations: Free and forced vibration of linear systems with single and two degrees of freedom, damping estimation and effects; vibration isolation, transmissibility ratio; resonance; critical speeds of shafts; Control system, PID controller, transfer function.

Machine Design: Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles and design of machine elements such as bolted, riveted and welded joints; shafts, gears, belt drives, rolling and sliding contact bearings, brakes and clutches, springs.

Section 3:	Fluid Mechanics and Thermal Sciences

Fluid Mechanics: Fluid properties; fluid statics, forces on submerged bodies, stability of floating bodies; control-volume analysis of mass, momentum and energy; fluid acceleration; differential equations of continuity and momentum; concept of velocity potential; Bernoulli's equation; dimensional analysis; viscous flow of incompressible fluids, boundary layer, elementary turbulent flow, flow through pipes, head losses in pipes, bends and fittings; One dimensional high speed compressible fluid flow; flow through converging and converging-diverging nozzles.

Heat Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept and electrical analogy, heat transfer through fins; unsteady heat conduction, lumped parameter system, thermal boundary layer, dimensionless parameters in free and forced convective heat transfer, heat transfer correlations for flow over flat plates and through pipes; boiling and condensation; effect of turbulence; heat exchanger performance, LMTD and NTU methods; radiative heat transfer, Stefan- Boltzmann law, Wien's displacement law, black and grey surfaces, view factors, radiation network analysis.

Thermodynamics: Thermodynamic systems and processes; properties of pure substances, behaviour of ideal and real gases; zeroth, first and second laws of thermodynamics, calculation of work, heat, energy changes and entropy changes in various processes; application of first and second laws for analysis of closed and open systems; thermodynamic property charts and tables, availability and irreversibility; thermodynamic relations.

Applications: *Power Engineering:* vapour and gas power cycles, concepts of regeneration and reheat; *I.C. Engines:* Air-standard Otto, Diesel and dual cycles; *Basics of Combustion:* Air- Fuel Ratio, Equivalence Ratio; *Refrigeration and air-conditioning:* Vapour and gas refrigeration and heat pump cycles, properties of moist air, psychrometric chart, basic psychrometric processes; *Turbomachinery:* Impulse and reaction principles, velocity diagrams, Pelton-wheel, Francis and Kaplan turbines, steam and gas turbines, Air and gas compressors, pumps and pump characteristics.

Section 4:	Materials, Manufacturing and Industrial Engineering

Engineering Materials: Crystal structure of common metals, phase diagrams, heat treatment; Properties and applications of engineering materials - metals and alloys, polymers, composites and ceramics; Engineering and true stress-strain diagrams.

Casting, Forming and Joining Processes: Different types of casting processes; Patterns, moulds and core; Solidification and cooling, riser and gating design, casting defects; Plastic deformation and yield criteria; Hot
working and cold working; Principles of bulk forming and sheet forming processes and estimation of load in these processes; Fundamentals of powder metallurgy and its applications; Principles of welding, brazing, soldering; Solid-state welding processes, adhesive bonding; Non-destructive testing methods.

Machining and Machine Tool Operations: Basic machining operations and machine tools; Single-point and multipoint cutting tools; Geometry of single-point turning tools - ASA and ORS systems; Mechanics of machining; Cutting tool materials, tool life and tool wear; Economics of machining; Abrasive machining processes; Principles and applications of non-traditional machining processes; Principles of work holding, jigs and fixtures.

Additive Manufacturing: Principles of different types of additive manufacturing processes for engineering materials; Additively manufactured products – advantages, limitations, and applications.

Metrology and Inspection: Limits, fits and tolerances; Linear and angular measurements; Comparators;

Interferometry; Form and finish measurement; Alignment and testing methods; Tolerance analysis in manufacturing and assembly; Principle of coordinate- measuring machine (CMM).
Computer Aided Manufacturing and Automation: Basic concepts of CAD/CAM and their integration tools; NC/CNC machines and CNC programming; Pneumatic, electro-pneumatic, and hydraulic actuators for automation; Programmable logic controllers.

Production Planning and Control: Work study, Productivity, Forecasting models, Aggregate production planning, Scheduling, Materials requirement planning, Six sigma, Lean manufacturing, Inventory Control – deterministic models, safety stock, inventory control systems, Quality and reliability concepts for product lifecycle analysis.

Operations Research: Linear programming, Simplex method, Transportation, Assignment, Network flow models, Simple queuing models, PERT and CPM.

MN Mining Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrices and Determinants; Inverse and Rank of matrix; Systems of linear equations; Eigen values and Eigen vectors.

Calculus: Limit, continuity and differentiability; Partial Derivatives; Mean value theorems; Indeterminate forms and L' Hospital's rule; Maxima and minima; Taylor's theorem; Sequences and series; Fourier series.

Vector Calculus: Gradient; Divergence and Curl; Line; surface and volume integrals; Stokes, Gauss and Green's theorems.

Differential Equations: Linear and non-linear first order ODEs; Higher order linear ODEs with constant coefficients; Cauchy's and Euler's equations.

Probability and Statistics: Probability: Joint, Conditional, Bayes' Theory; Descriptive Statistics; Sampling theory and hypothesis testing; Binomial, Poisson, exponential and normal distributions; Pearson Correlation and linear regression.

Numerical Methods: Solutions of linear algebraic equations; Interpolation; Integration of trapezoidal and Simpson's rule; Single and multi-step methods for differential equations.

Section 2: Mining Geology, Mine Development and Surveying

Mining Geology: Minerals, Rocks and their Origin, Classification, Ore Genesis; Structural Geology.

Mine Development: Methods of access to deposits; Underground drivages; Drilling methods and machines; Explosives and initiation system, blasting tools, blast design practices; ground vibration

Mine Surveying: Levels and levelling, tacheometry, triangulation; Errors and adjustments; Correlation; Underground surveying; Curves and contouring; Photogrammetry; Theodolite, EDM, Total Station, GPS, Remote sensing and Astronomical survey.

Section 3: Geomechanics and Ground Control

Engineering Mechanics: Equivalent force systems; Equations of equilibrium; Two dimensional frames and trusses; Friction forces; Particle kinematics and dynamics; Beam analysis.

Geomechanics: Geo-technical properties of rocks; Rock mass classification; Instrumentations and in-situ stress measurement techniques; Theories of rock failure; Stress distribution around mine openings; Subsidence; Slope and Dump stability.

Ground Control: Design of pillars and supporting systems; Mine filling. Strata Control.

Section 4: Mining Methods and Machinery

Mining Methods: Surface mining: layout and haul road development, loading, transportation and mechanization, continuous mining systems; highwall mining; Underground coal mining:bord and pillar systems, longwall mining, thick seam mining methods, Underground metal mining: open, supported and caving stoping methods, stope mechanization, ore handling systems.

Mining Machinery: Generation and transmission of mechanical, hydraulic and pneumatic power; Materials handling: wire ropes, haulages, conveyors, face and development machineries, hoisting systems, pumps; comminution methods and machinery, Rock-tool interaction and mechanical cutting.

Section 5:	Surface Environment, Mine Ventilation and Underground Hazards

Surface Environment: Air, water and soil pollution: Standards of quality, causes and dispersion of contamination and control; Noise pollution and control; Land reclamation; EIA.

Mine Ventilation: Underground atmosphere; Heat load sources and thermal environment, air cooling; Mechanics of airflow, distribution, natural and mechanical ventilation; Mine fans and usage; Auxiliary ventilation; Ventilation survey and planning; Ventilation networks.

Underground Hazards: Mine Gases, Methane drainage; Underground hazards from fires, explosions, dust and inundation; Rescue apparatus and practices; Safety management plan; Safety data analytics; Mine illumination; Mine legislation; Occupational health and safety.

Section 6:	Mineral Economics, Mine Planning, Systems Engineering

Mineral Economics: Mineral resource classification; Discounted cash flow analysis; Mine valuation; Mineral taxation.

Mine Planning: Sampling methods, practices and interpretation; Reserve estimation techniques: Basics of geostatistics and quality control; Optimization of facility location; Mine planning and its components, Determination of mine size and mine life; Ultimate pit design; Grade-tonnage relationship, ore dilution, recovery and cut-off grade; Equipment Selection.

Systems Engineering: Concepts of reliability; Reliability of simple systems; Maintainability and availability; Linear programming, transportation and assignment problems; Network analysis; Inventory models; Queuing theory.

MT Metallurgical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrices and determinants; systems of linear equations; eigenvalues and eigenvectors.

Calculus: Limit, continuity and differentiability; partial derivatives; maxima and minima; sequences and series; test for convergence; Fourier series.

Vector Calculus: Gradient, divergence and curl; line, surface and volume integrals; Gauss theorem.

Differential Equations: Linear and non-linear first order ODEs; higher order linear ODEs with constant coefficients; Cauchy's and Euler's equations; PDEs – one dimensional heat and wave equations.

Probability and Statistics: Definitions of probability; conditional probability; mean, median, mode and standard deviation; random variables; Poisson, normal and binomial distributions; analysis of experimental data; linear least squares method.

Numerical Methods: Roots of linear and non-linear algebraic equations of single variable (bisection, secant, Newton- Raphson methods); numerical integration (trapezoidal rule) and differentiation (Taylor series expansion).

Section 2: Metallurgical Thermodynamics

Laws of Thermodynamics: First law – energy conservation, Second law - entropy; enthalpy, Gibbs and Helmholtz free energy; Maxwell's relations; chemical potential; applications to metallurgical systems; solutions, ideal and regular solutions; Gibbs phase rule, phase equilibria, binary phase diagram and lever rule; free-energy vs. composition diagrams; equilibrium constant, activity, Ellingham and phase stability diagrams.

Electrochemistry: Single electrode potential; electrochemical cells; Nernst equation; potential-pH diagrams.

Section 3: Transport Phenomena and Rate Processes

Momentum Transfer: Concept of viscosity; shell balances; Bernoulli's equation; mechanical energy balance equation; flow past plane surfaces and through pipes.

Heat transfer: Conduction - Fourier's Law, 1-D steady state conduction; convection; heat transfer coefficient and correlations; radiation; Stefan-Boltzmann Law; Kirchhoff's Law.

Mass Transfer: Diffusion and Fick's laws, mass transfer coefficients and correlations.

Dimensional Analysis: Significance of dimensionless numbers and their applications.

Basic Laws of Chemical Kinetics: First order reactions; reaction rate constant; Arrhenius relation; heterogeneous reactions; oxidation kinetics.

Electrochemical Kinetics: Polarization.

Section 4: Mineral Processing and Extractive Metallurgy

Comminution; Size classification; Flotation, Gravity, magnetic and electrostatic separation methods of mineral beneficiation.

Principles of pyro, hydro and electro metallurgy; unit processes for extraction of non-ferrous metals – aluminium, copper, titanium, zinc, and associated heat and material balance.

Ironmaking: Thermodynamics of blast furnace ironmaking; heat and material balance in blast furnace; production of sinter, pellets, metallurgical coke and testing, alternative routes of iron making (rotary kiln, MIDREX, COREX).

Primary Steel Making: Structure and properties of slags; thermodynamics and kinetics of steelmaking; basic oxygen furnace and electric arc furnace steel making.

Secondary Steel Making: Ladle process – deoxidation, degassing, argon stirring, desulphurization, inclusion shape control; basics of stainless steel manufacturing.

Continuous Casting: Basics of continuous casting, casting defects, thin slab casting.

Section 5:	Physical Metallurgy

Materials Characterisation: X-ray Diffraction-Bragg's law; optical microscopy; imaging and spectroscopy in SEM.

Crystal Imperfections: Point, line and surface defects; coherent, semi-coherent and incoherent interfaces.

Diffusion in Solids: Atomic models for interstitial and substitutional diffusion; volume, surface and grain boundary diffusion, Kirkendall effect; uphill diffusion.

Phase Transformation: Driving force; homogeneous and heterogeneous nucleation; growth kinetics; solidification in isomorphous, eutectic and peritectic systems; cast structures and macrosegregation; dendritic solidification and constitutional supercooling; coring and microsegregation.

Solid-state Transformations: Precipitation; eutectoid transformation, diffusionless transformations; precipitate coarsening, Gibbs-Thomson effect; glass transition in ceramics and polymers.

Principles of heat treatment: Heat treatment of steels; time-temperature-transformation (TTT) and continuous cooling transformation (CCT) diagrams; surface hardening; recovery, recrystallization and grain growth; heat treatment of cast irons and aluminium alloys.

Corrosion: Basic forms of corrosion and its prevention.

Section 6:	Mechanical Behaviour of Materials

Elasticity; strain tensor and stress tensor; representation by Mohr's circle; uniaxial tensile testing and stress-strain curves for metals, ceramics, and polymers; Tresca and von Mises yield criteria; plastic deformation by slip and twinning.

Dislocation Theory: Edge, screw and mixed dislocations; sources and multiplication of dislocations; stress fields around dislocations; partial dislocations; dislocation interactions and reactions.

Strengthening Mechanisms: Work/strain hardening, strengthening due to grain boundaries, solid solution, precipitation and dispersion.

Fracture behaviour: Griffith theory; linear elastic fracture mechanics; fracture toughness; fractography; ductile to brittle transition; toughening mechanisms in ceramics.

Fatigue: Low and high cycle fatigue; crack growth.

High Temperature deformation: Mechanisms of high temperature deformation and failure; creep and stress rupture, stress exponent and activation energy.

Section 7:	Manufacturing Processes

Metal Casting: Mould design involving feeding, gating and risering, casting practices, casting defects.

Hot, Warm and Cold Working of Metals: Metal forming – fundamentals of metal forming processes of rolling, forging, extrusion, wire drawing and sheet metal forming; defects in forming.

Metal Joining: Principles of soldering, brazing and welding; welding metallurgy, defects in welded joints in steels and aluminium alloys.

Powder Metallurgy: Production of powders, compaction and sintering.

Non-destructive Testing (NDT): Dye-penetrant, ultrasonic, radiography, eddy current, acoustic emission and magnetic particle inspection methods.

Section 8:	Materials Science and Non-Metallic Materials

Classification of engineering materials; chemical bonding- ionic, covalent, metallic and secondary bonding in materials; Structure of metals and alloys, ionic and covalent bonded solids and polymers.

Polymers: Molecular weight; thermoplastics and thermosets; copolymers; crystallinity of polymers.

Ceramics: Radius ratio and electroneutrality rules for determining crystal structure; Schottky and Frenkel defects, non-stoichiometric defects.

Composites: Types of reinforcements and matrices; enhancement in modulus and strength; isostrain and isostress loading conditions.

Electronic Properties: Band gap; Fermi energy; conductors, semiconductors and insulators.

Magnetic properties: Magnetization and B-H curves, principles of ferro-, ferri-, antiferro-, para- and dia-magnetism.

NM Naval Architecture and Marine Engineering

Section 1: Engineering Mathematics

Determinants and matrices, Systems of linear equations, Eigen values and eigen vectors. Functions, gradient, divergence, curl, chain rules, partial derivatives, directional derivatives, definite and indefinite integrals, line surface and volume integrals, theorems of Stokes, Gauss and Green. Linear, non-linear, first and higher order ordinary and partial differential equations, separation of variables.

Laplace transformation, analytical functions of complex variables, Fourier series, numerical methods for differentiation and integration, complex analysis, probability and statistics.

Section 2: Applied Mechanics and Structures

Engineering Mechanics: Free-body diagrams and equilibrium; trusses and frames; virtual work; kinematics and dynamics of particles and rigid bodies in plane motion; impulse and momentum (linear and angular) and energy formulations.

Mechanics of Materials: Stress and strain, elastic constants, Poisson's ratio; Mohr's circle for plane stress and plane strain; shear force and bending moment diagrams; bending and shear stresses; torsion; Euler's theory of columns; energy methods; theories and failure, material testing methods.

Vibrations: Free and forced vibration of damped and undamped systems, single and multi DOF systems.

Machine Design: Design for static and dynamic loading; Design of machine elements such as shafts, gears, rolling and sliding contact bearings; Joining techniques such as bolting, riveting and welding.

Section 3: Fluid Mechanics and Marine Hydrodynamics

Fluid Mechanics: Fluid properties; fluid statics, stability of floating bodies; Conservation laws: Mass, momentum and energy (Integral and differential form); Dimensional analysis and dynamic similarity; sources, sinks, doublets, line vortex and their superposition; Stoke's integral theorem. Generalised Bernoulli's equation, sources, sinks, dipole, Flow with circulation, potential flow with rotational symmetry, hydrodynamical lift, Kutta-Joukowski theorem. Vortex motion- Fundamental concepts, vortex analogy to Biot-Savart's law, straight parallel vortex filaments, vortex sheets. Viscous flow - Navier-Stokes equations, Couette flow, Plane poiseuille flow. Equation of continuity, Euler's equation, Bernoulli's equation, Viscous flow of incompressible fluids, elementary turbulent flow, boundary layer, flow through pipes.

Boundary layer theory- Prandtl's boundary layer equations, criterion for separation, Blasius solution, Skin friction, displacement thickness, momentum thickness, Turbulent boundary layer, Boundary layer control. Airfoils- Lift, drag, circulation, pressure distribution-theory of thin aerofoils, wings of infinite and finite span, circulation distribution, Cavitation.

Vorticity and Kelvin's theorem, Potential flow theory, Sources, Sinks and Doublets, hydrodynamic forces in potential flow, D'Alembert's paradox, added-mass, slender-body theory, hydrodynamic model testing, scaling laws, application of potential theory to surface waves, energy transport, wave/body forces, linearised theory of lifting surfaces.

Section 4: Naval Architecture and Ocean Engineering

Ship geometry and physical fundamentals - Archimedes' principle, buoyancy and weight of ship, laws of flotation, heel and trim, stable and unstable equilibrium of ships, importance of streamlined hull shape, ship main particulars, hydrostatic calculations,

Stability and Trim of Ships: Statical stability at small angles of heel, Inclining experiment. Shift of centre of gravity due to addition or removal of mass, transverse movement of mass and effect, Free surface effect, Effect of suspended mass, Stability at large angles of heel, angle of loll, curves of statical stability, dynamical stability, Probabilistic and deterministic Damage Stability Different Characteristic curves of dynamic stability. Floodable length calculations and curves. Loss of stability due to grounding, docking stability.

Resistance and Propulsion: Components of ship resistance, form factor, hull roughness, model testing and ship resistance prediction methods, tank wall effects, determination of ship resistance different series test results, resistance of advanced vehicles, appendage and added resistance. Geometry of screw propeller, propeller theories, hull-propeller interactions, different propulsive efficiency definitions. Propeller cavitation and effects. Propeller design and series. Open water and self-propulsion model tests. Different types of propellers and their working principles. Propeller material, strength and manufacturing. Unconventional propellers.

Ship Manoeuvring and Motions: Ship path keeping and changing, equations of motion, linearised equations and control fixed stability indexes, model tests. Stability and control in the horizontal and vertical planes – definitive manoeuvres and sea trials. Rudder hydrodynamics, design and operation. Influence of propeller, hull, appendages etc. on rudder performance. Experimental methods for the determination of hydrodynamic derivatives.

Ocean waves – regular, irregular, trochoidal. Wave spectrum, encounter frequency. Types of ship motions, coupled and non-coupled motions, equations of motion. Dynamic effects of ship motion in seaway. Different ship motion stabilisers – passive and active. Different numerical and experimental methods to determine ship motions – strip theory, BEM, FEM. Seakeeping features of high-performance marine vehicles.

Ship Structures and Strength: Shipbuilding materials, joining techniques, ship structural and framing systems – bottom, side, deck, bulkhead, end structures, and structural connections. Primary and secondary structural members, superstructure, hatch covers, machinery foundations, cargo handling systems and support structures.

Loads acting on ships in seaway, longitudinal and transverse strength considerations and estimation methods. Strength of hull girder, stiffened plate analysis, torsion of hull girder, deformation and stresses, local strength analysis; Reliability analysis and ultimate strength of hull girder, structural vibrations, fatigue and fracture.

Physical Oceanography: Physical properties of seawater, Different types of ocean waves - tides and wind waves, and their importance. Offshore Structures: Fixed offshore platforms - Jackets, Gravity platforms; Floating platforms - semi-submersibles, jack-ups, TLPs, FPSOs; Mooring, station keeping. Port and Harbour Engineering: Ports and Harbours, Port structures - Jetties, Dolphins, Liquid berths, Dredging, Navigation.

Section 5:	**Thermodynamics and Marine Engineering**

Thermodynamics: First law of thermodynamics - Closed system undergoing a cycle; closed system undergoing a change of state; Internal energy of a system; Expansion work; Process using ideal gas - constant pressure, constant volume, isothermal; adiabatic and polytropic process -work done and heat added in different process; First law applied to one - dimensional steady flow process, flow energy, steady flow energy equation (ID). Second law of Thermodynamics - Different statements; Reversible and irreversible process; Corollaries of second law - Absolute temperature scale; Carnot cycle - Carnot engine, refrigerator and heat pump. Clausius inequality and definition of entropy, change of entropy of an ideal gas; Gas power cycles and I.C.Engines; Gas power cycles: Carnot cycle, Brayton cycle, Erricson cycle, Sterling cycle etc.; Air standard cycles- Otto- Diesel, Dual and Joule cycle; Evaluation of thermal efficiency and mean effective pressure; Internal Combustion engine - Classification of I.C. engines -Principle of operation of spark Ignition and Compression Ignition engines both two stroke and four stroke; Stages of combustion in S.I. and C.I. engines; Knocking and detonation- factors controlling knock and detonation, methods of preventing Knocking and detonation; Refrigeration - principle of operation of Simple vapour compression system, Comparison with vapour compression systems; Air conditioning principles - Sensible heating and cooling, Humidification and dehumidification, Cooling and humidification, Cooling and dehumidification-Heating and humidification, Heating and dehumidification, Adiabatic mixing of air streams –cooling and heating load calculation.

Marine Diesel Engines: General engine principles, Low speed and medium speed diesel engines, Two and Four stroke engines, Scavenging and turbo charging, Fuel oil system, Lubricating oil systems, cooling systems, torque and power measurement, Starting air systems and reversing systems, controls and safety devices, Couplings and Gearboxes, Specific Fuel Consumption. Waste heat recovery system, MARPOL regulations and Energy Efficiency Design Index (EEDI), Ship Energy Efficiency Management Plan (SEEMP).
Marine Steam Turbines: Types of turbines, compounding, reheat, turbine construction, rotors, blades, casing, Gland sealing, diaphragms, nozzles, bearings etc. Lubrication systems, expansion arrangements, Gearings. Marine gas turbines – fundamentals of G.T, Structure of gas turbines, gearing, operational features, controls, combined cycles. Nuclear propulsion – physical principles of the operation of nuclear reactors – use of nuclear propulsion on seagoing vessels, Electrical Propulsion,

Marine Boilers: Types - fire tube, water tube boilers, Package boilers, Cochran Boilers, Composite boilers, steam to steam generators, double evaporation boilers, exhaust gas heat exchangers, auxiliary steam plant systems, exhaust gas boilers, composite boilers. Boiler mounting, combustion, feed system, feed water treatment.

Engine Dynamics: Torsional vibration of engine and shafting, axial shaft vibration, critical speeds, engine rating, rating corrections, trial tests etc. Relationship of engine to the propeller classification society rules on engine construction, Engine room arrangement. Automation of ship propulsion plants, Maintenance requirements and reliability of propulsion plants.

Marine Auxiliary Machinery & Systems: Different types of pumps and piping systems in ships - hot water, drinking water, cooling water and seawater, fuel oil systems, lubricating oil system filters, coolers, centrifuges, purifiers and clarifiers, bilge and ballast systems, sewage disposal, oily water separator, air compressors, boilers, heat exchangers, waste heat recovery systems; Heat, ventilation and air conditioning systems; Dech machinery and cargo handling systems; Propulsions and steering gear systems.

PE	Petroleum Engineering

Section 1:	Engineering Mathematics

Linear Algebra: Matrix algebra; Systems of linear equations; Eigenvalues and eigenvectors.
Calculus: Functions of single variable; Limit, continuity and differentiability; Taylor series; Mean value theorems; Evaluation of definite and improper integrals; Partial derivative, Total derivative; Maxima and minima; Gradient, divergence and curl; Vector identities; Directional derivatives; Line, surface and volume integrals; Stokes, Gauss and Green's theorems.
Differential Equations: First order equations: linear and nonlinear; Higher order linear differential equations with constant coefficients; Cauchy's and Euler's equations; Initial and boundary value problems; Laplace transform; Solution of one-dimensional diffusivity equation and Laplace equation.
Complex Variables: Complex number; Polar form of complex number; Triangle inequality.
Probability and Statistics: Definitions of probability and sampling theorems; Conditional probability; Mean, median, mode and standard deviation; Random variables; Poisson, normal and binomial distributions; Linear regression analysis.
Numerical Methods: Numerical solutions of linear and non-linear algebraic equations; Integration by trapezoidal and Simpson's rule; Single and multi-step methods for numerical solution of differential equations.

Section 2:	Petroleum Exploration

Classification and description of some common rocks with special reference to clastic and non-clastic reservoir rocks; Origin, migration and accumulation of petroleum; Petroleum exploration methods; Petroleum resource classification and evaluation.

Section 3:	Oil and Gas Well Drilling Technology

Well planning; Drilling methods; Drilling rigs; Rig operating systems; Drilling fluids, function and properties; Drilling fluid maintenance equipment; Oil and gas well cementing operations; Drill bit types and their applications; Drill string and casing string function, operation, selection and design; Drilling problems, their control and remedies; Directional drilling tools; Directional survey; Application of horizontal, multilateral, extended reach; Slim wells; Intelligent drilling and completion techniques: image assisted drilling, managed pressure drilling, underbalanced drilling.

Section 4:	Reservoir Engineering

Petrophysical properties of reservoir rocks; Coring and core analysis; Reservoir fluid properties; Phase behaviour of a hydrocarbon system; Single phase and multiphase flow through porous media; Water and gas coning; Reservoir pressure measurement; Reservoir drives, drive mechanisms and recovery factors; Theory of material balance; Reserve estimation and techniques; Field development and reservoir management; Reservoir geomechanics: Stress analysis and fracturing; Basics of reservoir simulation: mathematical models, finite difference discretization, Cartesian and radial grid systems, black oil reservoir simulation, history matching.

Section 5:	Petroleum Production Operations

Well equipment; Well completion techniques; Well production problems and mitigation; Well servicing and Workover operations; Workover and completion fluids; Formation damage; Well stimulation techniques; Artificial lift techniques; Field processing of oil and gas; Storage and transportation of petroleum and petroleum products; Metering and measurements of oil and gas; Production system analysis and optimization including inflow performance, tubing performance, and nodal analysis; Production testing; Multiphase flow in tubing and flow-lines; Flow assurance: Problems and remedies; Pressure vessels, storage tanks, shell and tube heat exchangers, pumps and compressors.

Section 6:	Offshore Drilling and Production Practices
Offshore oil and gas operations and ocean environment; Buoyancy and stability; Offshore fixed platforms, Offshore mobile units, station keeping methods like mooring and dynamic positioning system; Offshore drilling from fixed platform, jack-up, ships and semi submersibles; Use of conductors, risers and umbilicals; Offshore well completion; Deep water applications of subsea technology; Offshore production: Oil processing platforms, water injection platforms, storage, Single Point Mooring (SPM) and Single Buoy Mooring (SBM), transportation and utilities; Deep water drilling and production system.	

Section 7:	Petroleum Formation Evaluation
Petrophysical evaluation of sub-surface formations: principles, applications, advantages and disadvantages of Spontaneous Potential (SP), resistivity, radioactive, acoustic logs, gamma ray logs and types of tools used; Logging While Drilling (LWD); Evaluation of Cement Bond Long (CBL)/ Variable Density Log (VDL), Ultrasonic Imager Tool (USIT), Segmented Frequency Tool (SFT), Repeat Formation Tester (RFT); Production logging tools, principles, limitations and applications; Special types of logging tools; Casing inspection tools: principles, applications and limitations; Formations micro scanner (FMS), Nuclear Magnetic Resonance (NMR) logging principles; Standard log interpretation methods; Cross-plotting methods.	

Section 8:	Oil and Gas Well Testing
Diffusivity equation and its solutions; Radius of investigation; Principle of superposition; Horner's approximation; Drill stem testing; Pressure transient tests: drawdown and build up-test analysis; Pressure derivative analysis; Wellbore effects; Multilayer reservoirs; Injection well testing; Multiple well testing; Interference testing; Pulse testing; Well-test analysis by use of type curves; Gas well testing; Inflow testing.	

Section 9:	Health Safety and Environment in Petroleum Industry
Health hazards in Petroleum Industry: toxicity, physiological, asphyxiation, respiratory and skin effect of petroleum hydrocarbons, sour gases; Safety System: manual and automatic shutdown system, blow down systems; Gas detection system; Fire detection and suppression systems; Personal protection system and measures; Health, Safety and Environment (HSE) policies; Disaster and crisis management in petroleum industry; Environment: Environment concepts, impact on ecosystem, air, water and soil; The impact of drilling and production operations on environment; Environmental transport of petroleum wastes; Offshore environmental studies; Offshore oil-spill and oil-spill control; Environmental regulations and compliance.	

Section 10:	Enhanced Oil Recovery Techniques
Basic principles and mechanism of Enhanced Oil Recovery (EOR); Screening of EOR processes; Concept of pattern flooding, recovery efficiency, permeability heterogeneity; Macroscopic and microscopic displacement efficiency; EOR methods: chemical flooding, miscible flooding, thermal recoveries (steam stimulation, hot water and steam flooding, in-situ combustion), microbial EOR, low salinity water flooding.	

Section 11:	Latest Trends in Petroleum Engineering
Coal bed methane, shale gas, oil shale, gas hydrate, heavy oil, physical and chemical trapping of CO_2 in underground reservoirs.	

PH Physics

Section 1:	Measurements and Error Analysis

Units and dimensions, dimensional analysis; least count, significant figures; Methods of measurement and error analysis for physical quantities associated with various measurements; 2-probe and 4-probe methods for resistance measurement; Grounding for electrical circuits, Ground loops; Design of DC power supply, Signal processing through lock-in amplifiers.

Section 2:	Mathematical Physics

Linear vector spaces: basis, orthogonality and completeness; matrices: similarity transformations, diagonalization, eigenvalues and eigen vectors; linear differential equations: simple applications of first and second order linear differential equations and solutions; complex analysis: Cauchy-Riemann conditions, Cauchy's theorem, singularities, residue theorem and applications; Fourier analysis; tensors: tensor transformations, covariant and contravariant tensors.

Section 3:	Classical Mechanics

D'Alembert's principle, Euler-Lagrange equation, Hamilton's principle, calculus of variations; symmetry and conservation laws; central force motion: Kepler problem; small oscillations: coupled oscillations and normal modes; rigid body dynamics: inertia tensor, orthogonal transformations, Euler angles, torque free motion of a symmetric top; Hamiltonian and Hamilton's equations of motion; canonical transformations: Poisson bracket. Special theory of relativity: Lorentz transformations, relativistic kinematics, mass-energy equivalence.

Section 4:	Thermodynamics and Statistical Mechanics

Laws of thermodynamics; macrostates and microstates; phase space; ensembles; partition function, free energy, calculation of thermodynamic quantities; classical and quantum statistics; degenerate Fermi gas; black body radiation and Planck's distribution law; Bose-Einstein condensation; first and second order phase transitions, phase equilibria, critical phenomena.

Section 5:	Electromagnetic theory

Solutions of electrostatic and magnetostatic problems including boundary value problems; method of images; separation of variables; dielectrics and conductors; magnetic materials; multipole expansion; Maxwell's equations; scalar and vector potentials; Coulomb and Lorentz gauges; electromagnetic waves in free space, non-conducting and conducting media; reflection and transmission at normal and oblique incidences; polarization of electromagnetic waves; Poynting vector, Poynting theorem, energy and momentum of electromagnetic waves.

Section 6:	Optical Physics

Wave equation: plane and spherical waves, superposition of waves, standing waves, phase and group velocities; Interference: spatial and temporal coherence, dielectric films, Newton’s ring, multiple-beam interference, Michelson interferometer, Fabry-Perot interferometer and etalon; diffraction: Fresnel and Fraunhofer diffraction, rectangular and circular aperture, Rayleigh criterion of resolution, diffraction from double slit and many slits. dispersion by a grating; polarization: Jones vectors and matrices for linear, circular and elliptical polarization, birefringence, ray-transfer matrix for mirrors and lenses; lasers: Einstein coefficients, population inversion, two and three level laser systems.

Section 7:	Quantum Mechanics

Basic ideas of quantum mechanics; uncertainty principle; linear vectors and operators in Hilbert space; time independent Schrodinger equation; one dimensional potentials: step potential, finite rectangular well, tunnelling from a potential barrier, particle in 1,2,3-dimensional box, particle in single and double delta function potentials, 1,2,3 dimensional harmonic oscillator: concept of degeneracy; central potentials; hydrogen-like atoms; orbital and spin angular momenta; addition of angular momenta; variational method, time independent perturbation theory; elementary scattering theory, Born approximation.

Section 8:	Atomic and Molecular Physics
Spectra of one-and many-electron atoms; spin-orbit interaction: L-S and j-j coupling schemes; fine and hyperfine structures; Zeeman, Paschen-Back and Stark effects; electric dipole transitions and selection rules; rotational and vibrational spectra of diatomic molecules; electronic transitions in diatomic molecules, Franck-Condon principle; Raman effect and basics of Raman spectroscopy; NMR, ESR, X-ray and Mossbauer spectroscopies.	
Section 9:	**Solid State Physics**
Elements of crystallography; diffraction methods for structure determination; bonding in solids; lattice vibrations and thermal properties of solids; free electron theory; band theory of solids: nearly free electron model; metals, semiconductors and insulators; conductivity, electron and hole statistics in intrinsic and extrinsic semiconductors, mobility and effective mass; metal-semiconductor junctions; ohmic and rectifying contacts; dielectric properties of solids; polarizability, ferroelectricity; magnetic properties of solids; dia, para, ferro, antiferro and ferri magnetism, ferromagnetic domains; superconductivity: type-I and type II superconductors, Meissner effect, London equation, BCS theory, flux quantization.	
Section 10:	**Nuclear and Particle Physics**
Nuclear binding energy, electric and magnetic moments; semi-empirical mass formula; nuclear models; liquid drop model, nuclear shell model; nuclear force and two nucleon problem; alpha decay, beta-decay, electromagnetic transitions in nuclei; Rutherford scattering, nuclear reactions, conservation laws; fission and fusion; particle accelerators and detectors; elementary particles; photons, baryons, mesons and leptons; quark model; conservation laws, isospin symmetry, charge conjugation, parity and time-reversal invariance.	
Section 11:	**Electronics**
p-n diodes, bipolar junction transistors, field effect transistors; negative and positive feedback circuits; oscillators, operational amplifiers and their applications, active filters; wave form generators: sine wave, square wave and triangular wave; basics of digital logic circuits, combinational and sequential circuits, flip-flops, timers, counters, registers, A/D and D/A conversion.	

PI	Production and Industrial Engineering

Section 1:	Engineering Mathematics

Linear Algebra: Matrix algebra; Systems of linear equations; Eigenvalues and eigenvectors.
Calculus: Functions of single variable; Limit, continuity and differentiability; Mean value theorems, Evaluation of definite integrals; Partial derivative; Total derivative; Maxima and minima; Gradient, divergence and curl; Vector identities; Directional derivatives; Line, Surface and Volume integrals; Stokes, Gauss and Green's theorems; Taylor series.
Differential Equations: First order equations: linear and nonlinear; Higher order linear differential equations with constant coefficients; Cauchy's and Euler's equations; Initial and boundary value problems; Laplace transform.
Probability and Statistics: Definitions of probability and sampling theorems; Conditional probability; Mean, median, mode and standard deviation; Linear regression, Random variables, Poisson, normal, binomial and exponential distributions.
Numerical Methods: Numerical solutions of linear and nonlinear algebraic equations; Integration by trapezoidal and Simpson's rules; Single and multi-step methods for differential equations.

Section 2:	General Engineering

Engineering Materials: Structure, physical and mechanical properties, and applications of common engineering materials (metals and alloys, semiconductors, ceramics, polymers, and composites – metal, polymer and ceramic based); Iron-carbon equilibrium phase diagram; Heat treatment of metals and alloys and its influence on mechanical properties; Stress-strain behavior of metals and alloys.
Applied Mechanics: Engineering mechanics – equivalent force systems, free body concepts, equations of equilibrium; Strength of materials – stress, strain and their relationship; Failure theories; Mohr's circle (stress); Deflection of beams, bending and shear stresses; Thick and thin cylinders; Torsion.
Theory of Machines and Design: Analysis of planar mechanisms, cams and followers; Governors and fly wheels; Design of bolted, riveted and welded joints; Interference/shrink fit joints; Friction and lubrication; Design of shafts, keys, couplings, spur gears, belt drives, brakes and clutches.
Thermal and Fluids Engineering: Fluid mechanics – fluid statics, Bernoulli's equation, flow through pipes, laminar and turbulent flows, equations of continuity and momentum, capillary action; Dimensional analysis; Thermodynamics – zeroth, first and second laws of thermodynamics, thermodynamic systems and processes, calculation of work and heat for systems and control volumes; Air standard cycles; Heat transfer – basic applications of conduction, convection and radiation.

Section 3:	Manufacturing Processes I

Casting: Types of casting processes and applications; Sand casting: patterns – types, materials and allowances; molds and cores–materials, making, and testing; design of gating system and riser; analysis of solidification and microstructure development; Other casting techniques: Pressure die casting, centrifugal casting, investment casting, casting defects and their inspection by non-destructive testing.
Metal Forming: Stress-strain relations in elastic and plastic deformation; von Mises and Tresca yield criteria, concept of flow stress; Hot, warm and cold working; Bulk forming processes – forging, rolling, extrusion and wire drawing; Sheet metal working processes – blanking, punching, bending and deep drawing; Ideal work and slab analysis; Defects in metal working and their causes.
Joining of Materials: Classification of joining processes; Principles of fusion welding processes using different heat sources (flame, arc, resistance, laser, and electron beam), heat transfer and associated losses; Arc welding processes - SMAW, GMAW, GTAW, plasma arc, submerged arc welding processes; Principles of solid state welding processes - friction welding, friction stir welding, ultrasonic welding; Welding defects - causes and inspection; Principles of adhesive joining, brazing and soldering processes.
Powder Processing: Production of metal/ceramic powders, compaction and sintering of metals and ceramic

powders.

Polymers and Composites: Polymer processing – injection, compression and blow molding, extrusion, calendaring and thermoforming; Molding of composites.

Section 4:	Manufacturing Processes II

Machining: Orthogonal and oblique machining, single point cutting tool and tool signature, chip formation, cutting forces, merchant's analysis, specific cutting energy and power; Machining parameters and material removal rate; Tool materials, tool wear and tool life; Thermal aspects of machining, cutting fluids, machinability; Economics of machining; Machining processes - turning, taper turning, thread cutting, drilling, boring, milling, gear cutting, thread production; Finishing processes – grinding, honing, lapping and super-finishing.

Machine Tools: Lathe, milling, drilling and shaping machines – construction and kinematics; Jigs and fixtures – principles, applications, and design.

Advanced Manufacturing: Principles and applications of USM, AJM, WJM, AWJM, EDM, LBM, EBM, PAM, CHM, ECM; Effect of process parameters on material removal rate, surface roughness and power consumption; Additive manufacturing techniques: Fundamentals, stereolithography, fused filament fabrication, selective laser sintering, selective laser melting, directed energy deposition.

Computer Integrated Manufacturing: Basic concepts of CAD and CAM, CNC; Automation in manufacturing; Industrial robots – configurations, drives and controls; Cellular manufacturing and FMS - group technology; Introduction to Internet of Things and digital twins.

Section 5:	Quality and Reliability

Metrology and Inspection: Accuracy and precision; Types of errors; Limits, fits and tolerances; Gauge design, Interchangeability, selective assembly; Linear, angular, and form measurements (straightness, flatness, roundness, runout and cylindricity) by mechanical and optical methods; Inspection of screw threads and gears; Surface roughness measurement by contact and non-contact methods.

Quality Management: Quality – concepts and cost; Statistical quality control – process capability analysis, control charts for variables and attributes and acceptance sampling; Six sigma; Total quality management, Just-in-Time inventory management; Quality assurance and certification - ISO 9001:2015, ISO 14001:2015; Integration of sustainable manufacturing with quality management.

Reliability and Maintenance: Reliability, availability and maintainability; Distribution of failure and repair times; Determination of MTBF and MTTR, reliability models; Determination of system reliability; Preventive and predictive maintenance and replacement, total productive maintenance.

Section 6:	Industrial Engineering

Product Design and Development: Principles of product design, tolerance design; Quality and cost considerations; Product life cycle; Standardization, simplification, diversification; Value engineering and analysis; Concurrent engineering; Design for "X".

Work System Design: Taylor's scientific management, Gilbreths' contributions; Productivity – concepts and measurements; Method study, micro-motion study, principles of motion economy; Work measurement – time study, work sampling, standard data, PMTS; Ergonomics; Job evaluation and merit rating.

Facility Design: Facility location factors and evaluation of alternate locations; Types of plant layout and their evaluation; Assembly line balancing; Material handling systems.

Section 7:	Operations research and Operations management

Operation Research: Linear programming – problem formulation, simplex method, duality and sensitivity analysis; Transportation and assignment models; Integer programming; Markovian queuing models; Introduction to discrete event simulation.

Engineering Economy and Costing: Elementary cost accounting and methods of depreciation; Break-even analysis; Activity based costing.

Production Control: Forecasting techniques – causal and time series models, moving average, exponential

smoothing, trend and seasonality; Aggregate production planning; Master production scheduling; MRP, MRP-II and ERP; Routing, scheduling and priority dispatching; Push and pull production systems, concepts of lean and agile manufacturing systems; Logistics, distribution, and supply chain management; Inventory – functions, costs, classifications, deterministic inventory models, quantity discount; Perpetual and periodic inventory control systems.

Project Management: CPM, PERT and Gantt chart. Time-cost tradeoff.

RA Robotics and Automation

Part A: Common Section

Section A.1: Engineering Mathematics

Linear Algebra: Matrices- transpose, determinant, rank, eigenvalues and eigenvectors, trace, adjoint, solutions to system of linear equations.

Calculus: Functions of a single variable, limit, continuity, and differentiability, mean value theorems, indeterminate forms; evaluation of definite and improper integrals; double and triple integrals; partial derivatives, total derivative, Taylor series (in one and two variables), maxima and minima; gradient, divergence and curl, vector identities.

Differential Equations: First-order equations (linear and nonlinear); higher-order linear differential equations with constant coefficients; Euler-Cauchy equation; initial and boundary value problems; Laplace transforms; solutions of heat, wave, and Laplace's equations; Fourier series.

Probability and Statistics: Axioms of probability, conditional probability, mean, median, mode, standard deviation, random variables, expectation, binomial, Poisson, and normal distributions; hypothesis testing, Probability Density Function (PDF), Cumulative Distribution Function (CDF).

Numerical Methods: Solutions of linear and non-linear algebraic equations; integration by trapezoidal and Simpson's rules; finite differences, explicit single and multi-step methods for differential equations.

Section A.2: Basics of Mechatronics

Network Elements: Ideal voltage and current sources, dependent sources, R, L, C, M elements; Network solution methods: Kirchoff's laws (KCL, KVL), Node and Mesh analysis; Network Theorems: Thevenin's, Norton's Superposition and Maximum Power Transfer theorem; Transient response of DC and AC networks, sinusoidal steady-state analysis, resonance, two-port networks, balanced three-phase circuits, complex power and power factor in AC circuits.

Digital Circuits: Boolean algebra, combinational (multiplexers, encoders, decoders), and sequential circuits (flip-flops, counters).

Sensors: Resistive, capacitive, inductive, piezoelectric, Hall effect sensors and associated signal conditioning circuits; transducers for industrial instrumentation- displacement (linear and angular), velocity, acceleration, force, torque, pressure.

Actuators: Principles of operation, performance, torque-speed characteristics of hydraulic and pneumatic actuators, DC motors, stepper motors, and servo motors.

Engineering Mechanics: Free-body diagrams and equilibrium; friction and its applications- rolling friction, belt-pulley; trusses and frames; kinematics and dynamics of rigid bodies in plane motion.

Programming: Flowcharts and pseudo code; Programming in Python: data types, operators, expressions, conditional statements (if, elif, else, case) looping statements (while, for), loop control statements (break and continue), functions, arrays, dictionary, strings, recursion.

Data Structures: Stack, queue, linked list, binary search tree, binary heap, graph.

Section A.3: Principles of Robotics and Automation

Robotic classification- serial and parallel manipulators, geometrical configuration, Links and joints, Coordinate systems and degrees-of-freedom; Rotation matrices in 2D and 3D; homogeneous transformations, forward kinematics. Robot applications- point-to-point and continuous path control, types of end-effectors, robot accuracy and repeatability.

Computer Integrated Manufacturing- Automation in Manufacturing, Programmable Logic Controllers (PLCs) in manufacturing, Automated material handling systems, Automated storage and retrieval systems, Automated identification, detection and capture systems; computer numerical control; Basics of single and multi-axis positioning systems; Basics of concurrent design and manufacturing planning for automation.

Part B1: Electrical Engineering

Section B1.1 Analog Circuits and Embedded Systems

Analog filters - low-pass, high-pass, band-pass and band-reject; Amplifiers: biasing, equivalent circuit and frequency response, feedback amplifiers, operational amplifiers- characteristics and applications; oscillators; Voltage Controlled Oscillators and timers, Schmitt triggers, sample and hold circuits, Analog-to-Digital (A/D) and Digital-to-Analog (D/A) converters; Switched Mode Power Supplies (SMPS).

Microprocessor and microcontroller applications, components of microcontrollers (CPU, memory, I/O ports, timers), interrupt handling; memory and input-output interfacing; basics of data acquisition systems.

Section B1.2 Signals and Systems

Representation of continuous and discrete time signals, shifting and scaling properties, linear time-invariant and causal systems, Fourier series representation of continuous and discrete time periodic signals, Shannon's sampling theorem, Definitions and properties of Fourier Transform, Laplace Transform and Z transform; R.M.S. value, average value calculation.

Section B1.3 Control Systems

Mathematical modeling and representation of systems, feedback principle, transfer function, Block diagrams and Signal flow graphs, Transient and Steady-state analysis of linear time-invariant systems, Stability analysis using Routh-Hurwitz and Nyquist criteria, Bode plots, Root Loci, Lag, Lead and Lead-Lag compensators; P, PI and PID controllers.

Part B2: Mechanical Engineering

Section B2.1 Mechanics of Materials

Stress and strain, elastic constants, Poisson's ratio; Mohr's circle for plane stress and plane strain; thin cylinders; shear force and bending moment diagrams; bending and shear stresses; concept of shear centre; deflection of beams; torsion of circular shafts; Euler's theory of columns; Castigliano's theorems; thermal stresses; strain gauges and rosettes; testing of materials with universal testing machine; testing of hardness and impact strength.

Section B2.2 Kinematics and Dynamics

Displacement, velocity, and acceleration analysis of plane mechanisms; dynamic analysis of linkages; gears and gear trains; balancing of reciprocating and rotating masses; gyroscope, Vibrations- free and forced vibration of single degree of freedom systems, the effect of damping, vibration isolation; resonance; critical speeds of shafts.

Section B2.3 Machine Design and Computer Integrated Manufacturing

Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles of the design of machine elements such as bolted, riveted and welded joints; shafts, rolling and sliding contact bearings, brakes and clutches, springs. Basic concepts of Computer Aided Design (CAD)/Computer Aided Manufacturing (CAM) and their integration tools; additive manufacturing.

ST	Statistics

Section 1:	Calculus

Finite, countable and uncountable sets; Sequences of real numbers, convergence of sequences, bounded sequences, monotonic sequences, Cauchy criterion for convergence; Series of real numbers, convergence, tests of convergence, alternating series, absolute and conditional convergence; Power series and radius of convergence; Functions of a real variable: Limit, continuity, monotone functions, uniform continuity, differentiability, Rolle's theorem, mean value theorems, Taylor's theorem, L'Hospital rules, maxima and minima, Riemann integration and its properties, improper integrals;

Functions of several real variables: Limit, continuity, partial derivatives, directional derivatives, gradient, Taylor's theorem, total derivative, maxima and minima, saddle point, method of Lagrange multipliers, double and triple integrals and their applications.

Section 2:	Matrix Theory:

Subspaces of $\mathbb{R}n$ and $\mathbb{C}n$, span, linear independence, basis and dimension, row space and column space of a matrix, rank and nullity, row reduced echelon form, trace and determinant, inverse of a matrix, systems of linear equations; Inner products in $\mathbb{R}n$ and $\mathbb{C}n$, Gram-Schmidt orthonormalization; Eigen values and eigen vectors, characteristic polynomial, Cayley-Hamilton theorem, symmetric, skew-symmetric, Hermitian, skew-Hermitian, orthogonal, unitary matrices and their eigen values, change of basis matrix, equivalence and similarity, diagonalizability, positive definite and positive semi-definite matrices and their properties, quadratic forms, singular value decomposition.

Section 3:	Probability

Axiomatic definition of probability, properties of probability function, conditional probability, Bayes' theorem, independence of events; Random variables and their distributions, cumulative distribution function, probability mass function, probability density function and their properties, expectation, variance, properties of expectation and variance, moments and moment generating function, probability generating function, quantiles, distribution of functions of a random variable, Chebyshev, Markov and Jensen inequalities.

Section 4:	Standard Univariate Distributions

Bernoulli, binomial, geometric, negative binomial, hypergeometric, discrete uniform, Poisson, continuous uniform, exponential, double exponential, gamma, beta distributions of first and second kinds, Weibull, normal, Cauchy.

Section 5:	Joint Distributions

Jointly distributed random variables and their distribution functions, probability mass function, probability density function and their properties, marginal and conditional distributions, conditional expectation and moments, product moments, simple correlation coefficient, joint moment generating function, independence of random variables, functions of random vector and their distributions, distributions of order statistics, joint and marginal distributions of order statistics; multinomial distribution, bivariate normal distribution, sampling distributions: central chi-square, central t, and central F distributions.

Section 6:	Convergence of Random Variables

Convergence in distribution, convergence in probability, convergence almost surely, convergence in $r-th$ mean and their inter-relations, Slutsky's lemma, Borel-Cantelli lemma; weak and strong laws of large numbers; central limit theorem for i.i.d. random variables.

Section 7:	Stochastic Processes
Markov chains with finite and countable state space, classification of states, limiting behaviour of n-step transition probabilities, stationary distribution, Poisson process, birth-and-death process, pure-birth process, pure-death process, Brownian motion and its basic properties.	
Section 8:	**Estimation**
Sufficiency, minimal sufficiency, factorization theorem, completeness, completeness of exponential families, ancillary statistic, Basu's theorem and its applications, unbiased estimation, uniformly minimum variance unbiased estimation, Rao-Blackwell theorem, Lehmann-Scheffe theorem, Cramer-Rao inequality, consistent estimators, method of moments estimators, method of maximum likelihood estimators and their properties; Interval estimation: pivotal quantities and confidence intervals based on them, coverage probability.	
Section 9:	**Testing of Hypotheses**
Neyman-Pearson lemma, most powerful tests, monotone likelihood ratio (MLR) property, uniformly most powerful tests, uniformly most powerful tests for families having MLR property, uniformly most powerful unbiased tests, uniformly most powerful unbiased tests for exponential families, likelihood ratio tests, large sample tests.	
Section 10:	**Non-parametric Statistics**
Empirical distribution function and its properties, goodness of fit tests, chi-square test, Kolmogorov-Smirnov test, run tests, sign test, Wilcoxon signed rank test, Mann-Whitney U-test, Kruskal-Wallis test, rank correlation coefficients of Spearman and Kendall.	
Section 11:	**Multivariate Analysis**
Multivariate normal distribution: properties, conditional and marginal distributions, maximum likelihood estimation of mean vector and dispersion matrix, Hotelling's $T2$ test, Wishart distribution and its basic properties, multiple and partial correlation coefficients and their basic properties.	
Section 12:	**Regression Analysis**
Simple and multiple linear regression, $R2$ and adjusted $R2$ and their applications, distributions of quadratic forms of random vectors: Fisher-Cochran theorem, Gauss-Markov theorem, tests for regression coefficients, confidence intervals.	

XE Engineering Sciences

XE0: Engineering Mathematics (Common for all XE candidates)

Section XE0.1: Linear Algebra

Algebra of real matrices: Determinant, inverse and rank of a matrix; System of linear equations (conditions for unique solution, no solution and infinite number of solutions); Eigenvalues and eigen vectors of matrices; Properties of eigenvalues and eigen vectors of symmetric matrices, diagonalization of matrices; Cayley-Hamilton Theorem.

Section XE0.2: Calculus

Functions of Single Variable: Limit, indeterminate forms and L'Hospital's rule; Continuity and differentiability; Mean value theorems; Maxima and minima; Taylor's theorem; Fundamental theorem and mean value theorem of integral calculus; Evaluation of definite and improper integrals; Applications of definite integrals to evaluate areas and volumes (rotation of a curve about an axis).

Functions of Two Variables: Limit, continuity and partial derivatives; Directional derivative; Total derivative; Maxima, minima and saddle points; Method of Lagrange multipliers; Double integrals and their applications.

Sequences and Series: Convergence of sequences and series; Tests of convergence of series with non-negative terms (Cauchy Condensation Test, Ratio, Root and integral tests); Power series; Taylor's series.

Section XE0.3: Vector Calculus

Gradient, divergence and curl; Line integrals and Green's theorem.

Section XE0.4: Complex variables

Complex numbers, Argand plane and polar representation of complex numbers; De Moivre’s theorem; Definition and examples of Analytic functions; Cauchy-Riemann equations.

Section XE0.5: Ordinary Differential Equations

First order equations (linear and nonlinear); Second order linear differential equations with constant coefficients; Cauchy-Euler equation; Second order linear differential equations with variable coefficients; Wronskian; Method of variation of parameters; Eigen value problem for second order equations with constant coefficients; Power series solutions for ordinary points.

Section XE0.6: Partial Differential Equations

Classification of second order linear partial differential equations, One dimensional heat and wave equations, two dimensional Laplace equation, Method of separation of variables, Fourier series method.

Section XE0.7: Probability and Statistics

Axioms of probability; Conditional probability; Total probability theorem, Bayes' Theorem; Mean, variance and standard deviation of random variables; Binomial, Poisson and Normal distributions; Correlation and linear regression.

Section XE0.8:	Numerical Methods

Solution of systems of linear equations using LU decomposition, Gauss elimination method; Lagrange and Newton's interpolations; Solution of polynomial and transcendental equations by Bisection method and Newton-Raphson method; Numerical integration by trapezoidal rule and Simpson's $1/3^{rd}$ and $3/8^{th}$ rules; Numerical solutions of first order differential equations by Euler's method.

XE1: Fluid Mechanics	
Section XE1.1:	**Classification of Flows**
Concept of a fluid, Viscous versus inviscid flows, Concept of viscosity, Newtonian versus non-Newtonian fluid, Incompressible versus compressible flows, Internal versus external flows, Steady versus unsteady flows, Laminar versus turbulent flows.	
Section XE1.2:	**Hydrostatics**
Buoyancy, Manometry, Forces on submerged bodies and their stability.	
Section XE1.3:	**Kinematics of Fluid Motion**
Eulerian and Lagrangian descriptions of fluid motion, Concept of local, Convective and material derivatives, Streamline, Streakline, and Pathline.	
Section XE1.4:	**Integral Analysis for a Control Volume**
Reynolds Transport Theorem (RTT) for conservation of mass and linear momentum.	
Section XE1.5:	**Differential Analysis**
Differential equations of mass and momentum for incompressible flows, Euler equation, Bernoulli equation and its application for venturi meter, Pitot-static tube, and Orifice meter. Navier-Stokes equation and its exact solutions for Couette flow and Poiseuille flow. Concept of fluid rotation, Vorticity, Stream function, and Circulation.	
Section XE1.6:	**Dimensional Analysis**
Concept of similarity, Buckingham Pi theorem and its applications. Dimensionless groups and their physical significance - Reynolds number, Froude number, and Mach number.	
Section XE1.7:	**Internal Flows**
Fully developed pipe flow - Friction factor, Darcy-Weisbach relation and Moody's chart, Major and minor losses. Concept of flow development.	
Section XE1.8:	**Potential Flows**
Velocity potential function, Uniform flow, Source, Sink, and Vortex.	
Section XE1.9:	**External Flows**
Concept of Prandtl boundary layer, Boundary layer thickness, Displacement thickness and momentum thickness. Qualitative idea of boundary layer separation, Streamlined and bluff bodies, Drag and lift forces.	

XE2: Materials Science

Section XE2.1: Classification and Structure of Materials

Classification of Materials: Metals, ceramics, polymers and composites.

Fundamentals of crystallography: Definitions of crystal, lattice and motif: Crystal=Lattice+Motif. Distinction between atoms and lattice points; Symmetry operations: Translations (required symmetry of crystals/lattices); Symmetry based definitions of 7 crystal systems; Unit cells: primitive and non-primitive cells; Fourteen Bravais lattices and their classification into crystal systems; Miller and Miller-Bravais indices of crystallographic planes and directions.

Close-packed crystal structures of elements: Cubic close-packed (CCP), Hexagonal close-packed (HCP) and body-centred cubic (BCC) structures; Stacking sequence of planes; Tetrahedral and octahedral voids.

Crystalline and other ordered structures of carbon: Diamond and Graphite in terms of lattice and motif; Graphene and fullerene; Carbon nanotubes.

Crystalline structure of compounds: NaCl, CsCl, ZnS (Zinc blend and Wurtzite), Perovskite, Spinels; Pauling's rule for structure of ionic compounds.

Structure of amorphous materials: Crystalline and glassy silica; Fused silica and soda-lime glass.
Solid solutions: Interstitial and substitutional; Hume-Rothery rules.

Structure of polymers: Monomers and polymers. Addition and condensation polymers. Bonding in polymers. C-C chain. Degree of polymerization. Chain configuration vs. chain conformations. Atactic, isotactic and syndiotactic configurations. Crystalline, semi-crystalline and amorphous polymers. Copolymers: alternating, block and random. Examples of common polymers: Polyethylene (PE), Polypropylene (PP), Polyvinylchloride (PVC), Polyetraflouroethylene (PTFE), Polystyrene (PS). Crosslinking. Natural and vulcanised rubber.

Defects in Crystalline Materials:
Zero-dimensional or point defects: Vacancies, interstitials, substitutional atoms, Frenkel and Schottky defects; Equilibrium concentration of point defects.

One-dimensional or line defects: Dislocations: edge, screw and mixed. Burgers vector and Burgers circuit; Burgers vectors of stable dislocations in simple cubic, body-centred cubic and face-centred cubic lattices; Dislocations meeting at a node; Line energy of a dislocation. Dislocation motion: glide and climb.

Two-dimensional or surface defects: Free surfaces, Grain boundaries, twin boundaries, stacking faults, phase boundary; Surface energy of a free surface in terms of a simple bond breaking model.

Section XE2.2: Thermodynamics, Kinetics and Phase Transformations

Extensive and intensive thermodynamic properties, laws of thermodynamics, phase equilibria, phase rule, phase diagrams - unary pressure-temperature diagrams, binary temperature-composition diagrams, construction of temperature composition diagrams from free energies, common tangent construction in free energy-composition diagrams, invariant reactions.

Reaction kinetics, rate constants, order of reactions, Arrhenius law, Fick's laws, Steady state and non-steady state solutions of diffusion equations, diffusion distance and diffusion time, applications of solutions of diffusion equations, atomistic mechanisms of diffusion, fast diffusion paths.

Solidification of pure metals and alloys, homogeneous and heterogeneous nucleation, nucleation rate, growth, partitioning during binary solidification; diffusional solid-state phase transformations (precipitation and eutectoid), overall transformation kinetics (TTT and CCT), martensitic/displacive transformation; glass transition.

Section XE2.3:	Properties and Applications of Materials

Mechanical properties: elastic and plastic deformation; atomic bonding and elasticity; shear strength of perfect crystals; plastic deformation by slip and dislocation motion; Strengthening mechanisms: strain hardening, solid solution hardening, precipitation hardening, grain size refinement; Grifith theory of fracture; fatigue: cyclic loading, S-N curve, crack initiation and propagation; Creep in crystalline materials: stages and mechanisms of creep; Composites: particle and fibre reinforced composites; elastic modulus (rule of mixtures).

Electronic Properties: Drude model and classical description of electrical conductivity, Drawbacks of classical theory, Quantum mechanical description including concept of Fermi energy, Fermi surface and density of states. Band Theory to explain insulators, conductors, and semiconductors via allowed and forbidden energy bands, Effective mass concept, Intrinsic and extrinsic semiconductors, temperature dependence of conductivity, Carrier concentration and mobility, drift vs. diffusion current, Hall Effect for a simple metal or semiconductor. Dielectric behavior, piezo- and ferro-electric behavior.

Magnetic Properties: Origin of magnetism in materials, types of Magnetism: Diamagnetism, Paramagnetism, Ferromagnetism, Ferrimagnetism and Antiferromagnetism, Magnetic Domains & Hysteresis, Hard and soft magnetic materials.

Thermal Properties: Specific heat, Classical Dulong–Petit Law, Wiedemann-Franz Law, Thermal conductivity of metals and insulators (role of electrons and phonons), Einstein and Debye model, heat conduction, thermal diffusivity, thermal expansion, and thermoelectricity.

Optical Properties: Refractive index, absorption and transmission of electromagnetic radiation.

Section XE2.4:	Characterization and Measurements of Properties

X-ray diffraction: Bragg's Law, structure factor, indexing of cubic diffraction patterns; spectroscopic techniques: UV-Vis, IR and Raman; band-gap measurement; Microscopy (optical, scanning and transmission electron microscopy): wavelength range, resolution, depth of field; Composition analysis using energy dispersive spectroscopy.

Tensile test: engineering and true stress-strain curves, parameters, such as, yield stress, ultimate tensile stress, elongation, area under the curve; Hardness: Brinell, Rockwell and Vickers.

Electrical conductivity, carrier mobility and concentrations.
Thermal analysis techniques: thermogravimetry and calorimetry.

Section XE2.5:	Processing of Materials

Heat Treatment of steels: TTT and CCT diagram: coarse and fine pearlite, martensite and bainite; Annealing, normalizing, quenching, tempering.

Heat treatment of aluminium alloys: Precipitation hardening: Solutionising, quenching and ageing. Hardness vs. aging time and its dependence on aging temperature.

Silicon processing: production of metallurgical and semiconductor grade, zone refining, single crystal growth, silicon oxidation, doping, photolithographic process Preparation of powders; sintering.

Section XE2.6:	Degradation of Materials

Electrochemical basis of corrosion of metals: standard electrode potential, galvanic series, Nernst equation, polarization and passivation; forms of corrosion; corrosion prevention
Polymer degradation: swelling and dissolution; bond rupture: radiation, chemical and thermal effects; weathering.

XE3: Solid Mechanics

Section XE3.1 Mechanics of Rigid Bodies

Equivalent forces and moments; equilibrium equations; analysis of determinate trusses and frames; sliding and sticking friction; the principle of minimum potential energy and its relation to stable equilibrium; particle kinematics and dynamics; dynamics of inter-connected and/or constrained rigid bodies under planar motion; systems that conserve energy and/or momentum.

Section XE3.2 Mechanics of Deformable Bodies

Definition of stress and strain; Transformation of stresses and strains; Principal Stresses; Mohr's circle for plane stress and plane strain; Elastic Constants; Generalized Hooke's Law; Thermal Stresses; Theories of Failure - von Mises, Tresca and maximum principal stress theories.

Axial force, shear force, and bending moment diagrams; axial, shear, and bending stresses; combined stresses; deflection (for symmetric bending); systems with up to one degree of static indeterminacy (i.e., up to one support or internal force not determinable from static equilibrium alone); energy methods (Castigliano's theorems); torsion of circular shaft; Euler Buckling; thin-walled pressure vessels.

Section XE3.3 Vibrations

Free and forced vibration of single-degree-of-freedom systems; effect of damping; base excitation.

XE4: Thermodynamics

Section XE4.1: Basic Concepts

Continuum, microscopic and macroscopic approaches; Thermodynamic systems (closed and open); Thermodynamic properties, state and equilibrium; State postulate for simple compressible substances, paths and processes on property diagrams; Concepts of heat and work, different modes of work; Zeroth law of thermodynamics, concept of temperature.

Section XE4.2: Properties of Pure Substances

Thermodynamic properties of pure substances in solid, liquid and vapor phases; P-v-T behaviour of simple compressible substances, Concept of triple point and critical point; Ideal and real gases, ideal gas equation of state and van der Waals equation of state.

Section XE4.3: First Law of Thermodynamics

Concept of energy and various forms of energy; Internal energy, enthalpy; Specific heats; First law applied to elementary processes, closed systems and control volumes, steady flow energy equation applied to simple engineering devices.

Section XE4.4: Second Law of Thermodynamics

Limitations of the first law of thermodynamics, concepts of heat engines and heat pumps/refrigerators, thermal efficiency, coefficient of performance; Kelvin-Planck and Clausius statements and their equivalence; Reversible and irreversible processes; Carnot cycle and Carnot principles/theorems; Thermodynamic temperature scale.

Section XE4.5: Entropy

Clausius inequality and concept of entropy, causes of irreversibility; Entropy generation, the principle of increase of entropy, T-s diagrams; Isentropic process and isentropic efficiency; Second law analysis of system and control volume; Second law efficiency; Concept of third law of thermodynamics.

Section XE4.6: Thermodynamic Relations

T-ds relations, Helmholtz and Gibbs functions, Gibbs relations, Maxwell relations, Joule-Thomson coefficient and inversion curve; Coefficient of volume expansion, adiabatic and isothermal compressibilities; Clapeyron and Clapeyron-Clausius equations.

Section XE4.7: Thermodynamic Cycles

Carnot vapor cycle, ideal Rankine cycle; Simple vapor-compression refrigeration cycle; Air-standard cycles - Otto, Diesel, and Brayton cycles.

Section XE4.8: Mixtures of Ideal Gases

Dalton’s and Amagat’s laws, properties of ideal gas mixtures, air-water vapor mixtures and simple thermodynamic processes; Specific and relative humidities; Dew point, dry bulb and wet bulb temperatures, adiabatic saturation temperature, Simple psychrometric processes.

XE5	Polymer Science and Engineering

Section XE5.1:	Polymer Chemistry

Monomers; Degree of polymerization; Classification of polymers; Polymerization reactions: addition and condensation, their kinetics; Metallocene polymers and other newer methods of polymerization; Copolymerization; Monomer reactivity ratios and its significance; Kinetics; Different copolymers; Random, alternating, azeotropic copolymerization; Block and graft copolymers; Techniques for polymerization-bulk, solution, suspension, emulsion.

Section XE5.2:	Polymer Characterization

Solubility and swelling; Concept of molecular weight distribution and its significance; Concept of average molecular weight; Determination of number average, weight average, viscosity average and Z-average molecular weights; Glass transition; Melting transition; Amorphous and crystalline states of polymers; Orientation in polymers and polymer crystallinity; Factors affecting crystallinity; Analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA); Microscopic (optical and electronic) techniques; GPC; Mooney viscosity; Morphology and microstructure (SEM,TEM, AFM).

Section XE5.3:	Synthesis, Manufacturing and Properties

Commodity and general-purpose thermoplastics: PE, PP, PS, PVC; Polyesters; Acrylic; PU polymers; Engineering Plastics: Nylon, PC, PBT, Polyphenylene oxide, ABS, Fluoropolymers; Thermosetting polymers: Polyurethane, PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds; Natural and synthetic rubbers: recovery of NR hydrocarbon from latex; SBR; Nitrile; CR; CSM; EPDM; IIR; BR; Silicone; TPE; Specialty plastics: PEK, PEEK, Polyphenylene sulfide, Polysulfone, Polyethersulfone, etc.; Bio-compostable polymers such as PCL, PLA, PBAT, PHA/PHB, natural and biodegradable polymers such as cellulose, starch, alginate.

Section XE5.4:	Polymer Blends and Composites

Polymer blends and composites, their significance; Choice of polymers for blending, blend miscibility: miscible and immiscible blends; Thermodynamics; Phase morphology; Polymer alloys; Polymer eutectics; Plastic-plastic, rubber-plastic and rubber-rubber blends; FRP, particulate, long and short fibre reinforced composites; Polymer reinforcement, reinforcing fibres – natural and synthetic.

Section XE5.5:	Additives, Compounding and Formulations

Polymer compounding-need and significance; Different compounding ingredients for rubber and plastics (crosslinkers, antioxidants, heat stabilizers, UV stabilizers, lubricants, processing aids, impact modifiers, flame retardant, antistatic agents. PVC stabilizers and plasticizers) and their function; Use of carbon black; Polymer mixing equipment; Vulcanization and kinetics.

Section XE5.6:	Polymer Rheology

Flow of Newtonian and non-Newtonian fluids, different flow equations, dependence of shear modulus on temperature, molecular/segmental deformations at different zones and transitions; Measurements of rheological parameters by capillary, parallel plate, cone-plate rheometer. viscoelasticity, creep and stress relaxation, oscillatory or dynamic testing, mechanical models, control of rheological characteristics through compounding, rubber curing in parallel plate viscometer, ODR and MDR.

Section XE5.7:	Polymer Processing

Spin coating; Electrospinning; Solution and melt spinning; Film casting; Compression molding; Transfer molding; Injection molding; Blow molding; Reaction injection molding; Filament winding; SMC; BMC; DMC; Extrusion;

pultrusion; Calendaring; Rotational molding; Thermoforming; Powder coating; Rubber processing in two-roll mill, internal mixer, twin screw extruder.

Section XE5.8:	**Polymer Testing**
Mechanical-static and dynamic, tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness; Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, swelling, ageing resistance, environmental stress cracking resistance, limiting oxygen index; Heat deflection temperature – Vicat softening temperature, ductile to brittle transition, glass transition temperature, coefficient of thermal expansion, shrinkage, flammability, dielectric constant, dissipation factor, power factor; Optical Properties - Refractive Index, Luminous Transmittance and Haze, Melt flow index.	

Section XE5.9:	**Polymer Recycling, Waste Management and Sustainability**
Polymer waste and its impact on environment; Sources, identification and separation techniques; Recycling classification: mechanical and chemical recycling, recycling of thermoplastics, thermosets and rubbers, applications of recycled materials; Life cycle assessment of polymer products (case studies like PET bottles, packaging bags); Recycling, segregation and disposal strategies of biodegradable and bio-compostable polymers, microplastics.	

XE6	Food Technology

Section XE6.1: Food Chemistry and Nutrition

Food Components Characterization and quantification techniques

Carbohydrates: Structure and functional properties of mono-, oligo-, & poly- saccharides including starch, cellulose, pectic substances and dietary fibre, gelatinization and retrogradation of starch.

Proteins: classification and structure of proteins in food, Protein denaturation, functional properties of proteins and starch.

Lipids: Classification and structure of lipids, rancidity, polymerization and polymorphism.

Pigments: carotenoids, chlorophylls, anthocyanins, tannins and myoglobin. Curcumin, betalains.

Food Flavours: Terpenes, esters, aldehydes, ketones and quinines. Enzymes: specificity, simple and inhibition kinetics, coenzymes, enzymatic and non- enzymatic browning, Food enzymology.

Nutrition: Balanced diet, essential amino acids and essential fatty acids, protein efficiency ratio, water soluble and fat soluble vitamins, role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases. Food Supplements, Concept of nutrigenomics.
Food adulteration (types of adulterants and their detection)

Chemical and Biochemical Changes: Changes occurring in foods during different processing. Changes occur in foods and food biopolymers (carbohydrates, proteins, lipids) during different processing.

Section XE6.2: Food Microbiology

Characteristics of Microorganisms: Morphology of bacteria, yeast, mold and actinomycetes, spores and vegetative cells, gram-staining, Resistant bacteria.

Microbial Growth: D-value, Z-value, F-value, Growth and death kinetics, serial dilution technique.

Food Spoilage: Spoilage microorganisms in different food products including milk, fish, meat, egg, cereals and their products.

Toxins from Microbes: Pathogens and non-pathogens including Staphylococcus, Salmonella, Shigella, Escherichia, Bacillus, Clostridium, and Aspergillus genera, Food borne diseases.

Fermented Foods and Beverages: Curd, yoghurt, cheese, pickles, soya-sauce, sauerkraut, idli, dosa, vinegar, alcoholic beverages, and sausage.

Probiotic foods: probiotic microorganisms, their benefits, prebiotics, synbiotics.

Section XE6.3: Food Products Technology

Processing Principles: Food Components Characterization and quantification techniques. Quality analysis of raw and processed food products. Thermal processing (blanching, pasteurization, sterilization), chilling, freezing, dehydration, addition of preservatives and food additives, Microwave, radiowave, and Infrared processing, irradiation, fermentation, hurdle technology, intermediate moisture foods.

Non thermal technologies: Ultrasonication, HPP, Pulse Electric Field, Cold plasma.

Food packaging and storage: packaging materials and their properties, aseptic packaging Active and Intelligent packaging, controlled and modified atmosphere storage. Microplastics in food. Cereal processing and products: milling of rice, wheat, and maize, Pulse processing, parboiling of paddy, bread, biscuits, extruded products and ready to eat breakfast cereals. Meat Analogue and Plant-based milk alternatives

Oil Processing: Expelling, solvent extraction, refining and hydrogenation.

Fruits and Vegetables Processing: Extraction, clarification, concentration and packaging of fruit juice, jam, jelly, marmalade, squash, candies, tomato sauce, ketchup, and puree, potato chips, pickles.

Plantation crops processing and products: Tea, coffee, cocoa, spice, extraction of essential oils and oleoresins from spices.

Milk and Milk Products Processing: Pasteurization and sterilization, cream, butter, ghee, ice- cream, cheese and milk powder.

Processing of animal products: Processing of frozen, canned, and dried products, ready to eat products of fish and meat. Curing, smoking, poultry processing, animal slaughtering

Waste Utilization: Pectin from fruit wastes, uses of by-products from rice milling. Edible films and packaging materials from waste

Food standards and Quality Maintenance: FPO, PFA, A-Mark, HACCP, food plant sanitation and cleaning in place (CIP). FSSAI, BIS, Codex Alimentarius, ISO, Food Safety and Management System (FSMS).

Section XE6.4:	**Food Engineering**

Mass and energy balance.
Momentum Transfer: Flow rate and pressure drop relationships for Newtonian fluids flowing through pipe, Reynolds number.

Heat transfer: heat transfer by conduction, convection, radiation, heat exchangers.

Mass Transfer: Molecular diffusion and Fick's law, conduction and convective mass transfer, permeability through single and multilayer films.

Mechanical Operations: Size reduction of solids, high pressure homogenization, filtration, centrifugation, settling, sieving, mixing & agitation of liquid.

Thermal operations: Thermal blanching, pasteurization, sterilization, sterilization, evaporation of liquid foods, hot air drying of solids, spray and freeze-drying, freezing and crystallization.

Mass Transfer Operations: Psychometric, humidification and dehumidification operations.

XE7	Atmospheric and Oceanic Sciences

Section XE7.1:	Atmospheric Science

Vertical Structure and Composition of the Atmosphere; Blackbody Radiation and Radiation Balance; Modes of Heat Transfer in the Atmosphere; Greenhouse Effect; Cloud Types; Laws of Thermodynamics; Gas Laws; Hydrostatic Equation; Clausius Clapeyron Equation; Adiabatic Processes, Humidity in the Atmosphere, Atmospheric Stability; Global Radiation Budget, Role of Greenhouse Gases.

Navier-Stokes and Continuity Equations; Compressible and Incompressible Fluids; Pressure Gradient, Centripetal, Centrifugal and Coriolis Forces; Geostrophic, Gradient and Cyclostrophic Balances; Circulations and Vorticity, General Circulation of the Atmosphere. Broad Features of Indian Monsoons; Fundamentals of Tropical Cyclones.

Section XE7.2:	Ocean Sciences

Vertical Profiles of Temperature and Salinity; Stability and Double Diffusion; Equation of State, Equations for Conservation of Mass, Momentum, Heat and Salt; Inertial Currents; Geostrophic Motion; Air-Sea Surface Fluxes; Wind-driven Circulation, Ekman and Sverdrup Transports; Storm Surges, Tides, Tsunamis and Wind Waves; Eddies and Gyres; Thermohaline Circulation.

Chemical Properties of Seawater, Major and Minor Elements, Ocean Acidification, Biogeochemical Cycling of Nutrients; Biological Pump; Primary and Secondary Biological Productivity; Marine Ecology.

XE8	Energy Science

Section XE8.1:	Energy Resources and Conversion Technologies

Fossil energy resources: R/P ratio, estimation of reserves, unconventional fossil resources (coal bed methane, shale gas, gas hydrates, frozen methane), peak oil theory.

Nuclear energy resources: Energy-mass relation, nuclear reaction conservation laws, binding energy and Q-values, radioactive decay, fission and fusion.

Solar thermal systems: Solar radiation distribution and measurement, solar geometry, optical efficiency, thermal efficiency, energy conversation for solar thermal collectors, flat plate collectors, evacuated tube collectors, solar air heaters, concentrating collectors.

Solar photovoltaic (PV) systems: I-V characteristics, efficiency, fill factor, series and parallel connections, sizing of PV systems (load factor, days of autonomy, battery size, inverter size, PV array size), maximum power point tracking.

Biomass: Biomass resources, biomass composition, characterisation, conversion methods (pyrolysis, gasification, steam reforming), biofuels.

Wind energy conversion systems: Wind resource analysis, types and characteristics of wind turbines, Betz limit, wind turbine motor design considerations, blade profile, wind energy generators.

Hydropower: Hydro resources, hydro power plants, turbines (Pelton, Kaplan, Francis), small hydro systems.

Section XE8.2:	Energy Storage, Economics, Environment, and Efficiency

Energy storage systems: Batteries (capacity, C-rate, state of charge, state of health, depth of discharge, energy and power densities); conservation of energy and mass for thermal energy storage, pumped hydro storage, and compressed air storage; charging, discharging, and roundtrip efficiency.

Economic analysis of energy systems: Simple Payback Period, Time Value of Money, Discount rate, Present Worth Factor, Capital Recovery Factor, Life Cycle Costing, Internal Rate of Return, Net Present Value, Annual Worth, Cost of Saved Energy, Levelized Cost of Energy.

Environmental impacts of energy use: Air pollution (SOx, NOx, CO, particulates), greenhouse gas emissions and their sources, emission factors and inventories.

Energy management: Energy auditing (methodology, analysis of past trends plants data), electrical systems (demand side management, power factor correction), motor efficiency testing, energy efficient motors, lighting (lighting levels, efficient options, fixtures, daylighting, timers), thermal and mechanical systems (insulation, compressors, pumps, boiler, heating and cooling systems).

XE9	Textile Engineering and Fibre Science

Section XE9.1: Textile Fibres

Classification of textile fibres; Essential requirements of fibre forming polymers; Gross and fine structures of natural fibres like cotton, wool, silk; Introduction to bast fibres; Properties and uses of natural and man-made fibres including carbon, aramid and ultra-high molecular weight polyethylene fibres; Physical and chemical methods of fibre and blend identification and blend analysis.

Molecular architecture, amorphous and crystalline phases, glass transition, plasticization, crystallization, melting, factors affecting Tg and Tm; Polymerization of nylon-6, nylon-66, poly (ethylene terephthalate), polyacrylonitrile and polypropylene; Melt spinning processes for PET, polyamide and polypropylene; Preparation of spinning dope; Principles of wet spinning, dry spinning, dry-jet-wet spinning and gel spinning; Spinning of acrylic, viscose and other regenerated cellulosic fibres such as polynosic and lyocell; Post spinning operations such as drawing, heat setting, tow-to-top conversion; Spin finish composition and applications; Different texturing methods.

Methods of investigating fibre structure such as density, x-ray diffraction, birefringence, optical and electron microscopy such as SEM and TEM, I.R. spectroscopy, thermal methods such as DSC, DMA, TMA and TGA; Structure and morphology of man-made fibres; Mechanical properties of fibres; Moisture sorption of fibres; Fibre structure-property correlation.

Section XE9.2: Yarn Manufacture, Yarn Structure and Properties

Principles of ginning; Principles of opening, cleaning and blending; Working principles of modern blowroom machines; Fundamentals of carding; Conventional vs. modern carding machine; Card setting; Card clothing; Periodic mass variation in card sliver; Card autoleveller; Principles of roller drawing; Roller arrangements in drafting systems; Periodic mass variation in drawn sliver; Drawframe autoleveller; Principles of cotton combing; Combing cycle and mechanisms; Recent developments in combing machine; Principles of drafting, twisting, and bobbin building in roving formation; Modern developments in roving machine; Principles of drafting, twisting and cop building in ring spinning; Causes of end breakages; Modern developments in ring spinning machine; Working principles of ring doubler and two-for-one twister; Relationship between single yarn twist and folded yarn twist; Principles of compact, rotor, air-jet, air-vortex, friction, core, wrap and twist-less spinning processes. Influence of fibre geometry, fibre configuration and fibre orientation in yarn; Fibre packing density of yarn; Yarn diameter; Yarn twist and its relation to yarn strength; Helical arrangement of fibres in yarns; Yarn contraction; Fibre migration in yarns; Stress-strain relation in yarn; Mass irregularity of yarn; Structure-property relationship in ring, compact, rotor, air-jet and friction spun yarns.

Section XE9.3: Fabric Manufacture, Structure and Properties

Principles of winding processes; Classification of winding methods; Patterning mechanism; Yarn clearers and tensioners; Different systems of yarn splicing; Warping objectives and classification; Different types of warping creels; Features of beam and sectional warping machines; Different sizing systems; Sizing of spun and filament yarns; Drawing-in process; Principles of pirn winding. Primary and secondary motions of loom; Shedding motion; Positive and negative shedding mechanisms; Type of sheds; Tappet, dobby and jacquard shedding; Weft insertion; Mechanics of weft insertion with shuttle; Shuttle picking and checking; Beat-up; Kinematics of sley; Loom timing diagram; Cam designing; Effect of sley setting and cam profile on fabric formation; Take- up and Let-off motions; Warp and weft stop motions; Warp protection; Weft replenishment; Principles of weft insertion systems of shuttle-less weaving machines such as projectile, rapier, water-jet and air-jet; Principles of functioning of multiphase and circular looms; Types of selvedges; Basic woven fabric constructions and their derivatives, such as crepe, cord, terry, gauze, leno, double cloth and other constructions; Drawing and lifting plans.

Fundamentals of weft knitting; Classification of weft knitting technologies; Weft knitted constructions such as plain, rib, interlock, purl and others; Different knit stitches such as loop, tuck, float and others; Principle of warp knitting; Classification of warp knitting technologies; Swinging and shogging motion of guide bar; Basic warp knit constructions such as pillar, tricot, atlas, inlay nets and others; Fibre preparation processes for nonwovens; Web formation and bonding processes; Spun-bonding and melt-blowing technologies; Applications of

nonwoven fabrics; Principles of braiding; Type of braids; Maypole braiding technology;

Peirce's equations for plain woven fabric geometry; Thickness, cover and maximum set of woven fabrics; Geometry of plain weft knitted loop; Munden's constants and tightness factor for plain weft knitted fabrics; Geometry of tubular braids.

Section XE9.4:	Textile Testing

Sampling techniques for fibres, yarns and fabrics; Sample size and sampling errors.

Moisture in textiles; Fibre length, fineness, crimp, maturity and trash content; Tensile testing of fibres; High volume fibre testing.

Linear density of sliver, roving and yarn; Twist and hairiness of yarn; Tensile testing of yarns; Evenness testing; Fault measurement and analysis of yarns.

Fabric thickness, compressibility, stiffness, shear, drape, crease recovery, tear strength, bursting strength, pilling and abrasion resistance; Tensile testing of fabrics; Objective evaluation of low stress mechanical characteristics; Air permeability; Wetting and wicking; Water-vapour transmission through fabrics; Thermal resistance of fabrics.

Section XE9.5:	Chemical Processing

Impurities in natural fibre; Singeing; Chemistry and practice of preparatory processes for cotton; Preparatory processing of wool and silk; Mercerization of cotton; Preparatory processes for manmade fibres and their blends; Optical brightening agent.

Classification of dyes; Dyeing of cotton, wool, silk, polyester, nylon and acrylic with appropriate classes of dyes; Dyeing of polyester/cotton and polyester/wool blends; Dyeing machines; Dyeing processes and machines for cotton knitted fabrics; Dye-fibre interaction; Introduction to thermodynamics and kinetics of dyeing; Brief idea about the relation between colour and chemical constitution; Beer-Lambert's law; Kubelka-Munk theory and its application in colour measurement; Methods for determination of wash, light and rubbing fastness.

Methods of printing such as roller printing and screen printing; Preparation of printing paste; Various types of thickeners; Printing auxiliaries; Direct styles of printing of (i) cotton with reactive dyes, (ii) wool, silk, nylon with acid and metal complex dyes, (iii) polyester with disperse dyes; Resist and discharge printing of cotton, silk and polyester; Pigment printing; Transfer printing of polyester; Inkjet printing; Printing faults.

Mechanical finishing of cotton; Stiff, soft, wrinkle resistant, water repellent, flame retardant and enzyme (bio-polishing) finishing of cotton; Milling, decatizing and shrink resistant finishing of wool; Antistatic and soil release finishing; Heat setting of synthetic fabrics; Minimum application techniques.

Pollution control and treatment of effluents.

XH	Humanities & Social Sciences

This part is to test the candidate's ability to comprehend and interpret written information – skills that are critical in research in the Humanities and Social Sciences. The section will not directly test language competence in terms of grammar, vocabulary etc. The focus is instead on critical reasoning (similar to what is often found in exams like LSAT, GRE, GMAT etc.) and analysis of the text and its stylistic and rhetorical structure.	
XH0: Reasoning and Comprehension (Common for all XH candidates)	
Section XH0.1:	**Reading Comprehension**
Ability to understand complex language material in short paragraphs and answer questions regarding them.	
Section XH0.2:	**Expression**
Questions on stylistic and rhetorical aspects of a short passage including corrections or modifications of particular sentences.	
Section XH0.3:	**Analytical Reasoning**
Ability to understand relationship in statements or short passages and being able to draw reasonable conclusions/inferences from them.	
Section XH0.4:	**Logical Reasoning**
Thinking critically to evaluate or to predict an argument, identify the main and supporting arguments, predict outcomes etc.	

XH1: Economics

Section XH1.1: Microeconomics

Theory of Consumer Behaviour: Cardinal Approach and Ordinal Approach; Consumer Preferences; Nature of the utility function; Marshallian and Hicksian demand functions; Duality Theorem. Slutsky equation and Comparative Statics. Homogeneous and Homothetic Utility Functions; Euler's Theorem. The Theory of Revealed Preference: Weak Axiom of Revealed Preference and Strong Axiom of Revealed Preference, Theory of Production and Costs: Short-run and Long-run Analysis, Existence, Uniqueness and Stability of Market Equilibrium: Walrasian and Marshallian Stability Analysis. The Cobweb Model, Decision making under uncertainty and risk. Asymmetric Information: Adverse Selection and Moral Hazard. Theory of Agency costs. The Theory of Search, Non-Cooperative games: Constant sum game, Mixed Strategy & Pure Strategy, Bayesian Nash Equilibrium, SPNE, Perfect Bayesian Equilibria., Theory of Firm: Market Structures — Competitive and Non-competitive equilibria and their efficiency properties. Structure-Conduct-Performance Paradigm, Factor Pricing: Marginal productivity Theory of Distribution in Perfectly Competitive markets; Theory of Employment in Imperfectly Competitive Markets — Monopolistic Exploitation, General Equilibrium Analysis. Welfare Economics: Fundamental Theorems, Social Welfare Function. Efficiency Criteria: Pareto-Optimality.

Section XH1.2: Macroeconomics

National Income Accounting: Closed Economy Concepts and Measurement and Open Economy Issues, Determination of output and employment: Classical & Keynesian Framework, Theories of Consumption: Absolute Income Hypothesis, Relative Income Hypothesis, Life Cycle Hypothesis, Permanent Income Hypothesis and Robert Hall's Random Walk Model; Investment Function Specifications - Dale Jorgenson's Neoclassical Theory of Capital Accumulation and Tobin's, Keynesian Stabilization Policies, (Autonomous) Multipliers and Investment Accelerator, Demand and Supply of Money, Components of Money Supply, Liquidity Preference and Liquidity Trap, Money Multiplier, Interest Rate determination, Central Banking, Objectives, Instruments (Direct and Indirect) of Monetary Policy, Prudential Regulation, Quantitative Easing (Unconventional Monetary Policy), Commercial Banking, Non-Banking Financial Institutions, Capital Market and its Regulation, Theories of Inflation and Expectations Augmented Phillips Curve, Real Business Cycles, Adaptive Expectations Hypothesis, Rational Expectation Hypothesis and its critique. Closed Economy IS – LM Model and Mundell Fleming Model: Monetary and Fiscal Policy Efficacy. The Impossible Trinity.

Section XH1.3: Statistics, Econometrics and Mathematical Economics

Basic Statistics: Probability Theory: Concepts of probability, Probability Distributions [Discrete and Continuous], Central Limit Theorem, Index Numbers and Construction of Price Indices, Sampling Methods & Sampling Distribution, Estimation and Hypothesis Testing; Econometrics: Simple Linear Regression Models; the Gauss Markov Theorem; Regression with multiple variables, Heteroscedasticity, Multicollinearity and Autocorrelation, Dummy variable regression, Simultaneous Equation Models – recursive and non-recursive, Identification Problem; Time Series Analysis: Dynamic Models, Models of Non-Stationarity, Spurious Regression, Univariate Time Series Analysis – AR, MA, ARMA, Multivariate Time Series Analysis – cointegration, error-correction, causality and VAR;; Mathematical Economics: Differential Calculus and its Applications, Linear Algebra – Matrices, Applications of Cramer's Rule, Static Optimization Problems and Applications, Input-Output Model, Linear Programming, Difference equations and Differential equations with applications.

Section XH1.4: International Economics

Theories of International Trade, International Trade under Imperfect Competition, Gains from Trade, Terms of Trade, Trade Multiplier, Tariff and Non-Tariff barriers to trade; Dumping and Anti-Dumping Policies, GATT, WTO and Regional Trade Blocks; Trade Policy Issues, Balance of Payments: Composition, Equilibrium and Disequilibrium and Adjustment Mechanisms, Foreign Exchange Market and Arbitrage, Exchange rate determination, IMF & World Bank.

Section XH1.5:	Public Economics

Market Failure and Remedial Measures: Asymmetric Information, Public Goods, Externality, Regulation of Market – Collusion and Consumers' Welfare, Public Revenue: Tax & Non-Tax Revenue, Direct & Indirect Taxes, Progressive and non-Progressive Taxation, Incidence and Effects of Taxation, Public expenditure, Public Debt and its management, Public Budget and Budget Multiplier, Tax Incidence, Fiscal Policy and its implications, Environment as a Public Good, Market Failure and Coase Theorem, Cost-Benefit Analysis.

Section XH1.6:	Development Economics

Theories of Economic Development: Adam Smith, David Ricardo, Karl Marx, J. Schumpeter, W. Rostow, Balanced & Unbalanced Growth, Big Push Approach, Indicators of Economic Development: HDI, SDGs, MDGs, Poverty and Inequalities – Concepts and Measurement Issues, Social Sector Development: Health, Education, Gender, Fertility, Morbidity, Mortality, Migration, Child Labor, Age Structure, Demographic Dividend, Models of Economic Growth: Harrod-Domar, Solow, Ramsey, Technical progress – Disembodied & Embodied, Endogenous Growth Models.

Section XH1.7:	Indian Economy

Economic Growth in India: Pattern and Structure, Agriculture, Industry & Services Sector: Pattern & Structure of Growth, Major Challenges, Policy Responses, Rural & Urban Development – Issues, Challenges & Policy Responses, Flow of Foreign Capital, Trade Policies, Infrastructure Development: Physical and Social; Public-Private Partnerships, Reforms in Land, Labour and Capital Markets, Poverty, Inequality & Unemployment, Functioning of Monetary Policy in India, Fiscal Policy in the Indian context: Structure of Receipts and Expenditure, Tax reforms-Goods and Services Tax, Issues of Growth and Equity, Fiscal Federalism, Centre-State Financial Relations and Finance Commissions of India; Sustainability of Deficits and Debt, The Fiscal Responsibility and Budget Management Act 2003, Demonetization and aftermath. India's balance of payments, Composition of India's Trade, Competitiveness of India's exports, India's exchange rate policy.

XH2: English

Section XH2.1: Literary Forms, Genres, and Modes of Expression

Poetry, drama, fiction (novels, short stories, graphic narratives), creative non-fiction, and nonfiction prose from the Medieval period to the present.

Literary Genres and Subgenres: History, evolution and importance of categorisation to understand different kinds of writing.
Aesthetic and rhetorical strategies, including narrative and poetic techniques, and figures of speech.

Section XH2.2: History of English Literature and Literary Studies

English Literary Traditions across Time: Chaucer to Contemporary English Literature.

Global Perspectives on Literary Studies: Anglophone literatures (British, American, Canadian and other Postcolonial literatures).

Intersections of literature with political, social, and intellectual movements.
Literary Studies in relation to Sociology, Psychology, Philosophy, Environment and other allied disciplines.

Section XH2.3: Comparative and World Literatures in English Translation

Literatures in English translation, particularly from India and the Global South.
Cross-cultural Exchanges and their impact on literary traditions.

Theoretical Frameworks for Comparative Literature: intertextuality, adaptation, interconnectedness and cosmopolitanism.
Multilingualism, Translation Studies, and the politics of language in literary production.

Section XH2.4: Critical Theories and Intellectual Traditions

Theoretical Paradigms, Socio-Cultural Movements shaping Literary Studies: Structuralism, Marxism, Feminism, Existentialism, Poststructuralism, Modernism, Postmodernism, New Historicism, Postcolonialism, Posthumanism, etc.

Interdisciplinary fields: Cultural Studies; Film and Media studies, Memory and Trauma studies, Dalit and Subaltern Studies, Environmental, Medical and Digital humanities, etc.

Indian Literary and Aesthetic Traditions: Classical poetics (Rasa, Dhvani, Vakrokti, Alamkara, Riti, Aucitya) and other indigenous frameworks for literary interpretation.

Section XH2.5: Contemporary Literary Cultures and Research Methodologies

Major literary awards and prizes; literary festivals; literary associations and networks.

Research in literary studies: archival research, ethnographic methods, textual analysis, discourse analysis, AI-assisted and multimodal approaches.

Structuring research arguments, academic integrity, plagiarism checking, citation ethics, and engagement with scholarly discourse.

XH3: Linguistics

Section XH3.1: Language and Linguistics (Fundamental Concepts)

This section covers the fundamental concepts of what language is and how linguists study it.

What is Language? Understanding language in its spoken, written, and signed forms; Difference between description and prescription.
Language and Culture: Exploring the connection between language and a community's cultural heritage; social/personal identities; linguistic determinism/relativity.
The Science of Language: Treating language as an object of scientific study, looking at its basic units and unique properties (design features); levels of adequacy of grammars; principles of creativity and productivity.
Knowledge vs. Use: Difference between a speaker's subconscious knowledge of grammar (*competence*) and their actual use of language in real-world situations (*performance*).
History of Linguistics: Major schools of thought in linguistics (European, American traditions, as well as the Indian Grammatical Tradition).

Section XH3.2: Levels of Grammatical Analysis (The primary components of grammar)

A. Phonetics and Phonology (Sounds):
Speech Production and Perception: Producing sounds using the vocal tract; articulation; phonation; acoustic properties of sounds; perceptual cues; auditory system.

Sound Systems: How languages organize sounds into a system; IPA; finding the abstract sound units (*phonemes*), analyzing their distribution (*allophones*, complementary vs. contrastive distribution); tonal, segmental and suprasegmental phonological processes and their representation (including distinctive features).

Modern Theories: Key ideas from theories (linear and non-linear approaches) like autosegmental phonology, generative phonology, lexical phonology, prosodic morphology, and optimality theory.

B. Morphology (Words):
Building Blocks: Identifying the smallest units of meaning (*morphemes*) and their variations (*allomorphs*); morpheme types.

Word Formation: The difference between grammatical changes to words (*inflection*) and creating new words (*derivation* and other processes of lexeme building); constraints on word formation; lexical and structural ambiguity; the morphology-phonology interface.

The Mental Dictionary: How words and the rules to create them are stored in the mind (*mental lexicon*).

Modern Theories: Key ideas from theories like distributed morphology, lexicalist vs paradigm based approaches, construction morphology.

C. Syntax (Sentences):
Sentence Structure: Understanding the basic units of syntax like words, phrases, and clauses, and the rules for combining them (e.g., *Phrase Structure Rules*, *X-bar Theory*); syntactic processes and representations; diagnostics of structure; sub-modules of syntax such as theta theory, case theory, binding, argument structure; valency alternations etc.; syntax-morphology and syntax-phonology interfaces; structural and semantic ambiguity.

Major Theories: The core principles of key syntactic theories, like generative grammar (including the Minimalist Programme), LFG, and HPSG.

Universal Grammar: The concept that all human languages share an underlying blueprint (*Universal Grammar*), which addresses the language acquisition problem; tacit knowledge vs. explicit knowledge; core grammar vs. peripheral grammar.

Syntactic Analysis: Analyzing common syntactic phenomena across languages.

D. Semantics and Pragmatics (Meaning):

Literal Meaning (Semantics): How word meanings combine to form sentence meaning (*compositionality*); truth conditions; basic logic (propositions, quantifiers); lexical semantics (e.g., *synonymy*, *antonymy*); propositional semantics (*paraphrase*, *entailment*, *contradiction* etc.); syntax-semantics and semantics-pragmatics interfaces.

Meaning in Context (Pragmatics): Contextual use of language including *speech* acts; implied meanings based on conversational rules (Grice's Maxims and *implicatures*), and assumed knowledge (*presuppositions*); deictic and indexical elements; discourse analysis.

Section XH3.3:	Historical Linguistics (Language Change)

Sound Changes over time: Sound laws (e.g., Grimm's Law, Verner's Law).

Grammar and Meaning Change: How grammars change (grammaticalization) and how word meanings shift over time.

Reconstruction: Comparative reconstruction of ancestral languages.

Language Contact including borrowing.

Section XH3.4:	Sociolinguistics (Language and Society)

Language Variation: How language varies based on social factors (e.g., creating *sociolects* or *dialects*); language contact and migration (including dialect geography); the formation of pidgins and creoles; linguistic variables and their co-variation along linguistic/social dimensions; communicative competence.

Bi- and Multilingualism: The study of phenomena like *code-switching* and *code-mixing*; mother tongue and other tongues.

Language and Policy: The role of language in society, including official language policies (especially in India); language endangerment (EGIDS), language loss, and revitalization; language maintenance and language documentation; minority and majority languages.

Section XH3.5:	Typology and Universals (Language Classification)

Classifying Languages: Grouping languages by their structural type (e.g., *agglutinative*, *isolating*, *fusional*) and by their family trees (*genetic classification*).

Language Universals: Identifying features or patterns that are common to all or most languages (e.g., Greenberg's universals on word order).

South Asian Languages: The key areal features of the major language families found in South Asia (*Indo-Aryan*, *Dravidian*, *Austro-Asiatic*, *Tibeto-Burman* etc.); constitutional provisions for languages.

Section XH3.6:	Methods of Analysis (How to Do Linguistics)

Data Collection: Methods for gathering linguistic data, such as fieldwork or experiments; elicitation techniques from speakers; sampling.

Data Analysis: Using both quantitative (basic statistical) and qualitative methods to analyze data.

Ethics: The ethical responsibilities involved in working with languages and their speakers.
Corpora: Development; annotation; types; analysis.

Section XH3.7:	Applied Linguistics (Linguistics in the Real World)

Psycholinguistics: The psychology of language; acquisition, production and comprehension of speech in real-time; language and the brain; bi- and multi-lingualism; language and cognition (e.g. the relationships between language, mind, and experience).

Computational Linguistics: Basic computational ideas of modelling and processing; corpora; parsing; LLMs; basic computational applications for speech recognition, morphological analysis or sentiment analysis etc.

Second Language Acquisition (SLA) and Language Teaching: Principles and practices of language teaching; methods and assessment; learning vs acquisition; cognitive resources.

Clinical Linguistics: assessments and evidence-based therapies; language disorders (both developmental and acquired).

XH4: Philosophy

Section XH4.1: Classical Indian Philosophy

Orthodox Systems: Sānkhya – Puruṣa, Prakṛti, Guṇas, Satkāryavāda, Mokṣa (Kaivalya), Pramāṇas and Theory of Error. Yoga – Pramāṇas, Theory of Error, Iśvara, Citta, Kleśa, Aṣṭānga-yoga, Kaivalya (Mokṣa). Nyāya – Pramāṇas, Hetvābhāsa, Iśvara, Asatkāryavāda, Theory of Error, Navya-Nyāya. Vaiśeṣika – Parataḥprāmāṇya, Padārthas (categories), Theory of Atomism (paramāṇuvāda). Mīmāmsā – Dharma, Apūrva, Mokṣa, Pramāṇas (both in Kumārila and Prabhākara), Anyathākhyāti. Vedānta – Advaita (Adhyāsa, Brahman, Iśvara, Ātman, Jīva, Mokṣa, Viśiṣṭādvaita (Tattva-traya, Mokṣa, and Refutation of Māyāvāda), Dvaita, Dvaitādvaita, Śuddhādvaita, Pramāṇa in Advaita and Viśiṣṭādvaita.

Heterodox Systems: Cārvāka – Pramāṇa, Indian materialism and Hedonism. Jainism – Pramāṇas, Syādvāda, Anekāntavāda, Padārtha (categories), Jīva and Ajīva, Mokṣa, Mahāvrata, Aṇuvrata. Buddhism – Ti-piṭaka, Sarvāstivāda, Sautrāntika, Mādhyamika, Yogācāra-Vijñānavāda, Pañca-skandha, Anityavāda, Anātmavāda, Doctrine of Momentariness, Doctrine of Dependent Origination, Pramānas, Doctrine of Two Truths, Doctrine of Tri-kāya, Ṣaḍ-pāramitās, Brahmavihāras, Pāñcaśīla, and Bodhisattva Ideal, and Upāyakauśalya.

Upaniṣads, Bhagavadgītā, and Dharmaśāstras: Philosophy of the Upaniṣads – Pure Monism, Brahman and Ātman, Pañca-kośa, Parā-vidyā and Aparā-vidyā, Meaning of Dharma, Ṛta, Purusārtha, Śreyas and Preyas, Varṇāśramadharma, Svadharma and Sādhāraṇa Dharma, Ṛna, Yajña, Karma-yoga, Sthitaprajña, Lokasaṃgraha, and Law of Karma.

Kāṣmira Śaivism, Śaivasiddhānta, Vīra Śaivism, Śāktism and Vaiṣṇavism: Kāṣmīra Śaivism – Pratyābhijña school, Śiva and Śakti, and Conception of Kriyā. Śaivasiddhānta – God (pati) and Divine Power (śakti), Proofs for God's Existence, Bondage and Liberation. Philosophical basis of Vīra Śaivism, Śāktism, and Vaiṣṇavism.

Section XH4.2: Contemporary Indian Philosophy

Swami Vivekananda: Practical Vedanta, Nature of Religion, Destiny of the Soul – Realisation of Immortality. Sri Aurobindo: Evolution, Mind and Supermind, Integral Yoga. Iqbal: Self, God, Man and Superman, Intellect and Intuition. Tagore: Religion of man, ideas on education, Concept of Nationalism. K. C. Bhattacharyya: *Swaraj* in ideas, Concept of Philosophy, subject as Freedom, the doctrine of *Māyā.* Radhakrishnan: Intellect and intuition, the Idealist view of life, concept of Universal Religion, Hindu view of life. J. Krishnamurti: Conception of thought, Freedom from the known, analysis of self, Choiceless awareness. Gandhi: Notion of Truth, Non-violence, *satyagraha*, *swaraj*, critique of modern civilization (*Hind Swaraj*). Ambedkar: Basic Features of Indian Constitution; Untouchability, Democracy. Daya Krishna: Three Myths about Indian Philosophy.

Section XH4.3: Classical and Modern Western Philosophy

Metaphysics: Pre-Socratic Philosophy of Thales, Anaxagoras, Anaximenies, Ionians, Pythagoras, Parmenides, Heraclitus, and Democritus. Plato and Aristotle**:** The question of Being (Ousia), Being as Idea in Plato's Phaedo, Republic and the Sophist, Being as the synthesis of Matter [*hyle*] and Form [*morphe*] in Aristotle's Metaphysics and Physics. Problem of evil and existence of God in St. Augustine, St. Anselm, and St. Thomas Aquinas. Metaphysics in Modern Philosophy: Substance, Mind-Body Dualism, Attribute, Parallelism, Pre-established harmony, the existence of God, Problem of Solipsism, Self and Personal Identity, Rejection of Metaphysics, Phenomena and Noumena, Transcendental Deduction of Categories, Being and Becoming, Absolute Idealism.

Epistemology: Plato and Aristotle's Theory of Knowledge, *Doxa*, *Episteme*, and Sophia, Method of Dialectics, Theoretical and Practical Reason, Theory of Causation. Descartes' Method of Doubt, *Cogito ergo sum*, Innate Ideas and its refutation, Principle of Non-contradiction, Sufficient Reason, and Identity of Indiscernibles. Locke's Three Grades of Knowledge, Berkeley's Critique of Abstract Ideas, Hume's Impressions and Ideas, Induction and Causality. Kant's Copernican Revolution, Forms of Sensibility, Possibility of Synthetic *a priori* Judgments. Hegel's Dialectics, Spirit, and Absolute Idealism. The Gettier Problem and major responses to it.

Ethics: Egoism, Altruism, Universalism, Subjectivism, Cultural Relativism, Super-naturalism, Ethical realism and anti-realism, Ethical Cognitivism and Non-cognitivism, Intuitionism. Concepts of Good, Right, Justice, Duty, Obligation, Cardinal Virtues, *Eudaemonism*. Kant's moral theory, Postulates of Morality, Good will, Categorical

Imperative, Duty, Means and ends, Maxims. Utilitarianism: Principle of Utility, Problem of Sanction and Justification of Morality, Moral theories of Bentham, J. S. Mill. Care Ethics. Theories of Punishment. Professional Ethics: Corporate Governance and Social Responsibility. Environmental Ethics: Nature as means or end, land ethic (Aldo Leopold), Deep Ecology (Arne Naess), Animal Rights (Peter Singer). Principles of Bioethics: Autonomy, Beneficence, Non-maleficence and Justice; Doctor-patient relationship, Euthanasia.

Social and Political Philosophy: Plato's theory of Justice and State, Aristotle's definition of State and Political Naturalism. Classical Liberalism and Social Contract Theory (Hobbes, Rousseau, Locke). Marx's Dialectical Materialism, Alienation, and critique of Capitalism. Rawls' Veil of Ignorance, Principles of Justice. Civic virtue, Libertarianism (Robert Nozick), Feminist Political Theory (Simone de Beauvoir, Judith Butler), Multiculturalism (Charles Taylor), Capability Approach.

Logic: Truth and Validity, Nature of Propositions, Categorical Syllogism, Laws of Thought. Classification of Propositions, Square of Opposition, Truth-Functions and Propositional Logic, Quantification, and Rules of Quantification. Symbolic Logic: Use of symbols, Truth Table for testing the validity of arguments, Differences between Deductive and Inductive Logic, Causality and Mill's Method.

Section XH4.4:	**Contemporary Western Philosophy**

Frege's Sense and Reference. Logical Positivism's Verification theory of meaning, Elimination of Metaphysics. Moore's Distinction between Sense and Reference, Defense of common-sense, Proof of an External World. Russell's Logical Atomism, Definite Descriptions, Refutation of Idealism. Wittgenstein on Language and Reality, the Picture Theory, critique of private language, Meaning and Use, Forms of life. Gilbert Ryle on Systematically Misleading Expressions, critique of Cartesian dualism. W.V.O. Quine's Two Dogmas of Empiricism. P.F. Strawson's concept of Person. Husserl's Phenomenological Method, Philosophy as a rigorous science, Intentionality, Phenomenological Reduction, Inter-subjectivity. Heidegger's concept of Being (*Dasein*), Being in the world. Sartre's Types of Being, Concept of Freedom, Bad-faith. Merleau-Ponty on Perception, Embodied Consciousness. William James's Pragmatic Theories of Meaning and Truth, Varieties of Religious experience. John Dewey on Pragmatist Epistemology with focus on Inquiry, Fallibilism and Experience, Education. Nietzsche on the Critique of Enlightenment, Will to Power, Genealogy of Morals, Idea of Overman. Richard Rorty's Critique of Representationalism. Habermas: Communicative Rationality.

XH5: Psychology

Section XH5.1: Research Methods and Statistics

Approaches to Research: Philosophical worldviews & criteria involved in approach. Research design: Quantitative, Qualitative, and Mixed methods.

Designing Research: Research problems, Purpose statement, Variables and Operational Definitions, Hypothesis, Sampling.

Nature of Quantitative & Qualitative Research: Interview, Self-completion questionnaires (Survey), Observation, Experiment, Quasi-experiment, Field studies, Focus groups discussions, Narratives, Case studies, Ethnography.

Ethics in conducting and reporting research.

Statistics in Psychology: Measures of Central Tendency and Dispersion. Normal Probability Curve. Parametric and Non-parametric tests, Effect size and Power analysis.

Correlational Analysis: Correlation [Product Moment, Rank Order], Partial correlation, multiple correlation. Special Correlation Methods: Biserial, Point biserial, tetrachoric, phi coefficient. Regression: Simple linear regression, Multiple regression. Factor analysis: Assumptions, Methods, Rotation and Interpretation.

Experimental Designs: Factorial Design, Randomized Block Designs, Repeated Measures Design, Single-subject designs, Cohort studies, Statistics for experimental design: ANOVA, MANOVA, ANCOVA.

Section XH5.2: Psychometrics

Foundations of Psychological measurement; Basic components: Scales and items' construction and analysis of items: Intelligence test items, Performance tests, Ability & Aptitude test, Personality questionnaires. Method of test construction. Standardization of measures: Reliability, Validity, Norms. Application of assessment and measurements in Tests. Applications of psychological testing in various settings-educations, counselling and guidance, clinical, organizational and developmental.

Section XH5.3: Biological and Evolutionary Basis of Behaviour

Heredity and behaviour, Evolution and natural selection, Nervous system, Structures of the brain and their functions. Neurons: Structure, functions, types, neural impulse, synaptic transmission. Neurotransmitters. Hemispheric lateralization, The endocrine system types and functions. Biological basis of Motivation: Hunger, Thirst, Sleep and Sex. Biological basis of emotion: The Limbic system. Biological basis of Memory. Hormonal regulation of behaviour. Methods of Physiological.

Psychology: Invasive methods – Anatomical methods, degeneration techniques, lesion techniques, chemical methods, microelectrode studies, Non-invasive methods – EEG, Scanning methods, Muscular and Glandular system: Genetics and behaviour: Chromosomal anomalies; Nature-Nurture controversy [Twin studies and adoption studies].

Section XH5.4: Perception, Learning, Memory and Forgetting

Sensation, sensory thresholds and sensory adaptations, Vision, hearing, touch and pain, smell and taste, kinesthesis and vestibular sense. Perception: Role of attention; organizing principles of perception, Gestalt perception, depth perception and illusions. Theories of learning: Classical conditioning, operant conditioning, social learning theory, cognitive learning. Memory: encoding, storage, retrieval, Information processing theories of memory, retrieval in long term memory, reconstructive nature of long-term memory. Forgetting: encoding failure, interference theory, memory trace decay theory.

Section XH5.5:	Cognition

Thinking, Intelligence and Language: Basic elements of thought: Concepts, Propositions, Imagery. Current paradigms of cognitive psychology: Information processing approach, ecological approach. Problem solving: Methods of problem solving, Strategies and obstacles, Role of Metacognitive processing. Decision-making: Choosing among alternatives, Intelligence: Theories of intelligence (Spearman; Thurstone; Jensen; Cattell; Gardner; Stenberg) and Emotional Intelligence; Measuring intelligence, Individual differences in Intelligence; Role of heredity and environment, Difference between Intelligence, Aptitude and Creativity.

Section XH5.6:	Personality

Theories of personality: Psychoanalytic, Behaviourist, Social, Cognitive, Humanism, Trait and Type theories. Biology of personality. Assessment of personality.

Section XH5.7:	Motivation, Emotion and Stress and Coping

Approaches to understanding motivation: Instinct, Drive-reduction, Arousal, Incentive, Humanistic, Achievement motivation, Intrinsic motivation, Aggression, Curiosity and Exploration. Emotions: Nature of emotions; Theories of emotions. Definition of stress, what are stressors, cognitive factors in stress. Factors in stress reaction: General adaptation syndrome, Effect of stress. Coping with stress: Problem-focused coping and Emotion-focused coping.

Section XH5.8:	Social Psychology

Social perception: Attribution, Impression formation, Social categorization, Implicit personality theory. Social influence: Conformity, Compliance and obedience, Attitudes, Beliefs and Values. Evaluating the social world, Attitude formation, Attitude change and persuasion, Cognitive dissonance, Prejudice, Discrimination, Aggression, Power and prosocial behaviour, Belief systems and value patterns. Group dynamics, Theories of intergroup relations and conflicts.

Section XH5.9:	Development Across the Life Span

Nature versus nurture in human development, Prenatal development: Chromosomes, Genes and DNA. Physical, cognitive and psychosocial development in infancy, childhood, adolescence and adulthood. Moral development. Theories of aging.

Section XH5.10:	Clinical Psychology and Organizational Behavior

Psychological disorders, Conceptions of mental disorders, Assessment and diagnosis, DSM and Other tools. Psychotherapies: Psychodynamic, Phenomenological/Experiential therapy, Behaviour therapy, Cognitive therapy, Rational emotive behavior therapy (REBT), Meditation, Biological therapy. Organizational Behavior, Organizational demographic and cultural diversity, Organizational Culture, Making decisions in organization, Power and Politics, Leadership theories, Leadership styles and effectiveness, Positive organizational behavior, Performance management by reward and punishment

Section XH5.11:	Applications of Psychology

Applications of theories of Motivation and Learning in School, Factors in educational achievement, Counselling and Guidance in Schools. Application of theories of motivation, learning, emotions, perceptions in Group dynamics and Organizational setup. Issues of Personal space, Crowding, and Territoriality. Intervention for Mental health and Wellbeing.

XH6: Sociology

Section XH6.1: Sociological Theory

Classical Sociological Traditions: Emile Durkheim (Social Solidarity, Social Facts, Religion, Functionalism, Suicide, Anomie, Division of Labour, Law; Max Weber (Types of authority, Social action, Protestant ethic and the spirit of capitalism, Bureaucracy, Ideal type, Methodology); Karl Marx: Class and class conflict, dialectical and historical materialism, capitalism, surplus value, alienation).

Structural-Functionalism and Structuralism: Bronislaw Malinowski; A.R. Radcliffe- Brown, Talcott Parsons (AGIL, Systems approach), Robert K. Merton (Middle range theory, reference groups, latent and manifest function), Claude Levi Strauss (Myths, Structuralism).

Hermeneutic and Interpretative Traditions: G.H. Mead, Alfred Schutz (Phenomenology); Harold Garfinkel (Ethnomethodology); Erving Goffman (Symbolic interaction, dramaturgy); Clifford Geertz (Culture, thick description).

Recent theoretical developments, Post-Modernism and Post-Structuralism: Pierre Bourdieu, Michel Foucault, Jurgen Habermas, Anthony Giddens, Frankfurt School.

Conflict Theory: Ralf Dahrendorf, Lewis Coser, Louis Althusser.

Indian Thinkers: M.K. Gandhi, B.R. Ambedkar, Radha Kamal Mukherjee, G. S. Ghurye, M.N. Srinivas, Irawati Karve, A. R. Desai, Andre Beteille.

Section XH6.2: Research Methodology and Methods

Conceptualizing Social Reality: Philosophy of Science (Karl Popper & Thomas Kuhn); Scientific Method and Epistemology in Social Science; Hermeneutic Traditions; Etic and Emic approaches; Inductive and Deductive methods; Objectivity and Reflexivity in Social Science; Ethics and Politics of research.

Research Design: Reading Social Science Research, Data and Documents; Fact, Concept and Theory; Hypotheses, Research Questions, Objectives.

Quantitative and Qualitative Methods: Ethnography; Survey Method; Historical Method; Comparative Method; Statistical Methods.

Research Techniques: Sampling; Questionnaire and Schedule; Statistical Analysis; Observation, Interview and Case study; Interpretation, Data Analysis and Report Writing.

Section XH6.3: Sociological Concepts

Sociological Concepts: Social Structure; Culture; Network; Status and Role; Identity; Community; Socialization; Diaspora; Values, Norms and Rules; Personhood, Habitus and Agency; Bureaucracy, Power and Authority; Self and society.

Social Institutions: Marriage, Family and Kinship; Economy; Polity; Religion; Education; Law and Customs.

Social Stratification: Social Difference, Hierarchy, Inequality and Marginalization: Caste and Class; Status and Power; Gender, Sexuality and Disability; Race, Tribe and Ethnicity.

Social Change: Evolution and Diffusion; Modernization and Development; Social Transformations and Globalization; Social Mobility –Sanskritization, Westernization, Educational and Occupational change.

Section XH6.4:	Agrarian Sociology and Rural Transformation

Rural and Peasant Society; Caste- Tribe Distinction and Continuum; Agrarian Social Structure and Emergent Class Relations; Land Ownership and Agrarian Relations; Decline of Agrarian Economy, De-Peasantization and Agrarian Change; Agrarian Unrest and Peasant Movements; Feudalism, Mode of production debate; Land reforms; Panchayati Raj; Rural development programmes and community development; Green revolution and agricultural change; Peasants and farmers movements.

Section XH6.5:	Family, Marriage and Kinship; Theoretical Approaches

Structural- Functionalist, Alliance and Cultural; Gender Relations and Power Dynamics; Inheritance, Succession and Authority; Gender, Sexuality and Reproduction; Children, Youth and Elderly; Emotions and Family; Emergent Forms of Family; Changing Marriage Practices; Changing Care and Support Systems; Family Laws; Domestic Violence and Crime against Women; Honour Killing.

Section XH6.6:	Indian Society/Sociology of India

Colonial, Nationalist, Indological perspectives (G.S. Ghurye); Structural-Functional approach (M.N. Srinivas); Dialectical approach (A.R. Desai); Subaltern studies (R. Guha); Non Brahmin perspectives (Phule, Dr. Babasaheb Ambedkar); Feminist perspectives (Leela Dube, Sharmila Rege); Social Institutions – Family, Kinship, Household, Village and Urban Settings; Social Stratification – Caste, Class, Tribe and Gender; Tradition and Modernity (M.N. Srinivas, Yogendra Singh, Dipankar Gupta); Peasants and agrarian sociology (Andre Beteille, A.R. Desai, D.N. Dhanagare); Social Movement (T.K. Oommen), Village studies; Communalism and Secularism.

Section XH6.7:	Social Movements

Introduction to Social Movements: Nature, Definitions, Characteristics; Social Movement and Social Change; Types of social movements (Reform, Rebellion, Revival, Revolution, Insurrection, Counter Movement).

Theories of Social Movements: Structural–functional; Marxist; Resource Mobilization Theory; New Social Movements.

Social Movement in India with Specific Reference to Social Basis, Leadership, Ideology and Actions: Peasant movement; Labour movement; Dalit movement; Women's movement, Environmental movement.

Social Movements, Civil Society and Globalization: Social movement and its relationship with state and civil society; Social movements and impact of globalization: Debates; Issues of citizenship.

Section XH6.8:	Sociology of Development

Perspectives on the Study of Development: Definitions and Indices; Liberal (Modernization theory), Marxist, and Neo-Marxist Perspectives (Dependency theory, World Systems)

The Micro-Politics of Development: Transforming Communities: Maps and Models; Knowledge and Power in Development; Re-inventing Development: Subaltern Movements; Post- colonial development; Decentralization and devolution; Participatory approaches.

Development and its critique: Post-development perspectives (Escobar); Alternative development paradigms; Feminist critique; Human development, development induced dispossession.

XL	Life Sciences

XL0: Chemistry (Common for all XL candidates)	
Section XL0.1:	**Atomic Structure and Periodicity**
Planck's quantum theory, wave particle duality, uncertainty principle, comparison between Bohr's model and quantum mechanical model of hydrogen atom, electronic configuration of atoms and ions. Hund's rule and Pauli's exclusion principle. Periodic table and periodic properties: ionization energy, electron affinity, electronegativity and atomic size.	
Section XL0.2:	**Structure and Bonding**
Ionic and covalent bonding, MO and VB approaches for diatomic molecules, VSEPR theory and shape of molecules, hybridization, resonance, dipole moment, structure parameters such as bond length, bond angle and bond energy, hydrogen bonding and van der Waals interactions. Ionic solids, ionic radii and lattice energy (Born-Haber cycle). HSAB principle.	
Section XL0.3:	**s, p and d Block Elements**
Oxides, halides and hydrides of alkali, alkaline earth metals, B, Al, Si, N, P, and S. General characteristics of 3d elements. Coordination complexes: valence bond and crystal field theory, colour, geometry, magnetic properties and isomerism.	
Section XL0.4:	**Bioinorganic Chemistry**
Oxygen transport and storage metalloproteins (hemoglobin, myoglobin, hemocyanin); Electron transport Fe-S metalloproteins; Carbonic anhydrase and Cu-Zn Superoxide dismutase.	
Section XL0.5:	**Chemical Equilibria**
Osmotic pressure, elevation of boiling point and depression of freezing point, ionic equilibria in solution, solubility product, common ion effect, hydrolysis of salts, pH, buffer and their applications. Equilibrium constants (K_c, K_p, and K_X) for homogeneous reactions.	
Section XL0.6:	**Electrochemistry**
Conductance, Kohlrausch law, cell potentials, EMF, Nernst equation, thermodynamic aspects and their applications.	
Section XL0.7:	**Reaction Kinetics**
Rate constant, order of reaction, molecularity, activation energy, zero, first and second order kinetics, catalysis and elementary enzyme reactions. Reversible and irreversible inhibition of enzymes.	
Section XL0.8:	**Thermodynamics**
Qualitative treatment of state and path functions, First law, reversible and irreversible processes, internal energy, enthalpy, Kirchoff equation, heat of reaction, Hess's law, heat of formation. Second law, entropy and free energy. Gibbs-Helmholtz equation, free energy change and spontaneity, Free energy changes from equilibrium constant.	
Section XL0.9:	**Structure-Reactivity Correlations and Organic Reaction Mechanisms**

Acids and bases, electronic and steric effects, Stereochemistry, optical and geometrical isomerism, tautomerism, conformers and concept of aromaticity. Elementary treatment of SN1, SN2, E1, E2 and radical reactions, Hoffmann/Saytzeff rules, addition reactions, Markownikoff rule and Kharasch effect. Elementary hydroboration reactions. Grignard's reagents and their uses. Aromatic electrophilic substitutions, nucleophilic aromatic substitutions, and orientation effect as exemplified by various functional groups. Identification of common functional groups by chemical tests.

Section XL0.10:	**Chemistry of Biomolecules**

Amino acids, proteins, nucleic acids and nucleotides. Peptide sequencing by chemical and enzymatic proteolytic methods. DNA sequencing by chemical and enzymatic methods. Carbohydrates (upto hexoses only). Lipids (triglycerides only). Principles of biomolecule purification-Ion exchange and gel filtration chromatography. Electronic absorption and fluorescence spectroscopy for the identification of biological molecules.

XL1: Biochemistry	
Section XL1.1	**Structure and Function of Biomolecules**
Organization of life; Importance of water; Structure and function of biomolecules: Carbohydrates, lipids, proteins, and nucleic acids; Protein structure, folding/misfolding, and function; Myoglobin, hemoglobin, lysozyme, ribonuclease A, carboxypeptidase, and chymotrypsin.	
Section XL1.2	**Enzymes and General Principles of Metabolism**
Enzymes: catalysis, specificity, and regulation, kinetics (up to two substrates), enzyme inhibitors; Regulatory Enzymes; Vitamins and coenzymes; General principles of metabolism, hormonal regulation of metabolism; Generation and utilization of ATP.	
Section XL1.3	**Metabolic Pathways and Associated Disorders**
Glycolysis, TCA cycle, pentose phosphate pathway, oxidative phosphorylation, gluconeogenesis, and fatty acid metabolism; Metabolism of nitrogen-containing compounds: nitrogen fixation, amino acids, and nucleotides. Photosynthesis, photophosphorylation, Calvin cycle. Metabolic disorders (Sugars, amino acids, and lipids).	
Section XL1.4	**Analytical Techniques**
Buffering against pH changes in biological systems, the Henderson-Hasselbalch equation; Ion exchange, size exclusion and affinity chromatography, Thin layer and paper chromatography, centrifugation; Characterization of biomolecules by electrophoresis; Analytical methods to study DNA-protein and protein–protein interactions; Lambert-Beer law, UV-visible, and fluorescence spectroscopy; next-generation DNA sequencing, PCR, and site-directed mutagenesis. Antibody-antigen interaction; Immunological techniques: immunodiffusion, immune-electrophoresis, RIA and ELISA, flow cytometry; monoclonal antibodies and their applications.	
Section XL1.5	**Cell Structure and Function**
Cell structure and organelles; Biological membranes; Transport across membranes; Membrane assembly, Protein targeting and degradation; Biosignalling; Receptor-ligand interaction; Two-component system, hormones and neurotransmitters; Toxins and ion channels.	
Section XL1.6	**Gene Expression and Its Regulation, and DNA Repair**
DNA replication, transcription, and translation; DNA damage and repair; Nuclease accessibility methods; Biochemical regulation of gene expression.	

XL2: Botany	
Section XL2.1:	**Plant Systematics**
Botanical nomenclature; History of plant taxonomy; Diversity and classification of plants; APG system of plant classification; Major families such as Apiaceae, Apocynaceae, Asteraceae, Lamiaceae, Myrtaceae, Solanaceae, Verbenaceae, Poaceae and Orchidaceae; Phylogenetics and cladistics; Molecular taxonomy and DNA barcoding; Centers for plant taxonomy and herbaria in India.	
Section XL2.2:	**Plant Anatomy**
Anatomy of root, stem and leaves, floral organs, embryo and young seedlings; Primary and secondary meristems; Stellar organization; Vascular system and their ontogeny; Xylem and phloem structure; Secondary growth in plants and wood anatomy; Plant cell structure and differences from animal cells.	
Section XL2.3:	**Plant development; Cell and Tissue Morphogenesis**
Life cycle of an angiosperm; Development of male and female gametophyte; Cell fate determination and tissue patterning; Spacing mechanisms in trichomes and stomata; Embryogenesis, organization and function of shoot and root apical meristems; Transition to flowering: photoperiodism and vernalization; ABC model of floral organ patterning, pollen germination, double fertilization, seed development; Xylem and phloem cell differentiation, photomorphogenesis; Phytochrome, cryptochrome, phototropin; Role of auxin, cytokinin, gibberellins, and brassinosteroids on plant development.	
Section XL2.4:	**Plant Physiology and Biochemistry**
Plant water relations, mechanisms of uptake and transport of water, ions, solutes from soil to plants, apoplastic and symplastic transport mechanisms; Mechanism of stomatal movements, nitrogen metabolism, photosynthesis; C3, C4 and CAM cycles, photorespiration, respiration: glycolysis, TCA cycle and electron transport chain; Plant responses and mechanisms of abiotic stresses including drought, salinity, freezing and heat stress, metal toxicity; Role of abscisic acid in abiotic stresses; Structure and function of biomolecules (proteins, carbohydrates, lipids, nucleic acid), enzyme kinetics; Structure and biosynthesis of major plant secondary metabolites (alkaloids, terpenes, phenylpropanoids, flavonoids); Biosynthesis, mechanism of action and physiological effects of auxin, cytokinin, gibberellic acids, brassinosteroid, ethylene, strigolactone, abscisic acid, salicylic and jasmonic acid; Plant peptide hormones; Concept of hormone-receptor-repressor; Senescence and programmed cell death.	
Section XL2.5:	**Genetics and Genomics**
Cell cycle and cell division; Principles of Mendelian inheritance, linkage, recombination, genetic mapping; Extra chromosomal inheritance; Introduction to epigenetics; Gene silencing- transgene silencing, post transcriptional gene silencing, miRNA and siRNA; Evolution and organization of eukaryotic genome structure, gene expression, gene mutation and repair, chromosomal aberrations (numerical: euploidy and aneuploidy and structural: deletion, duplication, inversion, translocation), transposons; Model organisms for functional genetics and genomics; Introduction to transcriptomics, proteomics and metabolomics; Large data analysis, bioinformatics, statistical analysis.	
Section XL2.6:	**Plant Breeding, Genetic Modification, Genome Editing**
Principles, methods – selection, hybridization, heterosis; Male sterility; Genetic maps and molecular markers; Embryo rescue; haploid and doubled haploids; Plant tissue culture: micropropagation, embryo culture and in vitro regeneration, somatic embryogenesis, artificial seed, cryopreservation, somaclonal variation, somatic cell	

hybridization, marker-assisted selection, gene transfer methods viz. direct and vector-mediated, generation of transgenic plants; Introduction to genome editing: CRISPR/Cas9, Cre-Lox system to generate chimeras; Plastid transformation; chemical mutagenesis.
Section XL2.7: Economic and Applied Botany
A general account of economically and medicinally important plants - cereals, pulses, plants yielding fibers, timber, sugar, beverages, oils, rubber, pigments, dyes, gums, drugs and narcotics; Economic importance of algae, fungi, lichen and bacteria; Major Indian cash crops; Effect of industrialization on agricultural botany such as plastic on fiber economy; Genetically modified crops and its regulation eg. Bt cotton, Bt brinjal, golden rice etc.; Chemical biology of phytochemicals; Postharvest processing of tea and essential oil-bearing plants.
Section XL2.8: Plant Pathology
Nature and classification of plant diseases; Diseases of important crops caused by fungi, bacteria, nematodes and viruses, and their control measures (chemical and biological) mechanism(s) of pathogenesis, resistance: basal, systemic, induced systemic resistance, gene for gene concept; Molecular detection of pathogens; Plant-microbe interactions: symbionts and mycorrhiza, pathogens and pests; Signaling pathways in plant defence response; Salicylic acid (SA) and jasmonic acid (JA) in plant-pathogen and plant-herbivore interaction, necrosis; Calcium signalling in plants; Host-parasitic plant interaction (such as Cuscuta).
Section XL2.9: Ecology and Environment
Ecosystems – types, dynamics, degradation, biogeochemical cycles, ecological succession; Food webs and energy flow through ecosystem; Vegetation types of the world, Indian vegetation types and biogeographical zones, climate and flora endemism; Pollution and global climate change, speciation and extinction, biodiversity and conservation strategies, ecological hotspots, afforestation, habitat restoration; Plant interactions with other organisms; epiphytes, parasites and endophytes.

XL3: Microbiology	
Section XL3.1:	**Historical Perspective**
Discovery of microbial world; Landmark discoveries relevant to the field of microbiology; Controversy over spontaneous generation; Role of microorganisms in transformation of organic matter and in the causation of diseases.	
Section XL3.2:	**Methods in Microbiology**
Pure culture techniques; Disinfection and Sterilization: principles, methods and assessment of efficacy; Principles of microbial nutrition; Enrichment culture techniques for isolation of microorganisms; Antigen and antibody detection methods for microbial diagnosis; Light-, phase contrast-, fluorescence- and electron-microscopy; PCR, Real-time PCR for quantitation of microbes; CRISPR-Cas.	
Section XL3.3:	**Microbial Taxonomy and Diversity**
Bacteria, Archea and their broad classification; Eukaryotic microbes: Yeasts, molds and protozoa; Viruses and their classification; Molecular approaches to microbial taxonomy and phylogeny.	
Section XL3.4:	**Prokaryotic Cells: Structure and Function**
Cell walls, cell membranes and their biosynthesis; Mechanisms of solute transport across membranes; Flagella and Pili, Capsules, Cell inclusions like endospores and gas vesicles; Bacterial locomotion, including positive and negative chemotaxis.	
Section XL3.5:	**Microbial Growth**
Definition of growth; Growth curve; Mathematical expression of exponential growth phase; Measurement of growth and growth yields; Synchronous growth; Continuous culture; Effect of environmental factors on growth; Sporulation; Quorum sensing; Bacterial biofilm and biofouling.	
Section XL3.6:	**Microbial Metabolism**
Energetics: redox reactions and electron carriers; Electron transport and oxidative phosphorylation; An overview of metabolism; Glycolysis; Pentose-phosphate pathway; Entner-Doudoroff pathway; Glyoxalate pathway; The citric acid cycle; Fermentation; Aerobic and anaerobic respiration; Chemolithotrophy; Photosynthesis; Calvin cycle; Biosynthetic pathway for fatty acids synthesis; Common regulatory mechanisms in synthesis of amino acids; Regulation of major metabolic pathways.	
Section XL3.7:	**Microbial Diseases and Host Pathogen Interaction**
Normal microbiota; Classification of infectious diseases; Reservoirs of infection; Nosocomial infection; Opportunistic infections; Emerging infectious diseases; Mechanism of microbial pathogenicity; Nonspecific defense of host; Antigens and antibodies; Humoral and cell mediated immunity; Vaccines; Passive immunization; Immune deficiency; Human diseases caused by viruses, bacteria, and pathogenic fungi.	
Section XL3.8:	**Control of Micro-organisms: Chemotherapy/Antibiotics**
General characteristics of antimicrobial drugs; Antibiotics: Classification, molecular mechanism of mode of action and resistance; Antifungal and antiviral drugs.	
Section XL3.9:	**Microbial Genetics**
Types of mutation; UV and chemical mutagens; Selection of mutants; Ames test for mutagenesis; Bacterial genetic system: transformation, conjugation, transduction, recombination, plasmids, transposons; DNA repair; Regulation of gene expression: repression and induction; Operon model; Bacterial genome with special reference to *E.coli*; Phage λ and its life cycle; RNA ; Mutation in virus genomes, virus recombination and reassortment; Basic concept of microbial genomics; Cell cycle and cell division in lower eukaryotes.	
SectionXL3.10:	**Microbial Ecology**
Microbial interactions; Carbon, sulphur and nitrogen cycles; Soil microorganisms associated with vascular plants; Bioremediation; Uncultivable microorganisms; Basic concept of metagenomics and metatranscriptomics.	

XL4: Zoology	
Section XL4.1:	**Animal Diversity**
Systematics and classification of animals, phylogenetic relationships (based on classical and molecular phylogenetic tools).	
Section XL4.2:	**Evolution**
Origin and history of life on earth, theories of evolution, natural selection, adaptation, speciation.	
Section XL4.3:	**Genetics**
Basic Principles of inheritance, molecular basis of heredity, sex determination and sex-linked characteristics, cytoplasmic inheritance, linkage, recombination and mapping of genes in eukaryotes, population genetics, genetic disorders, roles of model organisms in understanding genetic principles.	
Section XL4.4:	**Biochemistry and Molecular Biology**
Nucleic acids, proteins, lipids and carbohydrates; replication, transcription and translation, Krebs cycle, glycolysis, enzyme catalysis, hormones and their actions, roles of vitamins and minerals.	
Section XL4.5:	**Cell Biology**
Basic principles of cellular microscopy, structure of cell, cytoskeletal organization, cellular organelles and their structure and function, cell cycle, cell division, chromosomes and chromatin structure.	
Section XL4.6:	**Gene expression in Eukaryotes**
Eukaryotic genome organization and regulation of gene expression, transposable elements.	
Section XL4.7:	**Animal Anatomy and Physiology**
Comparative anatomy and physiology, respiratory system, muscular system, circulatory system, digestive system, nervous system, excretory system, endocrine system, reproductive system, skeletal system.	
Section XL4.8:	**Parasitology and Immunology**
Nature of parasite, host-parasite relation, protozoan and helminthic parasites, the immune system, cellular and humoral immune response.	
Section XL4.9:	**Development Biology**
Gametogenesis, Embryonic development, cellular differentiation, organogenesis, metamorphosis, Model organisms used in developmental biology, genetic and molecular basis of development, stem cells.	
Section XL4.10:	**Ecology**
The ecosystem, Animal distribution, ecological niche and its contribution to ecological diversity, the food chain, population dynamics, species diversity, zoogeography, biogeochemical cycles, conservation biology, ecotoxicology, biodiversity hotspots in India.	
Section XL4.11:	**Animal Behaviour**
Type of animal behaviours and their evolution, courtship, mating and territoriality, instinct, learning and memory, social behaviour across the animal taxa, communication, pheromones.	

XL5	Food Technology

Section XL5.1: Food Chemistry and Nutrition

Food Components Characterization and quantification techniques

Carbohydrates: Structure and functional properties of mono-, oligo-, & poly- saccharides including starch, cellulose, pectic substances and dietary fibre, gelatinization and retrogradation of starch.

Proteins: classification and structure of proteins in food, Protein denaturation, functional properties of proteins and starch.

Lipids: Classification and structure of lipids, rancidity, polymerization and polymorphism.

Pigments: carotenoids, chlorophylls, anthocyanins, tannins and myoglobin. Curcumin, betalains.

Food Flavours: Terpenes, esters, aldehydes, ketones and quinines. Enzymes: specificity, simple and inhibition kinetics, coenzymes, enzymatic and non- enzymatic browning, Food enzymology.

Nutrition: Balanced diet, essential amino acids and essential fatty acids, protein efficiency ratio, water soluble and fat soluble vitamins, role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases. Food Supplements, Concept of nutrigenomics.
Food adulteration (types of adulterants and their detection)

Chemical and Biochemical Changes: Changes occurring in foods during different processing. Changes occur in foods and food biopolymers (carbohydrates, proteins, lipids) during different processing.

Section XL5.2: Food Microbiology

Characteristics of Microorganisms: Morphology of bacteria, yeast, mold and actinomycetes, spores and vegetative cells, gram-staining, Resistant bacteria.

Microbial Growth: D-value, Z-value, F-value, Growth and death kinetics, serial dilution technique.

Food Spoilage: Spoilage microorganisms in different food products including milk, fish, meat, egg, cereals and their products.

Toxins from Microbes: Pathogens and non-pathogens including Staphylococcus, Salmonella, Shigella, Escherichia, Bacillus, Clostridium, and Aspergillus genera, Food borne diseases.

Fermented Foods and Beverages: Curd, yoghurt, cheese, pickles, soya-sauce, sauerkraut, idli, dosa, vinegar, alcoholic beverages, and sausage.

Probiotic foods: probiotic microorganisms, their benefits, prebiotics, synbiotics.

Section XL5.3: Food Products Technology

Processing Principles: Food Components Characterization and quantification techniques. Quality analysis of raw and processed food products. Thermal processing (blanching, pasteurization, sterilization), chilling, freezing, dehydration, addition of preservatives and food additives, Microwave, radiowave, and Infrared processing, irradiation, fermentation, hurdle technology, intermediate moisture foods.

Non thermal technologies: Ultrasonication, HPP, Pulse Electric Field, Cold plasma.

Food packaging and storage: packaging materials and their properties, aseptic packaging Active and Intelligent packaging, controlled and modified atmosphere storage. Microplastics in food. Cereal processing and products: milling of rice, wheat, and maize, Pulse processing, parboiling of paddy, bread, biscuits, extruded products and ready to eat breakfast cereals. Meat Analogue and Plant-based milk alternatives.

Oil Processing: Expelling, solvent extraction, refining and hydrogenation.

Fruits and Vegetables Processing: Extraction, clarification, concentration and packaging of fruit juice, jam, jelly, marmalade, squash, candies, tomato sauce, ketchup, and puree, potato chips, pickles.

Plantation crops processing and products: Tea, coffee, cocoa, spice, extraction of essential oils and oleoresins from spices.

Milk and Milk Products Processing: Pasteurization and sterilization, cream, butter, ghee, ice- cream, cheese and milk powder.

Processing of animal products: Processing of frozen, canned, and dried products, ready to eat products of fish and meat. Curing, smoking, poultry processing, animal slaughtering.

Waste Utilization: Pectin from fruit wastes, uses of by-products from rice milling. Edible films and packaging materials from waste.

Food standards and Quality Maintenance: FPO, PFA, A-Mark, HACCP, food plant sanitation and cleaning in place (CIP). FSSAI, BIS, Codex Alimentarius, ISO, Food Safety and Management System (FSMS).

Section XL5.4:	**Food Engineering**

Mass and energy balance.
Momentum Transfer: Flow rate and pressure drop relationships for Newtonian fluids flowing through pipe, Reynolds number.

Heat transfer: heat transfer by conduction, convection, radiation, heat exchangers.

Mass Transfer: Molecular diffusion and Fick's law, conduction and convective mass transfer, permeability through single and multilayer films.

Mechanical Operations: Size reduction of solids, high pressure homogenization, filtration, centrifugation, settling, sieving, mixing & agitation of liquid.

Thermal operations: Thermal blanching, pasteurization, sterilization, sterilization, evaporation of liquid foods, hot air drying of solids, spray and freeze-drying, freezing and crystallization.

Mass Transfer Operations: Psychometric, humidification and dehumidification operations.