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BEYOND CLASSROOM

GATE SYLLABUS FOR ALL SUBJECTS

1. **Aerospace Engineering (AE)**

- **Section 1: Engineering Mathematics**

Core Topics:

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

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

Differential Equations: First order linear and nonlinear differential equations, higher-order linear ODEs with constant coefficients. Partial differential equations and separation of variables methods.

Special Topics:

Fourier Series, Laplace Transforms, Numerical methods for linear and nonlinear algebraic equations, Numerical integration and differentiation. Complex analysis. Probability and statistics.

- **Section 2: Flight Mechanics**

Core Topics:

Basics: Atmosphere: Properties, standard atmosphere. Classification of aircraft. Airplane (fixed-wing aircraft) configuration and various parts. Pressure altitude; equivalent, calibrated, indicated air speeds; Primary flight instruments: Altimeter, ASI, VSI, Turn-bank indicator. The angle of attack, sideslip; Roll, pitch & yaw controls. Aerodynamic forces and moments.

Airplane performance: Drag polar; takeoff and landing; steady climb & descent; absolute and service ceiling; range and endurance, load factor, turning flight, V-n diagram. Winds: head, tail & crosswinds.

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

Special Topics:

Dynamic stability: Euler angles; Equations of motion; Decoupling of longitudinal and lateral-directional dynamics; longitudinal modes; lateral-directional modes.

- **Section 3: Space Dynamics**

  Core Topics:

  Central force motion, determination of trajectory, and orbital period in simple cases. Kepler's laws; escape velocity

- **Section 4: Aerodynamics**

  Core Topics:

  Basic Fluid Mechanics: Conservation laws: Mass, momentum, and energy (Integral and differential form); Dimensional analysis and dynamic similarity; Potential flow theory: sources, sinks, doublets, line vortex, and their superposition. Elementary ideas of viscous flows including boundary layers.

  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 number.

  Compressible Flows: Basic concepts of compressibility, One-dimensional compressible flows, Isentropic flows, Fanno flow, Rayleigh flow; Normal and oblique shocks, Prandtl-Meyer flow; Flow through nozzles and diffusers.

  Special Topics:

  Wind Tunnel Testing: Measurement and visualization techniques. Shock - boundary layer interaction.

- **Section 5: Structures**

  Core Topics:

  Strength of Materials: Stress and strain: Three-dimensional transformations, Mohr's circle, principal stresses, Three-dimensional Hooke's law, Plane stress, and strain. Failure theories: Maximum stress, Tresca, and von Mises. Strain energy. Castigliano's principles. Statically determinate and indeterminate trusses and beams. Elastic flexural buckling of columns.

  Flight vehicle structures: Characteristics of aircraft structures and materials. Torsion, bending, and shear of thin-walled sections. Loads on aircraft.

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

2. Agricultural Engineering (AG)

- **Section 1: Engineering Mathematics**

Linear Algebra: Matrices and determinants, linear and orthogonal transformations, Caley-Hamilton theorem; Eigenvalues and Eigenvectors, 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, and power-operated equipment for tillage, sowing, planting, fertilizer application, inter-cultivation, spraying, mowing, chaff cutting, harvesting and threshing calculation of performance parameters - field capacity, efficiency, application rate, and losses; cost analysis of implements and tractors.

- **Section 3: Farm Power**

Sources of Power: Sources of power on the farm - human, animal, mechanical, electrical, wind, solar, and biomass; biofuels.

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; calculation of power, torque, fuel consumption, heat load, and power losses; performance index, cost analysis of implements and tractors.

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 the 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, Moody's diagram; 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, 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 Levelling: Measurement of distance and area; instruments for surveying and leveling; chain surveying, methods of traversing; measurement of angles and bearings, plane table surveying; types of levelling; 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 the 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; 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; hydrothermal treatments; drying and milling of cereals, pulses, and oilseeds; drying kinetics; psychometric – 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.

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.

3. Architecture and Planning (AR)

- **Part A: General**

Section 1: Architecture, Planning, and Design

Architectural Graphics; Visual composition in 2D and 3D; Computer application in Architecture and Planning; Anthropometrics; Organization of space; Circulation- horizontal and vertical; Space Standards; Universal design; Building Byelaws; Codes and standards;

Section 2: Construction and Management

Project management techniques e.g. PERT, CPM, etc.; Estimation and Specification; Professional practice and ethics; Form and Structure; Principles and design of disaster-resistant structures; Temporary structures for rehabilitation;

Section 3: Environmental Planning and Design

Natural and man-made ecosystem; Ecological principles; Environmental considerations in planning and design; Environmental pollution- types, causes, controls and abatement strategies; Sustainable development, goals, and strategies; Climate change and built environment; climate responsive design;

Section 4: Urban Design, landscape and Conservation

Historical and modern examples of urban design; Elements of the urban built environment – urban form, spaces, structure, pattern, fabric, texture, grain, etc.; Concepts and theories of urban design; Principles, tools and techniques of urban design; Public spaces, character, spatial qualities and Sense of Place; Urban design interventions for sustainable development and transportation; Development controls – FAR, densities and building bye-laws. ; Urban renewal and conservation; heritage conservation; historical public spaces and gardens; Landscape design; Site planning;

Section 5: Planning process

Salient concepts, theories, and principles of urban planning; concepts of cities - Eco-City, Smart City; Concepts and theories by trendsetting planners and designers; Ekistics; Urban Sociology; Social, Economic and environmental cost-benefit analysis; Methods of non-spatial and spatial data analysis; Development guidelines such as URDPFI;

Section 6: Housing

Housing typologies; Concepts, principles, and examples of a neighbourhood; Residential densities; Affordable Housing; Real estate valuation;

Section 7: Services and Infrastructure

Firefighting Systems; Building Safety and Security systems; Building Management Systems; Water treatment; Water supply and distribution system; Water harvesting systems; Principles, Planning, and design of stormwater drainage system; Sewage disposal methods; Methods of solid waste management - collection, transportation, and disposal; Recycling and Reuse of solid waste; Land-use – transportation - urban form inter-relationships; Design of roads, intersections, grade separators, and parking areas; Hierarchy of roads and level of service; Para-transits and other modes of transportation, Pedestrian and slow-moving traffic planning;

- **Part B1: Architecture**

  Section B1.1: History and Contemporary Architecture

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

  Section B1.2: Building Construction and Structural systems

  Building construction techniques, methods, and details; Building systems and prefabrication of building elements; Principles of Modular Coordination; Construction planning and equipment; Building material characteristics and applications; Principles of the strength of materials; Alternative building materials; Foundations; Design of structural elements with different materials; Elastic and Limit State design; Structural systems; Principles of Pre-stressing; High Rise and Long Span structures, gravity and lateral load resisting systems.

  Section B1.3: Building Services and Sustainability

  Solar architecture; Thermal, visual and acoustic comfort in built environments; Natural and Mechanical ventilation in buildings; Air-Conditioning systems; Sustainable building strategies; Building Performance Simulation and Evaluation; Intelligent Buildings; Water supply; Sewerage and drainage systems; Sanitary fittings and fixtures; Plumbing systems; Principles of internal and external drainage system; Principles of electrification of buildings; Elevators and Escalators - standards and uses;

- **Part B2: Planning**

  Section B2.1: Regional and Settlement Planning

  Regional delineation; settlement hierarchy; Types and hierarchy of plans; Various schemes and programs of the central government; Transit-Oriented Development (TOD), SEZ, SRZ, etc.; Public Perception and user behaviour; National Housing Policies, Programs, and Schemes. ; Slums, Squatters, and informal housing; Standards for housing and community facilities; Housing for special areas and needs;

  Section B2.2: Planning Techniques and Management

  Application of G.I.S and Remote Sensing techniques in urban and regional planning; Tools and techniques of Surveys – Physical, Topographical, Land use and Socio-economic Surveys; Urban Economics, Law of demand and supply of land and its use in planning; Graphic presentation of spatial data; Local self-governance, Panchayati raj institutions; Planning Legislation and implementation – Land Acquisition Act, PPP, etc.; Decision support system and Land Information System; Urban geography and econometrics; Management of Infrastructure Projects; Demography and equity in planning ;

  Section B2.3: Infrastructure Planning

  Process and Principles of Transportation Planning and Traffic Engineering; Road capacity and Travel demand forecasting; Traffic survey methods, Traffic flow Analysis; Traffic

analyses and design considerations; Traffic and transport management and control in urban areas; Mass transportation planning; Intelligent Transportation Systems; Urban and Rural Infrastructure System Network.

4. **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, 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 de-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, aperiodic, and impulse signals; Sampling theorem; Laplace and Fourier transforms; impulse response of systems; transfer function, the frequency response of the 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 filters.

- **Section 4 - Analog and Digital Electronics**

Basic characteristics and applications of a 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; Sequential circuits - latches and flip flops, state diagrams, shift registers, and counters; 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; de potentiometer; bridges for measurement of R, Land C, Q-meter. Basics of control system - transfer function.

- **Section 6 - Sensors and Bioinstrumentation**

Sensors: resistive, capacitive, inductive, piezoelectric, Hall effect, electrochemical, optical; Sensor signal conditioning circuits; application of LASER in sensing and therapy. Origin of biopotentials 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) and Safety of Biomedical Instruments.

- **Section 7 - Human Anatomy and Physiology**

Basics of a cell, types of tissues and organ systems; Homeostasis; Basics of organ systems - musculoskeletal, respiratory, circulatory, excretory, endocrine, nervous, gastrointestinal, and reproductive.

- **Section 8 - Medical Imaging Systems**

Basic physics, 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, Deformation Mechanics, structure and mechanical properties of bone - cortical and cancellous bones; Soft Tissues - Structure, functions,

material properties, viscoelastic properties, Maxwell & Voight models; Biofluid mechanics - Flow properties of blood in the intact human cardiovascular system.

- **Section 10 - Biomaterials**

  Basic properties of biomaterials - Metallic, Ceramic, Polymeric, and Composite; Fundamental characteristics of implants - biocompatibility, bioactivity, biodegradability; Basics of drug delivery; Basics of tissue engineering. Biomaterial characterization techniques - Rheology, Atomic Force Microscopy, Electron Microscopy, Transmission Electron Microscopy Fourier Transform Infrared Spectroscopy.

5. Biotechnology

- **Section 1: Engineering Mathematics**

  Linear Algebra: Matrices and determinants; Systems of linear equations; Eigenvalues and Eigenvectors.

  Calculus: Limits, continuity, and differentiability; Partial derivatives, maxima, and minima; Sequences and series; Test for convergence.

  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.

  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 the metabolism of carbohydrates, lipids, amino acids, and nucleic acids; 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: Bacterial classification and diversity**;** Microbial Ecology - microbes in marine, freshwater, and terrestrial ecosystems; Microbial interactions; Viruses - structure and classification**;** Methods in microbiology**;** Microbial growth and nutrition**;** Nitrogen fixation**;** Microbial diseases and host-pathogen interactions; Antibiotics and antimicrobial resistance.

  Immunology: Innate and adaptive immunity, humoral and cell-mediated immunity; Antibody structure and function; Molecular basis of antibody diversity; T cell and B cell development; Antigen-antibody reaction; Complement; Primary and secondary lymphoid organs; Major histocompatibility complex (MHC); Antigen processing and presentation; Polyclonal and monoclonal antibody; Regulation of immune response; Immune tolerance; Hypersensitivity; Autoimmunity; Graft versus host reaction; 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; Horizontal gene transfer and transposable elements; Chromosomal variation; Genetic disorders; Population genetics; Epigenetics; Selection and inheritance; Adaptive and neutral evolution; Genetic drift; Species and speciation.

Cell Biology: Prokaryotic and eukaryotic cell structure**;** Cell cycle and cell growth control**;** Cell-cell communication; Cell signaling and signal transduction; 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**

Engineering principles applied to biological systems: Material and energy balances for reactive and non-reactive systems; Recycle, bypass and purge processes; Stoichiometry of growth and product formation; Degree of reduction, electron balance, theoretical oxygen demand.

Classical thermodynamics and Bioenergetics: Laws of thermodynamics; Solution thermodynamics; Phase equilibria, reaction equilibria; Ligand binding; Membrane potential; Energetics of metabolic pathways, oxidation and reduction reactions.

Transport Processes: Newtonian and non-Newtonian fluids, fluid flow - laminar and turbulent; Mixing in bioreactors, mixing time; Molecular diffusion and film theory; Oxygen transfer and uptake in the bioreactor, k_La and its measurement; Conductive and convective heat transfer, LMTD, overall heat transfer coefficient; Heat exchangers.

- **Section 5: Bioprocess Engineering and Process Biotechnology**

Bioreaction engineering: Rate law, zero and first-order kinetics; 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.

Upstream and Downstream Processing: Media formulation and optimization; Sterilization of air and media; Filtration - membrane filtration, ultrafiltration; 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.

Instrumentation and Process Control: Pressure, temperature, and flow measurement devices; Valves; First-order and second-order systems; Feedback and feedforward control; Types of controllers - proportional, derivative and integral control, tuning of controllers.

- **Section 6: Plant, Animal and Microbial Biotechnology**

Plants: Totipotency; Regeneration of plants; Plant growth regulators and elicitors; Tissue culture and cell suspension culture system - methodology, the 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 7: 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 the production of recombinant proteins; Transposons and gene targeting;

Molecular tools: Polymerase chain reaction; DNA/RNA labeling and sequencing; Southern and northern blotting; In-situ hybridization; DNA fingerprinting, RAPD, RFLP; Site-directed mutagenesis; Gene transfer technologies; CRISPR-Cas; Biosensing and biosensors.

Analytical tools: Principles of microscopy - light, electron, fluorescent and confocal**;** Principles of spectroscopy

- UV, visible, CD, IR, fluorescence, 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.

6. Civil Engineering (CE)

- **Section 1: Engineering Mathematics**

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

Calculus: Functions of a 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: Sampling theorems; Conditional probability; Descriptive statistics - Mean, median, mode and standard deviation; Random Variables – Discrete and Continuous, Poisson and Normal Distribution; Linear regression.

Numerical Methods: Error analysis. Numerical solutions of linear and non-linear 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; Free Vibrations of undamped SDOF system.

Solid Mechanics: Bending moment and shear force in statically determinate beams; Simple stress and strain relationships; Simple bending theory, flexural and shear stresses, shear centre; Uniform torsion, Transformation of stress; buckling of column, combined and direct bending stresses.

Structural Analysis: Statically determinate and indeterminate structures by force/ energy methods; Method of superposition; Analysis of trusses, arches, beams, cables, and frames; Displacement methods: Slope deflection and moment distribution methods; Influence lines; Stiffness and flexibility methods of structural analysis.

Construction Materials and Management: Construction Materials: Structural Steel - Composition, material properties, and behavior; **Concrete** - Constituents, mix design, short-term and long-term properties. Construction Management: Types of construction projects; Project planning and network analysis - PERT and CPM; Cost estimation.

Concrete Structures: Working stress and Limit state design concepts; Design of beams, slabs, columns; Bond and development length; Prestressed concrete beams.

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, plate girders, and trusses; Concept of plastic analysis - beams and frames.

- **Section 3: Geotechnical Engineering**

Soil Mechanics: 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.

Foundation Engineering: Sub-surface investigations - Drilling boreholes, 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; Stress distribution in soils – Boussinesq's theory; Pressure bulbs, Shallow foundations – Terzaghi's and Meyerhoff's bearing capacity theories, the effect of the water table; Combined footing and raft foundation; Contact pressure; Settlement analysis in sands and clays; Deep foundations - dynamic and static formulae, Axial load capacity of piles in sands and clays, pile load test, pile under lateral loading, pile group efficiency, negative skin friction.

- **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.

Hydrology: Hydrologic cycle, precipitation, evaporation, evapotranspiration, watershed, infiltration, unit hydrographs, hydrograph analysis, reservoir capacity, flood estimation, and routing, surface run-off models, groundwater hydrology - steady state well hydraulics and aquifers; Application of Darcy's Law.

Irrigation: Types of irrigation systems and methods; Crop water requirements - Duty, delta, evapotranspiration; Gravity Dams and Spillways; Lined and unlined canals, Design of weirs on a permeable foundation; cross drainage structures.

- **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, the quantity of domestic wastewater, primary and secondary treatment. Effluent discharge standards; Sludge 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).

- **Section 6: Transportation Engineering**

Transportation Infrastructure: Geometric design of highways - cross-sectional elements, sight distances, horizontal and vertical alignments.

A 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; Highway capacity.

- **Section 7: Geomatics Engineering**

Principles of surveying; Errors and their adjustment; Maps - scale, coordinate system; Distance and angle measurement - Levelling and trigonometric levelling; Traversing and triangulation survey; Total station; Horizontal and vertical curves.

Photogrammetry and Remote Sensing - Scale, flying height; Basics of remote sensing and GIS.

7. Chemical Engineering (CH)

- **Section 1: Engineering Mathematics**

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

Calculus*:* Functions of a single variable, Limit, continuity and differentiability, Taylor series, Mean value theorems, 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 and wave equations, and Laplace equation.

Complex variables*:* Complex number, polar form of a 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 the numerical solution of differential equations.

- **Section 2: Process Calculations and Thermodynamics**

Steady and unsteady state mass and energy balances including multiphase, multicomponent, reacting, and non-reacting systems. Use of tie components; recycle, bypass, and purge calculations; Gibb's phase rule and degree of freedom analysis.

First and Second laws of thermodynamics. Applications of first law to close and open systems. Second law and Entropy. Thermodynamic properties of pure substances: Equation of State and residual properties, properties of mixtures: partial molar properties, fugacity, excess properties, and activity coefficients; phase equilibria: predicting VLE of systems; chemical reaction equilibrium.

- **Section 3: Fluid Mechanics and Mechanical Operations**

Fluid statics, surface tension, Newtonian and non-Newtonian fluids, transport properties, shell-balances including a differential form of Bernoulli equation and energy balance, equation of continuity, equation of motion, equation of mechanical energy, Macroscopic friction factors, dimensional analysis, and similitude, flow through pipeline systems, velocity profiles, flow meters, pumps and compressors, elementary boundary layer theory, flow past immersed bodies including packed and fluidized beds, Turbulent flow: fluctuating velocity, universal velocity profile and pressure drop.

Particle size and shape, particle size distribution, size reduction and classification of solid particles; free and hindered settling; centrifuge and cyclones; thickening and classification, filtration, agitation, and mixing; conveying of solids.

- **Section 4: 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 5: 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; design and operation of equipment for distillation, absorption, leaching, liquid-liquid extraction, drying, humidification, dehumidification and adsorption, membrane separations(microfiltration, ultra-filtration, nano-filtration and reverse osmosis).

- **Section 6: Chemical Reaction Engineering**

Theories of reaction rates; kinetics of homogeneous reactions, interpretation of kinetic data, single and multiple reactions in ideal reactors, the 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; rate and performance equations for catalyst deactivation

- **Section 7: Instrumentation and Process Control**

Measurement of process variables; sensors and transducers; P&ID equipment symbols; process modeling and linearization, transfer functions and dynamic responses of various systems, systems with an inverse response, process reaction curve, controller modes (P, PI, and PID); control valves; transducer dynamics; analysis of closed-loop systems including stability, frequency response, controller tuning, cascade and feedforward control.

- **Section 8: 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 types of equipment such as heat exchangers and multistage contactors.

- **Section 9: Chemical Technology**

  Inorganic chemical industries (sulfuric acid, phosphoric acid, Chlor-alkali industry), fertilizers (Ammonia, Urea, SSP and TSP); natural products industries (Pulp and Paper, Sugar, Oil, and Fats); petroleum refining and petrochemicals; polymerization industries (polyethylene, polypropylene, PVC, and polyester synthetic fibers).

8. Computer Science and Information Technology (CS)

- **Section1: Engineering Mathematics**

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

  Linear Algebra: Matrices, determinants, a 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. Combinational and sequential circuits. Minimization. Number representations and computer arithmetic (fixed and floating-point).

- **Section 3: Computer Organization and Architecture**

  Machine instructions and addressing modes. ALU, data-path, and control unit. Instruction pipelining, pipeline hazards. Memory hierarchy: cache, main memory, and secondary storage; I/O interface (interrupt and DMA mode).

- **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 optimization, Data flow analyses: constant propagation, liveness analysis, common subexpression 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**

  Concept of layering: OSI and TCP/IP Protocol Stacks; Basics of a packet, circuit, and virtual circuit-switching; Data link layer: framing, error detection, Medium Access Control, Ethernet bridging; Routing protocols: shortest path, flooding, distance vector, and link-state routing; Fragmentation and IP addressing, IPv4, CIDR notation, Basics of IP support protocols (ARP, DHCP, ICMP), Network Address Translation (NAT); Transport layer: flow control and congestion control, UDP, TCP, sockets; Application layer protocols: DNS, SMTP, HTTP, FTP, Email.

9. Chemistry (CY)

- **Section 1: Physical Chemistry**

  Structure: Postulates of quantum mechanics. Operators. Time-dependent and time-independent Schrödinger equations. Born interpretation. Dirac bra-ket notation. Particle in a box: infinite and finite square wells; the concept of tunneling; particle in 1D, 2D, and 3D-box; applications. Harmonic oscillator: harmonic and anharmonic potentials; Hermite polynomials. Rotational motion: Angular momentum operators, Rigid rotor. Hydrogen and hydrogen-like atoms: atomic orbitals; radial distribution function. Multi-electron atoms: orbital approximation; electron spin; Pauli exclusion principle; Slater determinants. Approximation Methods: Variation method and secular determinants; first-order perturbation techniques. Atomic units. Molecular structure and Chemical bonding: Born-Oppenheimer approximation; Valence bond theory and a linear combination of atomic orbitals – molecular orbital (LCAO-MO) theory. Hybrid orbitals. Applications of LCAO-MO theory to H_2^+, H_2; molecular orbital theory (MOT) of homo- and heteronuclear diatomic molecules. Hückel approximation and its application to annular □– electron systems.

Group theory: Symmetry elements and operations; Point groups and character tables; Internal coordinates and vibrational modes; symmetry adapted linear combination of atomic orbitals (LCAO-MO); construction of hybrid orbitals using symmetry aspects.

Spectroscopy: Atomic spectroscopy; Russell-Saunders coupling; Term symbols and spectral details; the origin of selection rules. Rotational, vibrational, electronic, and Raman spectroscopy of diatomic and polyatomic molecules. Line broadening. Einstein's coefficients. 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 coefficients. Ideal and Non-ideal solutions, Raoult's Law and Henry's Law, Chemical equilibria. Dependence of equilibrium constant on temperature and pressure. Ionic mobility and conductivity. Debye-Hückel limiting law. Debye-Hückel-Onsager equation. Standard electrode potentials and electrochemical cells. Nernst Equation and its application, the relationship between Electrode potential and thermodynamic quantities, Potentiometric, and conductometric titrations. Phase rule. Clausius- Clapeyron equation. Phase diagram of one component systems: CO_2, H_2O, S; two-component systems: liquid- vapour, liquid-liquid, and solid-liquid systems. Fractional distillation. Azeotropes and eutectics. Statistical thermodynamics: microcanonical, canonical, and grand canonical ensembles, Boltzmann distribution, partition functions, and thermodynamic properties.

Kinetics (Topic has been rearranged): Elementary, parallel, opposing, and consecutive reactions. Steady-state approximation. Mechanisms of complex reactions. Unimolecular reactions. Potential energy surfaces 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 photochemical and photophysical processes.

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.

- **<u>Section 2: Inorganic Chemistry</u>**

Main Group Elements: Hydrides, halides, oxides, oxoacids, nitrides, sulfides – shapes, and reactivity. Structure and bonding of boranes, carboranes, silicones, silicates, boron nitride, borazines, and phosphazenes. Allotropes of carbon, phosphorous, and sulfur. Industrial synthesis of compounds of main group elements. Chemistry of noble gases, pseudohalogens, and interhalogen compounds. Acid-base concepts and principles (Lewis, Brønsted, HSAB, and acid-base catalysis).

Transition Elements: Coordination chemistry – structure and isomerism, theories of bonding (VBT, CFT, and MOT). 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, substitution, and redox reactions. Metal-metal multiple bonds.

Lanthanides and Actinides: Recovery. Periodic properties, spectra, 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, acetic acid synthesis, metathesis, and olefin oxidation. Heterogeneous catalysis - Fischer-Tropsch reaction, Ziegler-Natta polymerization.

Radioactivity: Detection of radioactivity, Decay processes, the half-life of radioactive elements, fission, and fusion processes.

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, structures of AX, AX_2, ABX_3 type compounds, spinels, band theory, metals, and semiconductors.

Instrumental Methods of Analysis: UV-visible, fluorescence and FTIR spectrophotometry, NMR and ESR spectroscopy, mass spectrometry, atomic absorption spectroscopy, Mössbauer spectroscopy (Fe and Sn), and X-ray crystallography. Chromatography including GC and HPLC. Electroanalytical methods- polarography, cyclic voltammetry, ion-selective electrodes. Thermoanalytical methods.

- **Section 3: Organic Chemistry**

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

Reaction Mechanisms: Basic mechanistic concepts – kinetic versus thermodynamic control, Hammond's postulate and Curtin-Hammett principle. Methods of determining reaction mechanisms through kinetics, identification of products, intermediates, and isotopic labelling. Linear free-energy relationship – Hammett and Taft equations. 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 – carbocations, carbanions, carbenes, nitrenes, arynes, and free radicals. Molecular rearrangements.

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, Sonogoshira, Negishi, Kumada, Hiyama, Tsuji-Trost, olefin metathesis, and McMurry. 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 carbon-heteroatom 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).

Pericyclic Reactions and Photochemistry: Electrocyclic, cycloaddition, and sigmatropic reactions. Orbital correlations - FMO and PMO treatments, Woodward-Hoffmann rule. Photochemistry of alkenes, arenes, and carbonyl compounds. Photooxidation and photoreduction. Di-π-methane rearrangement, Barton-McCombie reaction, Norrish type-I, and II cleavage reaction.

Heterocyclic Compounds: Structure, preparation, properties, and reactions of furan, pyrrole, thiophene, pyridine, indole, quinoline, and isoquinoline.

Biomolecules: Structure, properties and reactions of mono- and disaccharides, 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). Applications of various chromatographic techniques such as thin-layer, column, HPLC, and GC. Applications of UV-visible, IR, NMR, and Mass spectrometry in the structural determination of organic molecules.

10. Electronics and Communications (EC)

- **Section 1: Engineering Mathematics**

Linear Algebra: Vector space, basis, linear dependence, and independence, matrix algebra, eigenvalues and eigenvectors, 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: First order equations (linear and nonlinear), higher-order linear differential equations, Cauchy's and Euler's equations, methods of solution using a variety 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.

- **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.

Continuous-time signals: Fourier series and Fourier transform, sampling theorem, and applications.

Discrete-time signals: DTFT, DFT, z-transform, discrete-time processing of continuous-time signals. LTI systems: definition and properties, causality, stability, impulse response, convolution, poles and zeroes, frequency response, group delay, phase delay.

- **Section 3: Electronic Devices**

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, LED, photodiode, 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 triggers, and oscillators.

- **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; Lag, lead and lag-lead compensation; 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, superheterodyne receivers.

Information theory: entropy, 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, S- parameters, Smith chart.

Rectangular and circular waveguides, light propagation in optical fibers, dipole and monopole antennas, linear antenna arrays.

11. Electrical Engineering (EE)

- **Section 1: Engineering Mathematics**

Linear Algebra: Matrix Algebra, Systems of linear equations, Eigenvalues, Eigenvectors.

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 the 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.

- **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: the 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, 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 overcurrent, differential, directional and distance protection; Circuit breakers, System stability concepts, Equal area criterion, Economic Load Dispatch (with and without considering transmission losses).

- **Section 7: 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; State-space model, Solution of state equations of LTI systems, R.M.S. value, average value calculation for any general periodic waveform.

- **Section 8: Electrical and Electronic Measurements**

Bridges and Potentiometers, Measurement of voltage, current, power, energy and power factor; Instrument transformers, Digital voltmeters and multimeters, 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, 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.

12. ES: Environmental Science and Engineering (ES)

- **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.

Differential Equations: Linear and non-linear first-order ordinary differential equations (ODE), Higher order linear ODEs with constant coefficients, Cauchy's and Euler's equations, Laplace transform and its application in solving linear ODEs.

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; Radioactivity of elements; Chemical equilibria; Thermodynamics and kinetics of chemical reactions.

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

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; Urban atmosphere—smog and particulate pollution; Chemistry of ozone formation; Chemistry of stratosphere.

- **Section 3: Environmental Microbiology**

Prokaryotic and eukaryotic microorganisms; Characteristics of diverse groups of microorganisms; Classification of microorganisms; Microbial diversity; Plant-microbe and soil-microbe interactions; 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; Bonds in biomolecules; Stereoisomerism in biomolecules; Structure of cell; Structure and function of the cytoplasmic membrane, cell wall, outer membrane, glycocalyx, chromosomes, endospores, storage products, mitochondria, and chloroplasts.

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; Water quality; 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; Reservoir and channel routing; Surface run-off models; Surface water management; Rainwater 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; Boundary layer theory; 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 and unlined 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 stormwater 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 of the atmosphere; Natural and anthropogenic sources of pollution; Atmospheric sources, sinks, transport; Indoor air pollution; Effects on health and environment; Air pollution: gases and particulate matter; Air quality standards; Primary and secondary pollutants; Criteria pollutants, ambient and source standards, air quality indices, visibility.

Particulate pollutants: measurement and control methods; Control of particulate air pollutants using gravitational settling chambers, cyclone separators, wet collectors, fabric filters (Bag-house 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; Vapour-liquid and vapour-solid equilibria; Diffusion, Fick's law, and interfacial mass transfer.

Automotive emission controls, fuel quality, diesel particulate filters, catalytic converters.

Air quality management: Point, line, and area sources; Inventory; Influence of meteorology -wind rose diagrams, stability, mixing height, topography, dispersion modelling, monitoring.

Noise pollution: Sources; Health effects; Standards; Measurement and control 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 and transportation, waste processing, and disposal (including reuse options, biological methods, energy recovery processes, and landfilling).

Hazardous waste management: Characteristics, generation, the fate of materials in the environment, treatment, and disposal.

Soil contamination and leaching of contaminants into groundwater.

Management of biomedical waste, plastic 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, global warming, climate change, urban heat islands, acid rain, ozone hole.

Ecology and various ecosystems; Biodiversity; Factors influencing the 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

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.

13. Ecology and Evolution (EY)

- **Section 1: Ecology**

Fundamental concepts: Abiotic and biotic components; scales (population, species, community, ecosystems, biomes); niches and habitats

Population ecology: Population growth rates (density dependent/independent); metapopulation ecology (colonization, persistence, extinction, patches, sources, sinks); age- structured populations

Interactions: Types (mutualism, symbiosis, commensalism, competition, parasitism, predation, etc); ecophysiology (physiological adaptations to the abiotic environment); prey-predator interactions (Lotka-Volterra equation, etc)

Community ecology: Community assembly, organization, and succession; species richness, evenness and diversity indices, species-area relationships; theory of island biogeography

Ecosystems structure and function: trophic levels and their interactions; nutrient cycles; primary and secondary productivity

- **Section 2: Evolution**

History of Evolutionary thought: Lamarckism; Darwinism; Modern Synthesis

Fundamentals: Variation; heritability; natural selection; fitness and adaptation; types of selection (stabilizing, directional, disruptive)

Diversity of life: Origin and history of life on earth; diversity and classification of life; systems of classification (cladistics and phenetics)

Life history strategies: Allocation of resources; tradeoffs; r/K selection; semelparity and iteroparity

Interactions: Co-evolution (co-adaptations, arms race, Red Queen hypothesis, co-speciation); prey-predator interactions (mimicry, crypsis, etc)

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, F_{ST}); polygenic traits; gene-environment interactions (phenotypic plasticity); heritability

Molecular evolution and phylogenetics: Neutral theory; molecular clocks; rates of evolution; phylogenetic reconstruction; molecular systematics

Macroevolution: Species concepts and speciation; adaptive radiation; convergence; biogeography

- **Section 3: Mathematics and Quantitative Ecology**

Mathematics and statistics in ecology: Simple functions (linear, quadratic, exponential, logarithmic, etc); the concept of derivatives and slope of a function; permutations and combinations; basic probability (probability of random events; sequences of events, etc); frequency distributions and their descriptive statistics (mean, variance, coefficient of variation, correlation, etc).

Statistical hypothesis testing: Concept of p-value; Type I and Type II error, test statistics like t-test and Chi-square test; basics of linear regression and ANOVA.

- **Section 4: Behavioural Ecology**

  Classical Ethology: Instinct; fixed action patters; imprinting; learned behavior; proximate and ultimate questions

  Sensory ecology: Neuroethology; communication (chemical, acoustic and visual signaling); recognition systems

  Foraging ecology: Foraging behaviour; optimal foraging theory

  Reproduction: Cost of sex; sexual dimorphism; mate choice; sexual selection (runaway selection, good-genes, handicap principle, etc); sexual conflict; mating systems; parental care

  Social living: Costs and benefits of group-living (including responses to predators); effect of competition (scramble and contest) on group formation; dominance relationships; eusociality; kin selection; altruism; reciprocity; human behaviour

- **Section 5: Applied Ecology & Evolution**

  Biodiversity and conservation: Importance of conserving biodiversity; ecosystem services; threats to biodiversity; invasive species; *in-situ* conservation (endemism, biodiversity hotspots, protected areas); *ex-situ* conservation; conservation genetics (genetic diversity, inbreeding depression); DNA fingerprinting and DNA barcoding

  Disease ecology and evolution: Epidemiology; zoonotic diseases; antibiotic resistance; vector control

  Plant and animal breeding: Marker-assisted breeding; genetic basis of economically important traits

  Global climate change: Causes; consequences; mitigation

14. Geomatics Engineering (GE) (NEW!)

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

Remote Sensing: Basic concept, Electromagnetic spectrum, Spectral signature, Resolutions- Spectral. Spatial, Temporal, and Radiometric, Platforms and Sensors, Remote Sensing Data Products - PAN, Multispectral, Microwave, Thermal, Hyperspectral, 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, Algorithms, DBMS, Creation of Databases (spatial and non-spatial), Spatial analysis - Interpolation, Buffer, Overlay, Terrain Modelling, and Network analysis.

- **Section 1**:

  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: Various Levels, Levelling methods, Compass, Theodolite, and Total Station and their uses, Tachometer, Trigonometric levelling, Traversing, Triangulation, and Trilateration.

  Aerial Photogrammetry: Types of photographs, Flying height, and scale, Relief (height) displacement, Stereoscopy, 3-D Model, Height determination using Parallax Bar, Digital Elevation Model (DEM), Slope.

- **Section 2**:

  Data Quantization and Processing: Sampling and quantization theory, Principle of Linear System, Convolution, Continuous and Discrete Fourier Transform.

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

  Radiometric and Geometric Corrections: Registration and Resampling techniques.

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

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

  Image Segmentation and Classification: Simple techniques.

15. Geology and Geophysics (GG)

- **Part A: Common Section**

  Earth and planetary system – terrestrial planets and moons of the solar system; size, shape, internal structure, and composition of the earth; the concept of isostasy; elements of seismology – body and surface waves, propagation of body waves in the earth's interior; Heat flow within the earth; Gravitational field of the Earth; geomagnetism and paleomagnetism; continental drift; plate tectonics – relationship with earthquakes, volcanism and mountain building; continental and oceanic crust – composition, structure, and thickness.

  Weathering and soil formation; landforms created by river, wind, glacier, ocean, and volcanoes.

Basic structural geology - stress, strain, and material response; brittle and ductile deformation; nomenclature and classification of folds and faults.

Crystallography – basic crystal symmetry and concept of point groups. Mineralogy – silicate crystal structure and determinative mineralogy of common rock-forming minerals.

Petrology of common igneous, sedimentary and metamorphic rocks.

Geological time scale; Geochronology and absolute time. Stratigraphic principles; major stratigraphic divisions of India.

Mineral, coal, and petroleum resources of India. Introduction to remote sensing.

Engineering properties of rocks and soils.

Elements of hydrogeology.

Principles and applications of gravity, magnetic, electrical, electromagnetic, seismic, and radiometric methods of prospecting for oil, mineral, and groundwater; introductory good logging.

- **Part B (Section-1): Geology**

Geomorphology - Geomorphic processes and agents; development and evolution of landforms in continental and oceanic settings; tectonic geomorphology.

Structural geology – Forces and mechanism of rock deformation; primary and secondary structures; geometry and genesis of planar and linear structures (bedding, cleavage, schistosity, lineation); folds, faults, joints, and unconformities; Stereographic projection; shear zones, thrusts, and superposed folding; basement cover relationship. Interpretation of geological maps.

Crystallography and mineralogy- Elements of crystal symmetry, form, and twinning; crystallographic projection; crystal chemistry; classification of minerals, physical and optical properties of rock-forming minerals.

Geochemistry – Cosmic abundance of elements; meteorites; geochemical evolution of the earth; geochemical cycles; distribution of major, minor, and trace elements in crust and mantle; elements of high temperature and low-temperature geochemical thermodynamics; isotopic evolution of the crust and the mantle, mantle reservoirs; geochemistry of water and water-rock interaction.

Igneous petrology – Classification, forms, textures, and genesis of common igneous rocks; magmatic differentiation; binary and ternary phase diagrams; major and trace elements as monitors of partial melting and magma evolutionary processes. Mantle plumes, hotspots, and large igneous provinces.

Sedimentology– Texture, structure, and sedimentary processes; petrology of common sedimentary rocks; Sedimentary facies and environments, cyclicities in sedimentary succession; provenance and basin analysis. Important sedimentary basins of India

Metamorphic petrology – Structures and textures of metamorphic rocks. Physico-chemical conditions of metamorphism and concept of metamorphic facies, grade, and baric

types; chemographic projections; metamorphism of pelitic, mafic, and impure carbonate rocks; the role of bulk composition including fluids in metamorphism; thermobarometry and metamorphic P-T-t paths, and their tectonic significance.

Paleobiology - Diversity of life through time, mass extinctions- causes and effects; taphonomy - processes of fossilization. Taxonomy. Morphology and functional morphology of invertebrates (bivalves, brachiopods, gastropods, echinoids, ammonites); microfossils (foraminifera, Ostracoda, conodonts, bryozoa); Vertebrate paleontology (Equus, Probicidea, Human); Paleobotany (plant, spores, pollens). **Basic concepts of ecology/paleoecology; classification** - ecological and taxonomic schemes (diversity and richness). Fossils and paleoenvironments.

Stratigraphy – Principles of stratigraphy and concepts of correlation; Lithostratigraphy, biostratigraphy, and chronostratigraphy. Principles of sequence stratigraphy and applications. Stratigraphy of peninsular and extra-peninsular India. Boundary problems in Indian stratigraphy.

Resource geology - Ore-mineralogy; ore-forming processes vis-à-vis ore-rock association (magmatic, hydrothermal, sedimentary, supergene, and metamorphogenic ores); fluid inclusions as ore genetic tools. Coal and petroleum geology; marine mineral resources. Prospecting and exploration of economic mineral deposits - sampling, ore reserve estimation, geostatistics, mining methods. Ore dressing and mineral economics. Distribution of mineral, fossil, and nuclear fuel deposits in India.

Global tectonics – Plate motions, driving mechanisms, plate boundaries, supercontinent cycles.

Applied geology – physicomechanical 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; rocks as construction materials; geological factors in the construction of engineering structures including dams, tunnels, and excavation sites. Analysis of slope stability.

Natural hazards (landslide, volcanic, seismogenic, coastal) and mitigation. Principles of climate change Hydrogeology – Groundwater flow and exploration, well hydraulics, and water quality.

Basic principles of remote sensing – energy sources and radiation principles, atmospheric absorption, the interaction of energy with earth's surface, aerial-photo interpretation, multispectral remote sensing in visible, infrared, thermal IR and microwave regions, digital processing of satellite images. GIS – basic concepts, raster, and vector mode operations.

- **Part B (Section-2): Geophysics**

Solid-Earth Geophysics - The earth as a planet; different motions of the earth; gravity field of the earth, Clairaut's theorem, size and shape of earth; geomagnetic field, paleomagnetism; Geothermics and heat flow; seismology and interior of the earth; variation of density, velocity, pressure, temperature, electrical and magnetic properties of the earth.

Geodesy - Gravitational Field of the Earth; Geoid; Ellipsoid; Geodetic Reference Systems; Datum; Everest (1830) and WGS 84 (1984) systems; GPS and DGPS; Levelling and Surveying.

Earthquake Seismology - Elements of elasticity theory- stress and strain tensors, Generalized Hooke's Law; Body and Surface Waves; Rotational, dilatational, irrational, and equivolumnal waves. Reflection and refraction of elastic waves; Inhomogeneous and evanescent waves and bounded waves;

Eikonal Equation and Ray theory; earthquakes-causes and measurements, magnitude and intensity, focal mechanisms; earthquake quantification, source characteristics, seismotectonic, and seismic hazards; digital seismographs, Earthquake statistics, wave propagation in elastic media, quantifying earthquake source from seismological data. Elements of Seismic Tomography.

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 Methods - Absolute and relative gravity measurements; Gravimeters; Land, airborne, shipborne and bore-hole gravity surveys; Tensorial Gravity sensors and surveys; various corrections for gravity data reduction – free air, Bouguer and isostatic anomalies; density estimates of rocks; regional and residual gravity separation; the principle of equivalent stratum; data enhancement techniques, upward and downward continuation; derivative maps, wavelength filtering; preparation and analysis of gravity maps; gravity anomalies and their interpretation – anomalies due to geometrical and irregular shaped bodies, depth rules, calculation of mass.

Magnetic Methods - Elements of Earth's magnetic field, units of measurement, magnetic susceptibility of rocks and measurements, magnetometers and magnetic gradiometers, Land, airborne, and marine magnetic and magnetic gradiometer surveys, Various corrections applied to magnetic data, IGRF, Reduction to Pole transformation, Poisson's relation of gravity and magnetic potential field, preparation of magnetic maps, upward and downward continuation, magnetic anomalies due to geometrical and irregular shaped bodies; Image processing concepts in the processing of magnetic anomaly maps; Depth rules; Interpretation of processed magnetic anomaly data; derivative, analytic signal and Euler Depth Solutions. Applications of gravity and magnetic methods for mineral and oil exploration.

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, Concept of Negative Apparent Resistivity and Negative Apparent Chargeability; Theory of Reciprocity, Sounding, and Profiling, Various electrode arrangements, application of linear filter theory, Sounding curves over multi-layered earth, Dar-Zarrouk parameters, reduction of layers, Triangle of anisotropy, interpretation of resistivity field data, Principles of equivalence and suppression, self-potential method and its origin; Electrical Resistivity Tomography (ERT);, Induced polarization, time and frequency domain IP measurements; interpretation and applications of SP, resistivity and IP data sets for ground-water exploration, mineral exploration, environmental and engineering applications.

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; Ground and Airborne Methods, measurements in different source-receiver configurations; Earth's natural electromagnetic methods-telluric, geomagnetic depth sounding and magnetotellurics; Electromagnetic profiling and Sounding, Time-domain EM method; EM scale modeling, processing of EM data and interpretation;

Ground Penetrating Radar (GPR) Methods; Effect of conducting overburden; Geological applications including groundwater, mineral environmental and hydrocarbon exploration.

Seismic methods - Elastic properties of earth materials; Reflection, refraction and CDP surveys; land and marine seismic sources, generation and propagation of elastic waves, velocity – depth models, geophones, hydrophones, digital recording systems, digital formats, field layouts, seismic noise and noise profile analysis, optimum geophone grouping, noise cancellation by shot and geophone arrays, 2D, 3D, and 4D seismic data acquisition, 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 seismic, VSP, AVO, multi-component seismic and seismic interferometry. Reservoir geophysics- Rock Physics and Petrophysics.

Geophysical Survey Design.

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, autocorrelation, cross-correlation, convolution, deconvolution, principles of digital filters, windows, poles, and zeros.

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. Pulsed Neutron Devices and Spectroscopy; Multi-Array and Triaxial Induction Devices; Quantitative evaluation of formations from good logs; Logging while drilling; High angle and horizontal wells; Clay Quantification; Lithology and Porosity Estimation; Saturation and Permeability Estimation; application of borehole geophysics in groundwater, mineral and oil exploration.

Radioactive Methods - Prospecting and assaying of mineral (radioactive and non-radioactive) deposits, half-life, decay constant, radioactive equilibrium, G M counter, scintillation detector, semiconductor devices, application of radiometric for exploration, assaying, and radioactive waste disposal.

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, machine learning, and artificial neural networks. Statistics of misfit and likelihood, Bayesian construction of posterior probabilities, sparsity promoting L1 optimization. Ambiguity and uncertainty in geophysical interpretation.

16. Instrumentation Engineering (IN)

- **Section 1: Engineering Mathematics**

Linear Algebra: Matrix algebra, systems of linear equations, consistency and rank, 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 equation (linear and nonlinear), 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: Sampling theorems, conditional probability, mean, median, mode, standard deviation, and variance; random variables: discrete and continuous distributions: normal, Poisson, and binomial distributions.

Numerical Methods: Matrix inversion, solutions of non-linear algebraic equations, iterative methods for solving differential equations, numerical integration, regression, and correlation analysis.

- **Section 2: Electricity and Magnetism**

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 the 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 3: Electrical Circuits and Machines**

Voltage and current sources: independent, dependent, ideal, and practical; v-i relationships of resistor, inductor, mutual inductance, and capacitor; transient analysis of RLC circuits with dc excitation.

Kirchoff's laws, mesh and nodal analysis, 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, locus diagrams, a realization of basic filters with R, L, and C elements. transient analysis of RLC circuits with ac excitation.

One-port and two-port networks, driving point impedance, and admittance, open-,, and short circuit parameters.

Single-phase transformer: equivalent circuit, phasor diagram, open circuit, and short circuit tests, regulation and efficiency; Three-phase induction motors: a principle of operation, types, performance, torque-speed characteristics, no-load and blocked rotor tests, equivalent circuit, starting and speed control; Types of losses and efficiency calculations of electric machines.

- **Section 4: Signals and Systems**

Periodic, aperiodic, and impulse signals; Laplace, Fourier, and z-transforms; transfer function, the frequency response of first and second-order linear time-invariant systems, the impulse response of systems; convolution, correlation. Discrete-time system: impulse response, frequency response, pulse transfer function; DFT and FFT; basics of IIR, and FIR filters.

- **Section 5: Control Systems**

Feedback principles, signal flow graphs, transient response, steady-state-errors, Bode plot, phase and gain margins, Routh and Nyquist criteria, root loci, design of lead, lag and lead-lag compensators, state-space representation of systems; time-delay systems; mechanical, hydraulic and pneumatic system components, synchro pair, servo, and stepper motors, servo valves; on-off, P, PI, PID, cascade, feedforward, and ratio controllers, tuning of PID controllers and sizing of control valves.

- **Section 6: Analog Electronics**

Characteristics and applications of a diode, Zener diode, BJT and MOSFET; small-signal analysis of transistor circuits, feedback amplifiers. Characteristics of ideal and practical operational amplifiers; applications of opamps: adder, subtractor, integrator, differentiator, difference amplifier, instrumentation amplifier, precision rectifier, active filters, oscillators, signal generators, voltage-controlled oscillators, and phase-locked loop, sources, and effects of noise and interference in electronic circuits.

- **Section 7: Digital Electronics**

Combinational logic circuits, minimization of Boolean functions. IC families: TTL and CMOS. Arithmetic circuits, comparators, Schmitt trigger, multi-vibrators, sequential circuits, flipflops, shift registers, timers, and counters; sample-and-hold circuit, multiplexer, analog-to-digital (successive approximation, integrating, flash and sigma-delta) and digital-to-analog converters (weighted R, R-2R ladder and current steering logic). Characteristics of ADC and DAC (resolution, quantization, significant bits, conversion/settling time); basics of number systems, Embedded Systems: Microprocessor and microcontroller applications, memory and input-output interfacing; basics of data acquisition systems, basics of distributed control systems (DCS) and programmable logic controllers (PLC).

- **Section 8: Measurements**

SI units, standards (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, Megohm, Maxwell, Anderson, Schering, and Wien for measurement of R, L, C and frequency, Q-meter. Measurement of voltage, current, and power in single and three-phase circuits; ac and DC probes; true RMS meters, voltage and

current scaling, instrument transformers, timer/counter, time, phase and frequency measurements, digital voltmeter, digital multimeter; oscilloscope, shielding, and grounding.

- **Section 9: Sensors and Industrial Instrumentation**

  Resistive-, capacitive-, inductive-, piezoelectric-, Hall effect sensors and associated signal conditioning circuits; transducers for industrial instrumentation: displacement (linear and angular), velocity, acceleration, force, torque, vibration, shock, pressure (including low pressure), flow (variable head, variable area, electromagnetic, ultrasonic, turbine, and open channel flow meters) temperature (thermocouple, bolometer, RTD (3/4 wire), thermistor, pyrometer, and semiconductor); liquid level, pH, conductivity and viscosity measurement. 4-20 mA two-wire transmitter.

- **Section 10: Communication and Optical Instrumentation**

  Amplitude- and frequency modulation and demodulation; Shannon's sampling theorem, pulse code modulation; frequency and time division multiplexing, amplitude-, phase-, frequency-, quadrature amplitude, pulse shift keying for digital modulation;

  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. UV-VIS Spectrophotometers, Mass spectrometer.

17. Mathematics (MA)

Calculus: Functions of two or more variables, continuity, directional derivatives, partial derivatives, total derivative, maxima and minima, saddle point, method of Lagrange's multipliers; Double and Triple integrals and their 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.

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 eigenvectors, 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.

Real Analysis: Metric spaces, connectedness, compactness, completeness; 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.

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, a 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.

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, method of Laplace transforms 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.

Algebra: Groups, subgroups, normal subgroups, quotient groups, homomorphisms, automorphisms; cyclic groups, permutation groups, Group action, 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.

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

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 the 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.

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, 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.

Topology: Basic concepts of topology, bases, subbases, subspace topology, order topology, product topology, quotient topology, metric topology, connectedness, compactness, countability and separation axioms, Urysohn's Lemma.

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.

18. Mechanical Engineering (ME)

- **Section 1: Engineering Mathematics**

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

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, 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 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 differential equations.

- **Section 2: Applied Mechanics and Design**

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

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; the concept of shear centre; deflection of beams; torsion of circular shafts; Euler's theory of columns; energy methods; thermal stresses; strain gauges and rosettes; testing of materials with a universal testing machine; testing of hardness and 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 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.

Machine Design: 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, gears, 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, the stability of floating bodies; control- volume analysis of mass, momentum, and energy; fluid acceleration; differential equations of continuity and momentum; Bernoulli's equation; dimensional analysis; a viscous flow of incompressible fluids, boundary layer, elementary turbulent flow, flow through pipes, head losses in pipes, bends and fittings; basics of compressible fluid flow.

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, Heisler's charts; thermal boundary layer, dimensionless parameters in free and forced convective heat transfer, heat transfer correlations for flow over flat plates and through pipes, the 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, the behavior of ideal and real gases; zeroth and first laws of thermodynamics, calculation of work and heat in various processes; second law of thermodynamics; thermodynamic property charts and tables, availability and irreversibility; thermodynamic relations.

Applications: ***Power Engineering***: Air and gas compressors; vapour and gas power cycles, concepts of regeneration and reheat. *I.C.* ***Engines***: Air-standard Otto, Diesel, and dual cycles. ***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.

- **Section 4: Materials, Manufacturing, and Industrial Engineering**

Engineering Materials: Structure and properties of engineering materials, phase diagrams, heat treatment, stress-strain diagrams for engineering materials.

Casting, Forming and Joining Processes: Different types of castings, design of patterns, molds and cores; solidification and cooling; riser and gating design. Plastic deformation and yield criteria; fundamentals of hot and cold working processes; load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal

forming processes; principles of powder metallurgy. Principles of welding, brazing, soldering, and adhesive bonding.

Machining and Machine Tool Operations: Mechanics of machining; basic machine tools; single and multi-point cutting tools, tool geometry and materials, tool life and wear; economics of machining; principles of non-traditional machining processes; principles of work holding, jigs, and fixtures; abrasive machining processes; NC/CNC machines and CNC programming.

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; concepts of the coordinate-measuring machine (CMM).

Computer Integrated Manufacturing: Basic concepts of CAD/CAM and their integration tools; additive manufacturing.

Production Planning and Control: Forecasting models, aggregate production planning, scheduling, materials requirement planning; lean manufacturing.

Inventory Control: Deterministic models; safety stock inventory control systems.

Operations Research: Linear programming, simplex method, transportation, assignment, network flow models, simple queuing models, PERT, and CPM.

19. Mining Engineering (MN)

- **Section 1: Engineering Mathematics**

Linear Algebra: Matrices and Determinants; Inverse and Rank of a matrix; Systems of linear equations; Eigenvalues and Eigenvectors. Cayley-Hamilton Theorem.

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; Test for convergence; 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: Measures of central tendency and dispersion; hypothesis testing; Binomial, Poisson, exponential and normal distributions; Correlation and regression analysis.

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 energetics, blasting devices, blast design practices; Rock-Tool Interaction applicable to mechanical cutting systems and their selection.

Mine Surveying: Levels and levelling, theodolite, tacheometry, triangulation; Contouring; Errors and adjustments; Correlation; Underground surveying; Curves; Photogrammetry; EDM, Total Station, GPS, Basics of GIS and remote sensing.

- **Section 3: Geomechanics and Ground Control**

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

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

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

- **Section 4: Mining Methods and Machinery**

Mining Methods: Surface mining: layout, development, loading, transportation and mechanization, continuous surface mining systems; high wall mining; Underground coal mining: bord and pillar systems, room and pillar mining, longwall mining, thick seam mining methods, Underground metal mining: open, supported and caved 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 machinery, hoisting systems, pumps; comminution methods and machinery.

- **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 their 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; Accident data analysis; assessment; mine lighting; Mine legislation; Occupational health and safety.

- **Section 6: MineralEconomics, 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 configuration and its determination, Optimum mill cut-off grade and its determination, Stope planning, Design of haul road, Selection of mining system vis-à-vis equipment system.

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

20. Metallurgical Engineering Section

- **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; 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; Laplace transforms; PDEs – Laplace, one-dimensional heat and wave equations.

Probability and Statistics: Definitions of probability and sampling theorems, 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: Solutions of linear and non-linear (Bisection, Secant, Newton-Raphson methods) algebraic equations; integration by trapezoidal and Simpson's rule; single and multi-step methods for differential equations.

- **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; Thermodynamics of point defects, surfaces, and interfaces, adsorption and segregation phenomena.

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 relations for forced convection Radiation: Black body radiation, Stefan-Boltzman Law, Kirchhoff's Law Mass transfer: Diffusion and Fick's laws, Mass transfer coefficients

  Dimensional analysis: Buckingham Pi theorem, Significance of dimensionless numbers

  Basic laws of chemical kinetics: First order reactions, the reaction rate constant, Arrhenius relation, heterogeneous reactions, oxidation kinetics

  Electrochemical kinetics: Polarization

- **Section 4: Mineral Processing and Extractive Metallurgy**

  Comminution techniques, Size classification, Flotation, Gravity, and other methods of mineral beneficiation; Agglomeration: sintering, pelletizing and briquetting

  Material and Energy balances in metallurgical processes; Principles and processes for the extraction of non-ferrous metals – aluminum, copper, and titanium

  Iron and steel making: Material and heat balance in blast furnace; Structure and properties of slags and molten salts – basicity of slags - sulphide and phosphate capacity of slags; Production of metallurgical coke

  Other methods of iron making (COREX, MIDRE)

  Primary steelmaking: Basic oxygen furnace, process dynamics, oxidation reactions, electric arc furnace

  Secondary steelmaking: Ladle process – deoxidation, argon stirring, desulphurization, inclusion shape control, principles of degassing methods; Basics of stainless steel manufacturing

  Continuous Casting: Fluid flow in the tundish and mold, heat transfer in the mold, segregation, inclusion control

- **Section 5: Physical Metallurgy**

  Chemical Bonding: Ionic, covalent, metallic, and secondary bonding in materials, the Crystal structure of solids – metals and alloys, ionic and covalent solids, and polymers

X-ray Diffraction – Bragg's law, optical metallography, principles of SEM imaging

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

Diffusion in solids: Diffusion equation, steady-state and error function solutions; Examples-homogenization, and carburization; Kirkendall effect; Uphill diffusion; Atomic models for interstitial and substitutional diffusion; Pipe diffusion and grain boundary 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, spinoidal decomposition, ordering, massive transformation, discontinuous precipitation, eutectoid transformation, diffusionless transformations; Precipitate coarsening, Gibbs-Thomson effect

Principles of heat treatment of steels, TTT and CCT diagrams; Surface hardening treatments; Recovery, recrystallization and grain growth; Heat treatment of cast iron and aluminum alloys

Electronic, magnetic, and optical properties of materials Basic forms of corrosion and its prevention

- **Section 6: Mechanical Metallurgy**

Strain tensor and stress tensor, Representation by Mohr's circle, elasticity, stiffness and compliance tensor, Yield criteria, Plastic deformation by slip and twinning

Dislocation theory: Edge, screw and mixed dislocations, source 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

Fatigue: Cyclic stress-strain behaviour - low and high cycle fatigue, crack growth

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 rising, 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 informing

Metal joining: Principles of soldering, brazing and welding, welding metallurgy, defects in welded joints in steels and aluminum 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

21. Naval Architecture & Marine Engineering (NM) (NEW!)

- SECTION 1: ENGINEERING MATHEMATICS

  Determinants and matrices, Systems of linear equations, Eigenvalues and eigenvectors. 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 technics 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 & 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 & 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 turbocharging, 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, feedwater 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.

22. Petroleum Engineering (PE)

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

Calculus: Functions of a single variable, Limit, continuity and differentiability, Taylor series, Mean value theorems, 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'stheorems.

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 and wave equations, and Laplace equation.

Complex variables: Complex number, polar form of a 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 the numerical solution of differential equations.

Petroleum Exploration: Classification and description of some common rocks with special reference to clastic and nonclastic reservoir rocks. Origin, migration, and accumulation of Petroleum. Petroleum exploration methods.

Oil and Gas Well Drilling Technology: Well planning. Drilling method. Drilling rigs Rig operating systems. Drilling fluids function and properties. Drilling fluid maintenance equipment. Oil & gas well-cementing operations. Drill bit types and their applications. Drill string & Casing string function, operations, selection & design. Drilling problems, their control & remedies. Directional drilling tools. Directional survey. Application of horizontal, multilateral, extended reach, slim wells.

Reservoir Engineering: Petrophysical properties of reservoir rocks. Coring and core analysis. Reservoir fluid properties. Phase behavior of hydrocarbon system. The flow of fluids through porous media. Water and gas coning. Reservoir pressure measurements. Reservoir drives, drive mechanics, and recovery factors. Reserve estimation &techniques.

Petroleum Production Operations: Well equipment. Well, completion techniques. Well, production problems and mitigation. Well, servicing & Workover operations. Workover & completion of fluids. Formation damage. Well, stimulation techniques. Artificial lift techniques. Field processing of oil & gas. Storage and transportation of petroleum and petroleum products. Metering and measurements oil & gas. Production system analysis & optimization. Production testing. Multiphase flow in tubing and flow-lines. Nodal system analysis. Pressure vessels, storage tanks, shell and tube heat exchangers, pumps and compressors, LNG value chain.

Offshore Drilling and Production Practices: Offshore oil and gas operations & ocean environment. Offshore fixed platforms, Offshore mobile units, Station keeping methods like mooring & dynamic positioning system. Offshore drilling from a fixed platform, jack-up, ships, and semi-submersibles. Use of conductors and risers. Offshore good completion. Deepwater applications of subsea technology. Offshore production: Oil processing platforms, water injection platforms, storage, SPM, and SBM transportation and utilities. Deepwater drilling rig. Deepwater production system. Emerging deepwater technologies.

Petroleum Formation Evaluation: Evaluation of petrophysical of sub-surface formations: Principles applications, advantages and disadvantages of SP, resistivity, radioactive, acoustic logs, and types of tools used. Evaluation of CBL/VDL, USIT, SFT, RFT. Production logging tools, principles, limitations, and applications. A special type of logging tool. Casing inspection tools (principles, applications, and limitations), Formations micro scanner (FMS), NMR logging principles. Standard log interpretation methods. Cross-plotting methods.

Oil and Gas Well Testing: Diffusivity equation, derivation & solutions. The radius of investigation. Principle of superposition. Horner's approximation. Drill Stem Testing. Pressure Transient Tests: Drawdown and build up- test 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.

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 & automatic shutdown system, blowdown systems. Gas detection system. Fire detection and suppression systems. Personal protection system & measures. HSE Policies. Disaster & crisis management in the Petroleum Industry. Environment: Environment concepts, impact on eco-system, air, water, and soil. The impact of drilling & production operations on the environment, Environmental transport of petroleum wastes. Offshore environmental studies. Offshore oil spill and oil spill control. Waste treatment methods.

Enhanced Oil Recovery Techniques: Basic principles and mechanism of EOR, Screening of EOR process. 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 & steam flooding, in-situ combustion), MicrobialEOR.

Latest trends in Petroleum Engineering: Coal bed methane, shale gas, oil shale, gas hydrate, and heavy oil.

23. PHYSICS (PH)

- **Section 1: Mathematical Physics**

Vector calculus: linear vector space: basis, orthogonality, and completeness; matrices; similarity transformations, diagonalization, eigenvalues and eigenvectors; linear differential equations: second-order linear differential equations and solutions involving special functions; complex analysis: Cauchy-Riemann conditions, Cauchy's theorem, singularities, residue theorem and applications; Laplace transform, Fourier analysis; elementary ideas about tensors: covariant and contravariant tensors.

- **Section 2: Classical Mechanics**

Lagrangian formulation: D'Alembert's principle, Euler-Lagrange equation, Hamilton's principle, calculus of variations; symmetry and conservation laws; central force motion: Kepler problem and Rutherford scattering; small oscillations: coupled oscillations and normal modes; rigid body dynamics: inertia tensor, orthogonal transformations, Euler angles, Torque free motion of asymmetric top; Hamiltonian and Hamilton's equations of motion; Liouville's theorem; canonical transformations: action-angle variables, Poisson brackets, Hamilton-Jacobi equation.

The special theory of relativity: Lorentz transformations, relativistic kinematics, mass-energy equivalence.

- **Section 3: 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; radiation from a moving charge.

- **Section 4: Quantum Mechanics**

Postulates of quantum mechanics; uncertainty principle; Schrodinger equation; Dirac Bra-Ket notation, linear vectors, and operators in Hilbert space; one-dimensional potentials: step potential, finite rectangular well, tunneling from a potential barrier, particle in a box, harmonic oscillator; two and three dimensional systems: the concept of degeneracy; hydrogen atom; angular momentum and spin; addition of angular momenta; variational method and WKB approximation, time-independent perturbation theory; elementary scattering theory, Born approximation; symmetries in quantum mechanical systems.

- **Section 5: Thermodynamics and Statistical Physics**

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 point.

- **Section 6: Atomic and Molecular Physics**

Spectra of one-and many-electron atoms; spin-orbit interaction: LS and jj couplings; fine and hyperfine structures; Zeeman 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; EPR, NMR, ESR, X-ray spectra; lasers: Einstein coefficients, population inversion, two and three-level systems.

24. Production and Industrial Engineering (PI)

- **Section 1: Engineering Mathematics**

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

Calculus: Functions of a single variable, Limit, continuity and differentiability, Mean value theorems, 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.

Complex Variables: Analytic functions, Cauchy’s integral theorem, Taylor series.

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; Trusses; Strength of materials – stress, strain, and their relationship; Failure theories; Mohr's circle (stress); Deflection of beams, bending and shear stresses; Euler's theory of columns; Thick and thin cylinders; Torsion.

Theory of Machines and Design: Analysis of planar mechanisms, cams, and followers; Governors and flywheels; 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; Pressure vessels.

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; casting techniques of cast iron, steels, and nonferrous metals and alloys; analysis of solidification and microstructure development; Other casting techniques: Pressure die casting, Centrifugal casting, Investment casting, Shell mold 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, stretch forming, spinning and deep drawing; Ideal work and slab analysis; Defects in metalworking and their causes.

Joining of Materials: Classification of joining processes; Principles of fusion welding processes using different heat sources (flame, arc, resistance, laser, 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, Cold and hot isostatic pressing.

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 and Wire EDM, LBM, EBM, PAM, CHM, ECM; Effect of process parameters on material removal rate, surface roughness, and power consumption; Additive manufacturing techniques.

Computer Integrated Manufacturing: Basic concepts of CAD and CAM, Geometric modeling, CNC; Automation in Manufacturing; Industrial Robots – configurations, drives, and controls; Cellular manufacturing and FMS - Group Technology, CAPP.

- **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, run out, 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 – concept, and costs; Statistical quality control – process capability analysis, control charts for variables and attributes and acceptance sampling; Six sigma; Total quality management; Quality assurance and certification - ISO 9000, ISO14000.

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's 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; Computer-aided layout design techniques; Assembly line balancing; Materials 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; Constrained and unconstrained nonlinear optimization; Markovian queuing models; Simulation – manufacturing applications.

Engineering Economy and Costing: Elementary cost accounting and methods of depreciation; Break-even analysis; Techniques for evaluation of capital investments; Financial statements; 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 JIT 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: Scheduling techniques – Gantt chart, CPM, PERT, and GERT.

25. Statistics

Calculus: Finite, countable, and uncountable sets; Real number system as a complete ordered field, Archimedean property; Sequences of real numbers, a 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.

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, the inverse of a matrix, systems of linear equations; Inner products in $\mathbb{R}^n$ and $\mathbb{C}^n$, Gram-Schmidt orthonormalization; Eigenvalues and eigenvectors, characteristic

polynomial, Cayley-Hamilton theorem, symmetric, skew-symmetric, Hermitian, skew-Hermitian, orthogonal, unitary matrices and their eigenvalues, change of basis matrix, equivalence and similarity, diagonalizability, positive definite and positive semi-definite matrices and their properties, quadratic forms, singular value decomposition.

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

Standard discrete and continuous univariate distributions: Bernoulli, binomial, geometric, negative binomial, hypergeometric, discrete uniform, Poisson, continuous uniform, exponential, gamma, beta, Weibull, normal.

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.

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, delta method.

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.

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.

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.

26. Textile Engineering and Fibre Science

- **ENGINEERING MATHEMATICS**

Linear Algebra: Matrices and Determinants; Systems of linear equations; Eigenvalues and Eigenvectors.

Calculus: Limit, continuity, and differentiability; Successive differentiation; Partial differentiation; Maxima and minima; Errors and approximations; Definite and improper integrals; Sequences and series; Test for convergence; Power series; Taylor series.

Differential Equations: First order linear and non-linear differential equations; Higher order linear differential equations with constant coefficients; Euler-Cauchy equation; Partial differential equations; Wave and heat equations; Laplace's equation.

Probability and Statistics: Random variables; Poisson, binomial and normal distributions; Mean, mode, median, standard deviation; Confidence interval; Test of hypothesis; Correlation analysis; Regression analysis; Analysis of variance; Control charts.

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

- **TEXTILE ENGINEERING AND FIBRE SCIENCE**

Section 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 T_g and T_m; 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 2: Yarn Manufacture, Yarn Structure, and Properties

Principles of ginning; Principles of opening, cleaning and blending; Working principles of modern blow room machines; Fundamentals of carding; Conventional vs. modern carding machine; Card setting; Card clothing; Periodic mass variation in card sliver; Card auto leveler; Principles of roller drawing; Roller arrangements in drafting systems; Periodic mass

variation in drawn sliver; Drawframeautoleveller; 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 the 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 the ring, compact, rotor, air-jet, and friction spun yarns.

Section 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 the 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 the 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 selvages.

Basic woven fabric constructions and their derivatives; crepe, cord, terry, gauze, leno, and double cloth constructions; Drawing and lifting plans.

Fundamentals of weft knitting; Classification of weft knitting technologies; Weft knitted constructions such as plain, rib, interlock, and purl; Different knit stitches such as loop, tuck, and float.

Principle of warp knitting; Classification of warp knitting technologies; Swinging and shogging motion of guide bar; Basic warp knit construction such aspillar, tricot, atlas, inlay, and nets.

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; Elasticamodel of plain-woven fabric; 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 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 fibers; High volume fiber testing.

The 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 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 fibers 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.

27. Engineering Mathematics (XE-A)

- **Section 1: Linear Algebra**

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

- **Section 2: Calculus**

  Functions of a 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 (ratio, root, and integral tests); Power series; Taylor's series; Fourier Series of functions of period 2π.

- **Section 3: Vector Calculus**

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

- **Section 4: Complex variables**

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

- **Section 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; Eigenvalue problem for second-order equations with constant coefficients; Power series solutions for ordinary points.

  Section 6: Partial Differential Equations

  Classification of second-order linear partial differential equations; Method of separation of variables: One-dimensional heat equation and two dimensional Laplace equation.

  Section 7: Probability and Statistics

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

Section 8: Numerical Methods

A solution of systems of linear equations using LU decomposition, Gauss elimination method; Lagrange and Newton's interpolations; Solution of polynomial and transcendental equations by Newton-Raphson method; Numerical integration by trapezoidal rule and Simpson's rule; Numerical solutions of first-order differential equations by explicit Euler's method.

28. FLUID MECHANICS (XE-B)

- **SECTION 1: Flow and Fluid Properties**

Fluid Properties: Density, viscosity, surface tension, the relationship between stress and strain-rate for Newtonian fluids.

Classification of Flows: Viscous versus inviscid flows, incompressible versus compressible flows, internal versus external flows, steady versus unsteady flows, laminar versus turbulent flows, 1-D, 2-D, and 3-D flows, Newtonian versus non-Newtonian fluid flow.

Hydrostatics: Buoyancy, manometry, forces on submerged bodies, and its stability.

- **SECTION 2: Kinematics of Fluid Motion**

Eulerian and Lagrangian descriptions of fluid motion.

Concept of local, convective, and material derivatives. Streamline, streakline, pathline, and timeline.

- **SECTION 3: Integral Analysis for a Control Volume**

Reynolds Transport Theorem (RTT) for conservation of mass, linear and angular momentum.

- **SECTION 4: Differential Analysis**

Differential equations of mass and momentum for incompressible flows. Inviscid flows - Euler equations and viscous flows - Navier-Stokes equations. Concept of fluid rotation, vorticity, stream function, and circulation.

Exact solutions of Navier-Stokes equations for Couette flow and Poiseuille flow, thin film flow.

- **SECTION 5: Dimensional Analysis**

Concept of geometric, kinematic, and dynamic similarity. Buckingham Pi theorem and its applications.

Non-dimensional parameters and their physical significance - Reynolds number, Froude number, and Mach number.

- **SECTION 6: Internal Flows**

Fully developed pipe flow.

Empirical relations for laminar and turbulent flows: friction factor, Darcy-Weisbach relation, and Moody's chart. Major and minor losses.

- **SECTION 7: Bernoulli's Equation and its Applications, Potential Flows**

Bernoulli's equation: Assumptions and applications.

Flow measurements - Venturi meter, Pitot-static tube, an orifice meter.

Elementary potential flows: Velocity potential function.

Uniform flow, source, sink, and vortex, and their superposition for flow past simple geometries.

- **SECTION 8: External Flows**

Prandtl boundary layer equations: Concept and assumptions.

Boundary layer characteristics: Boundary layer thickness, displacement thickness, and momentum thickness. Qualitative idea of boundary layer separation, streamlined and bluff bodies, and drag and lift forces.

29. Materials Science (XE-D)

- **Classification and Structure of Materials**

Classification of materials: metals, ceramics, polymers, and composites.

Nature of bonding in materials: metallic, ionic, covalent, and mixed bonding; the structure of materials: fundamentals of crystallography, symmetry operations, crystal systems, Bravais lattices, unit cells, primitive cells, crystallographic planes, and directions; structures of metals, ceramics, polymers, amorphous materials, and glasses.

Defects in crystalline materials: 0-D, 1-D, and 2-D defects; vacancies, interstitials, solid solutions in metals and ceramics, Frenkel and Schottky defects; dislocations; grain boundaries, twins, stacking faults; surfaces and interfaces.

- **Thermodynamics, Kinetics, and Phase Transformations**

Extensive and intensive thermodynamic properties, laws of thermodynamics, phase equilibria, phase rule, phase diagrams (unary and binary), basic electrochemistry.

Reaction kinetics, fundamentals of diffusion, Fick's laws, their solutions, and applications.

Solidification of pure metals and alloys, nucleation and growth, diffusional solid-state phase transformations (precipitation and eutectoid), martensitic transformation.

- **Properties and Applications of Materials**

  Mechanical properties of metals, ceramics, polymers, and composites at room temperature; stress-strain response (elastic, anelastic, and plastic deformation).

  Electronic properties: free electron theory, Fermi energy, the density of states, elements of band theory, semiconductors, Hall effect, dielectric behaviour, piezo-, and ferroelectric behaviour.

  Magnetic Properties: Origin of magnetism in materials, para-, dia-, Ferro- and ferri-magnetism.

  Thermal properties: Specific heat, heat conduction, thermal diffusivity, thermal expansion, and thermoelectricity. Optical properties: Refractive index, absorption, and transmission of electromagnetic radiation.

  Examples of materials exhibiting the above properties, and their typical/common applications.

- **Characterization and Measurements of Properties**

  X-ray diffraction; spectroscopic techniques such as UV-Vis, IR, and Raman; optical microscopy, electron microscopy, composition analysis electron microscopes.

  Tensile test, hardness measurement.

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

- **Processing of Materials**

  Heat treatment of ferrous and aluminum alloys; preparation of ceramic powders, sintering; thin film deposition: evaporation and sputtering techniques, and chemical vapour deposition, thin-film growth phenomena.

- **Degradation of Materials**

  Corrosion and its prevention; embrittlement of metals; polymer degradation.

30. Solid Mechanics

Section 1: Mechanics of rigid bodies

Equivalent force systems; free-body diagrams; equilibrium equations; analysis of determinate trusses and frames; friction; the principle of minimum potential energy; particle kinematics and dynamics; dynamics of rigid bodies under planar motion; law of conservation of energy; law of conservation of momentum.

Section 2: Mechanics of deformable bodies

Stresses and strains; transformation of stresses and strains, principal stresses and strains; Mohr's circle for plane stress and plane strain; generalized Hooke's Law; elastic constants; thermal stresses; theories of failure.

Axial force, shear force, and bending moment diagrams; axial, shear, and bending stresses; combined stresses; deflection (for symmetric bending); torsion in circular shafts; thin-walled pressure vessels; energy methods (Castigliano's Theorems); Euler buckling.

Section 3: Vibrations

Free vibration of undamped single degree of freedom systems.

31. Thermodynamics (XE-E)

- **Section 1: Basic Concepts**

Continuum and macroscopic approach; thermodynamic systems (closed and open); thermodynamic properties and equilibrium; state of a system, state postulate for simple compressible substances, state diagrams, paths and processes on state diagrams; concepts of heat and work, different modes of work; zeroth law of thermodynamics; the concept of temperature.

- **Section 2: 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 and unsteady flow analysis.

- **Section 3: Second Law of Thermodynamics**

Limitations of the first law of thermodynamics, concepts of heat engines and heat pumps/refrigerators, Kelvin- Planck and Clausius statements and their equivalence; reversible and irreversible processes; Carnot cycle and Carnot principles/theorems; thermodynamic temperature scale; Clausius inequality and concept of entropy; microscopic interpretation of entropy, the principle of increase of entropy, T-s diagrams; second law analysis of control volume; availability and irreversibility; third law of thermodynamics.

- **Section 4: Properties of Pure Substances**

Thermodynamic properties of pure substances in solid, liquid, and vapor phases; P-v-T behaviour of simple compressible substances, phase rule, thermodynamic property tables and charts, ideal and real gases, ideal gas equation of state and van der Waals equation of

state; law of corresponding states, compressibility factor, and generalized compressibility chart.

- **Section 5: Thermodynamic Relations**

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

- **Section 6: Thermodynamic Cycles**

  Carnot vapor cycle, ideal Rankine cycle, Rankine Reheat cycle, air-standard Otto cycle, air-standard Diesel cycle, air-standard Brayton cycle, vapor-compression refrigeration cycle.

- **Section 7: Ideal Gas Mixtures**

  Dalton's and Amagat's laws, properties of ideal gas mixtures, air-water vapor mixtures and simple thermodynamic processes involving them; specific and relative humidities, dew point and wet bulb temperature, adiabatic saturation temperature, psychrometric chart.

32. Polymer Science and Engineering

- **Section 1: Chemistry of high polymers**

  Monomers, functionality, degree of polymerizations, classification of polymers, glass transition, melting transition, criteria for rubberiness, polymerization methods: 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. Concept of intermolecular order (morphology) – amorphous, crystalline, orientation states. Factor affecting crystallinity. Crystalline transition. Effect of morphology on polymer properties.

- **Section 2: Polymer Characterization**

  Solubility and swelling, Concept of molecular weight distribution and its significance, the concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, polymer crystallinity, analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques, Molecular wt. distribution: Broad and Narrow, GPC, Mooney viscosity.

- **Section 3: Synthesis, manufacturing, and properties**

  Commodity and general purpose thermoplastics: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, 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, Speciality plastics: PEK, PEEK, PPS, PSU, PES, etc. Biopolymers such as PLA, PHA/PHB.

- **Section 4: Polymer blends and composites**

  Difference between 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 fibers – natural and synthetic, base polymer for reinforcement (unsaturated polyester), ingredients/recipes for reinforced polymer composite.

- **Section 5: Polymer Technology**

  Polymer compounding-need and significance, different compounding ingredients for rubber and plastics (Antioxidants, Light 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, crosslinking and vulcanization, vulcanization kinetics.

- **Section 6: Polymer rheology**

  The 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 rotating, parallel plate, cone-plate rheometer. Visco-elasticity-creep and stress relaxations, mechanical models, control of rheological characteristics through compounding, rubber curing in parallel plate viscometer, ODR, and MDR.

- **Section 7: Polymer processing**

  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 the two-roll mill, internal mixer, Twin-screw extruder.

33. Food Technology (XE-G)

- **Section 1: Food Chemistry and Nutrition**

  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, biochemical changes in post mortem, and tenderization of muscles. Lipids: Classification and structure of lipids, rancidity, polymerization, and polymorphism. Pigments: carotenoids, chlorophylls, anthocyanins, tannins, and myoglobin. Food flavours: terpenes, esters, aldehydes, ketones, and quinines. Enzymes: specificity, simple and inhibition kinetics, coenzymes, enzymatic, and non-enzymatic browning. Nutrition: balanced diet, essential amino acids, and essential fatty acids, protein efficiency ratio, water-soluble and fat-soluble vitamins, the role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases. Chemical and biochemical changes: changes occur in foods during different processing.

- **Section 2: Food Microbiology**

Characteristics of microorganisms: morphology of bacteria, yeast, mold and actinomycetes, spores and vegetative cells, gram-staining. Microbial growth: 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. Fermented foods and beverages: curd, yoghurt, cheese, pickles, soya-sauce, sauerkraut, idli, dosa, vinegar, alcoholic beverages, and sausage.

- **Section 3: Food Products Technology**

Processing principles: thermal processing, chilling, freezing, dehydration, the addition of preservatives and food additives, irradiation, fermentation, hurdle technology, intermediate moisture foods. Food packaging and storage: packaging materials, aseptic packaging, controlled and modified atmosphere storage. Cereal processing and products: milling of rice, wheat, and maize, parboiling of paddy, bread, biscuits, extruded products, and ready-to-eat breakfast cereals. Oil processing: expelling, solvent extraction, refining, and hydrogenation. Fruits and vegetables p 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: drying, canning, and freezing of fish and meat; production of egg powder. Waste utilization: pectin from fruit wastes, uses of by-products from rice milling. Food standards and quality maintenance: FPO, PFA, A-Mark, ISI, HACCP, food plant sanitation, and cleaning in place (CIP).

- **Section 4: Food Engineering**

Mass and energy balance; Momentum transfer: Flow rate and pressure drop relationships for Newtonian fluids flowing through a pipe, Reynolds number. Heat transfer: heat transfer by conduction, convection, radiation, heat exchangers. Mass transfer: molecular diffusion and Flick'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 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.

34. Atmospheric & Ocean Science (XE-H)

- **Section A: 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; Weather and Climate.

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, Monsoon Depressions; Tropical Convergence Zones; Tropical Cyclones.

- **Section B: 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; Eastern and Western Boundary Currents, Equatorial Currents, Indian Ocean Current Systems; Thermohaline Circulation.

Chemical Properties of Seawater, Major and Minor Elements, Ocean Acidification, Biochemical Cycling of Nutrients, Trace Metals, and Organic Matter. Biological Pump; Primary and Secondary Biological Productivity; Air-sea Exchange of Biogenic Dissolved Gases; Marine Ecology.

35. Reasoning and Comprehension (XH-B1)

This is to test the candidate's ability to comprehend and interpret written information – skills that are critical to 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.

Questions of this section XH-B1 will test the following skills:

Reading Comprehension – ability to understand complex language material in short paragraphs and answer questions regarding them

Expression – questions on stylistic and rhetorical aspects of a short passage including corrections or modifications of particular sentences

Analytical reasoning – the ability to understand relationships in statements or short passages and being able to draw reasonable conclusions/inferences from them.

Logical reasoning – Thinking critically to evaluate or to predict an argument, identify the main and supporting arguments, predict outcomes, etc.

36. Economics (XH-C1)

C1.1 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.

C1.2 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.

C1.3 Statistics, Econometrics and Mathematical Economics: Probability Theory: Concepts of probability, Probability Distributions [Discrete and Continuous], Central Limit Theorem, Index Numbers and Construction of Price Indices, Sampling Methods & Sampling Distribution, Statistical Inferences, Hypothesis Testing, Linear Regression Models and the Gauss Markov Theorem, Heteroscedasticity, Multicollinearity and Autocorrelation, Spurious regressions and Unit roots, Simultaneous Equation Models – recursive and non-recursive. Identification Problem, 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

C1.4 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.

C1.5 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.

C1.6 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.

C1.7 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.

37. English (XH-C2)

C2.1 Multi-genre works of literature in English—poetry, the novel, and other forms of fiction including the short story, drama, creative non-fiction, and non-fiction prose—with emphasis on the long 19th and 20th centuries

C2.2 Especially in a comparative context, anglophone and in English translation, works of literature from India and, extending to some degree, the larger Indian subcontinent

C2.3 Literary criticism and theory; critical and cultural intellectual-traditions and approaches widely referred to and used in the discipline of English

C2.4 History of English literature and English literary studies

C2.5 Research approaches and methodologies, including interpretive techniques responsive to literary forms, devices, concepts, and genres

Note: (i) The five units above list aspects the question paper will include rather than signal separate modules or sections; these five units listed are not necessarily exclusive to each other either. The question paper will also not be divided into sections corresponding to the above aspects; and, (ii) While the paper will test candidates for a reasonable breadth of disciplinary knowledge, it would prioritize conceptual depth and methodological sensitivity demonstrative of disciplinary training over information wherever possible.

38. Linguistics (XH-C3)

- **C3.1 Language and Linguistics**: Language spoken, written and signed; description and prescription; language and cultural heritage; language and social identity; language as an object of inquiry – its structure, units, and components; design features; writing systems; biological foundations and language faculty; linguistic competence and performance; levels of grammar; contrast and complementation; rules - context-dependent and context-free; levels of adequacy for analysis; interdisciplinary approaches; schools of linguistic thought (European, American) and the Indian Grammatical Tradition.
- **C3.2 Levels of Grammar and Grammatical Analysis:**

Phonetics and Phonology: vocal tract anatomy; phonation; articulatory parameters; classification of sounds; gestural theory of speech production; cardinal vowels; secondary and co-articulation; suprasegmentals - length, stress, tone, intonation and juncture; IPA; basic physics of sound and phonation and articulation; acoustic cues for speech sounds; organization of phones into phonemes; phoneme inventories and cross-linguistic properties; syllable structure and phonological properties; principles of phonological analysis - phonetic similarity, contrastive and complementary distribution, free variation, allophones; linear and non-linear approaches; levels of representation; phonological rules; distinctive features (major class, manner, place, etc.); feature geometry; rule ordering, markedness and unspecified featural values; core principles of lexical phonology, optimality theory, autosegmental phonology, and prosodic morphology.

Morphology: Concepts of morpheme, morph, allomorph, zero allomorph, conditions on allomorphs; lexeme and word; types of morphemes – structural and functional; affixes vs clitics; grammatical categories; morphological theories - generative, lexicalist, process and distributed morphology; identification of morphemes and parts of speech; alternation; morphophonology; inflection vs. derivation; conjugation and declension; word creation and word formation rules and processes; creativity and productivity, blocking, bracketing paradoxes, constraints on affix ordering; mental lexicon; lexical

categories; valency changing operations.

Syntax: Basic syntactic units and their types: word, phrase, clause, sentence and their description and generation; grammatical and case relations; key ideas from syntactic theories, Generative Grammars including Minimalist Program, HPSG, Relational Grammar, and Lexical Functional Grammar; phrase structure rules (including X-bar theory); universal grammar and cross-linguistic properties; the idea of grammaticality judgments; solving the language acquisition problem; diagnostics of structure; syntactic phenomena such as movement, binding, ellipses, case-checking, islands, argument structure, etc.; unergatives and unaccusatives.

Semantics and Pragmatics: Types of meaning, lexical and compositional; syntax-semantics interface (semantic roles, binding, scope, LF, etc.); sense and reference, connotation and denotation, lexical-semantic relations (homonymy, hypo/hypernymy, antonymy, synonymy, ambiguity); prototype theory and componential analysis; sentence meaning and truth conditions, contradictions, entailment; basic set theory; propositions, truth values, sentential connectives; arguments, predicates, quantifiers, variables; in/definiteness, mood, and modality; language use in context; sentence meaning and utterance meaning; speech acts;

deixis; presupposition and implicature: Gricean maxims; information structure; politeness, power, and solidarity; discourse analysis.

- **C3.3 Historical Linguistics:**

  Neogrammarian laws of phonetic change such as Grimm's, Verner's, Grassmann's Laws; genesis and spread of sound change; split and merger; conditioned vs. unconditioned change; lexical diffusion of sound change; analogical changes and paradigm levelling; a relative chronology of different changes; study of sound change in progress; morphosyntactic (syncretism, grammaticalization, and lexicalization) and semantic change (extension, narrowing, figurative speech); linguistic reconstruction - external vs. internal: the comparative method; lexicostatistics; language contact and dialect geography – borrowing and impact of borrowing; pidgins and creoles; bi- and multilingualism as the source for borrowing; dialect geography - dialect atlas; isogloss, focal, transition and relic areas.

- **C3.4 Sociolinguistics:**

  Micro-and macro approaches to language in society; linguistic repertoire language, dialect, sociolect, idiolect; diglossia; taboo, slang, and euphemism; elaborated and restricted codes; speech community and communicative competence; ethnography of speaking; lingua franca; diasporic language; linguistic variables and their co-variation along linguistic/social dimensions; language policies and development (especially in India); language contact and outcomes (language loss, pidginization, and creolization); code-mixing and code-switching; language movements – state and societal interventions; script development and modifications; linguistic minorities; language ecology and endangerment linguistic vitality, language endangerment (EGIDS scale), parameters of endangerment, documentation, and revitalization.

- **C3.5 Areal Typology, Universals, Cross-linguistic Features:**

  morphological types of languages agglutinative, analytical (isolating), synthetic fusional (inflecting), polysynthetic (incorporating) languages; formal and substantive universals, absolute and statistical universals; implicational and non-implicational universals (Greenberg); linguistic relatedness—genetic, typological and areal classification of languages; universals and parametric variation; word order typology; salient features of South Asian languages - Indo- Aryan, Dravidian, Austro-Asiatic, and Tibeto-Burman language families; Linguistic Survey of India; contact-induced typological change.

- **C3.6 Methods of analysis**:

  Experimental and non-experimental methods; sampling and tools; identification of variables and their variants; data processing and interpretation; quantitative analysis of data; ethnomethodology; participant observation; field methods and elicitation; document creation; ethics.

- **C3.7 Applied Linguistics**

  (Can be expanded to include Interdisciplinary areas that focus on language and Language Teaching depending on interest and requirement.)

Example: Psycholinguistics: the study of how humans learn, represent, comprehend, and produce language. Topics include word recognition and storage, sentence production and comprehension, reading, speech perception, language acquisition, the neural representation of language, bilingualism, and language disorders.

39. Philosophy (XH-C4)

- **C4.1 Classical Indian Philosophy**

C4.1.1 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, and, **Vedānta** – Advaita (Adhyāsa, Brahman, Iśvara, Ātman, Jīva, Mokṣa, Viśiṣṭādvaita (Tattva-traya, Mokṣa, and Refutation of Māyāvāda), Dvaita, Dvaitādvaita, Śuddhādvaita, Pramāṇa in Advaita and Viśiṣṭādvaita.

C4.1.2 Heterodox Systems: **Cārvāka** – Pramāṇa, Indian marerislism and Hedonism, **Jainism**- Pramāṇas, Syādvāda, Anekāntavāda, Padārtha (categories), Jīva and Ajīva, Mokṣa, Mahāvrata, Aṇuvrata, and, **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.

C4.1.3 Upaniṣads, Bhagavadgītā, and Dharmaśāstras: Philosophy of the Upaniṣads – Pure Monism, Brahmam and Ātman, Pañca-kośa, Parā-vidyā and Aparā-vidyā, Meaning of Dharma, Ṛta, Purusārtha, Śreyas and Preyas, Varṇāśrama-dharma, Dharma- Svadharma and Sādhāraṇa Dharma, Ṛna, Yajña, Karma-yoga, Sthitaprajña, Lokasaṃgraha, and Law of Karma.

C4.1.4 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, Vīra Śaivism – Philosophical basis of Vīra Śaivism, Śāktism - Philosophical basis of Śāktism, and Vaiṣṇavism – Philosophical basis of Vaiṣṇavism.

- **C4.2 Contemporary Indian Philosophy**

C4.2.1 Vivekananda: Notion of God, Freedom and Karma, Nature of Soul/self, Practical Vedanta, and Universal Religion. **Aurobindo**: World Process – Involution and Evolution, Four Theories of Existence, The Supermind, Integral Yoga, and Gnostic Being. **Iqbal**: Nature of Intuition, Nature of Self, and Notion of God. **Tagore**: Humanism and Nature of Man, Notion of Religion, and Nationalism. **K. C. Bhattacharyya**: Concept of Absolute and Its Alternative Forms, and Notion Subjectivity and Freedom. **Radhakrishnan:** Nature of Ultimate Reality, Religious Experience, Intellect and Intuition, Hindu View of Life. **J. Krishnamurti**: Notion of Freedom, Choiceless Awareness, Truth is a Pathless Land and Notion of Education. **Gandhi**: Notion of Truth, Non-violence, Satyagraha, Swaraj, and Trusteeship. **Ambedkar:** Annihilation

of Caste, Neo-Buddhism, Democracy, and Natural Rights and Law. **M. N. Roy**: Radical Humanism and Materialism.

40. Psychology (XH-C5)

- **C5.1 Research Methods and Statistics**

C5.1.1 Approaches to research Philosophical worldviews & criteria involved in the approach. Research design: quantitative & qualitative, mixed methods.

C5.1.2 Designing research: Research problems, purpose statement, Variables, and Operational Definitions, Hypothesis, Sampling.

C5.1.3 Nature of quantitative & qualitative research: Structured, semi-structured interviewing, self-completion questionnaires (Survey), observation, Experimental, Quasi-experimental, Field studies, Focus groups discussions, Narratives, Case studies, Ethnography.

C5.1.4 Ethics in conducting and reporting research

C5.1.5 Statistics in Psychology: Measures of Central Tendency and Dispersion. Normal Probability Curve. Parametric and Non-parametric tests Affect size and Power analysis.

C5.1.6 Correlational Analysis: Correlation [Product Moment, Rank Order], Partial correlation, multiple correlations. Special Correlation Methods: Biserial, Point biserial, tetrachoric, phi coefficient. Regression: Simple linear regression, Multiple regression. Factor analysis: Assumptions, Methods, Rotation, and Interpretation.

C5.1.7 Experimental Designs: ANOVA [One-way, Factorial], Randomized Block Designs, Repeated Measures Design, Latin Square, Cohort studies, Time series, MANOVA, ANCOVA. Single-subject designs.

- **C5.2 Psychometrics:**

Foundations of Psychological measurement**;** Basic components: scales 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.

- **C5.3 Biological and evolutionary basis of behaviour**:

the 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. The biological basis of emotion: The Limbic system, 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]

- **C5.4 Perception, Learning, Memory, and Forgetting:**

What is a 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, the physical aspects of memory.

41. XH-C6: Sociology

- **C6.1 Sociological Theory**

C6.1.1 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)

C6.1.2 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)

C6.1.3 Hermeneutic and Interpretative Traditions: G.H. Mead, Alfred Schutz (Phenomenology); Harold Garfinkel (Ethnomethodology); Erving Goffman (Symbolic interaction, dramaturgy); ·Clifford Geertz (Culture, thick description)

C6.1.4 Post-Modernism, Post-Structuralism and Post-Colonialism: Pierre Bourdieu, Michel Foucault, Jurgen Habermas, Anthony Giddens, Frankfurt School

C6.1.5 Conflict theory: Ralf Dahrendorf; C Wright Mills

C6.1.6 Indian Thinkers, M.K. Gandhi, B.R. Ambedkar, Radha Kamal Mukherjee, G. S. Ghurye, M.N. Srinivas, Irawati Karve,

C6.2 Research Methodology and Methods

C6.2.1 Conceptualizing Social Reality: Philosophy of Science; ·Scientific Method and Epistemology in Social Science; Hermeneutic Traditions; Objectivity and Reflexivity in Social Science; Ethics and Politics of research

C6.2.2 Research Design:·Reading Social Science Research, Data, and Documents; Induction and Deduction; Fact, Concept, and Theory;·Hypotheses, Research Questions,

Objectives C6.2.3 Quantitative and Qualitative Methods: Ethnography; Survey Method; Historical Method; Comparative Method

C6.2.4 Research Techniques; Sampling; Questionnaire and Schedule; Statistical Analysis; Observation, Interview, and Case study; Interpretation, Data Analysis and Report Writing

C6.3 Sociological Concepts

C6.3.1 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

C6.3.2 Social Institutions: Marriage, Family, and Kinship; Economy; Polity; Religion; Education; Law and Customs

C6.3.3 Social Stratification: Social Difference, Hierarchy, Inequality, and Marginalization: Caste and Class; Status and Power; Gender, Sexuality, and Disability; Race, Tribe, and Ethnicity C6.3.4 Social Change: Evolution and Diffusion; Modernization and Development; Social Transformations and Globalization; Social Mobility –Sanskritization, Educational and Occupational change

42. Chemistry (XL-P)

- **Section 1: Atomic Structure and Periodicity**

  Planck's quantum theory, wave-particle duality, uncertainty principle, comparison between Bohr's model and quantum mechanical model of a 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 2: Structure and Bonding**

  Ionic and covalent bonding, MO and VB approach 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 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, color, geometry, magnetic properties, and isomerism.

- **Section 4: Chemical Equilibria**

Osmotic pressure, the 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 (Kc, Kp, and Kx) for homogeneous reactions.

- **Section 5: Electrochemistry**

  Conductance, Kohlrausch law, cell potentials, EMF, Nernst equation, thermodynamic aspects, and their applications.

- **Section 6: Reaction Kinetics**

  Rate constant, the order of reaction, molecularity, activation energy, zero, first and second-order kinetics, catalysis, and elementary enzyme reactions. Reversible and irreversible inhibition of enzymes.

- **Section 7: Thermodynamics**

  Qualitative treatment of state and path functions, First law, reversible and irreversible processes, internal energy, enthalpy, Kirchoff equation, the heat of reaction, Hess's law, the heat of formation. The second law, entropy, and free energy. Gibbs·Helmholtz equation, free energy change, and spontaneity, Free energy changes from equilibrium constant.

- **Section 8: 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, orientation effect as exemplified by various functional groups. Identification of common functional groups by chemical tests.

- **Section 9: 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 (up to hexoses only). Lipids (triglycerides only). Principles of biomolecule purification-Ion exchange and gel filtration chromatography.

  Identification of these biomolecules and Beer-Lambert's law.

43. Biochemistry (XL-Q)

- **Section 1:**

  Organization of life; Importance of water; Structure and function of biomolecules: Amino acids, Carbohydrates, Lipids, Proteins, and Nucleic acids; Protein structure, folding / misfolding and function; Myoglobin, Hemoglobin, Lysozyme, Ribonuclease A, Carboxypeptidase and Chymotrypsin.

- **Section 2:**

  Enzyme kinetics, regulation, and inhibition; Vitamins and Coenzymes; Bioenergetics and metabolism; Generation and utilization of ATP; Metabolic pathways and their regulation: glycolysis, TCA cycle, pentose phosphate pathway, oxidative phosphorylation, gluconeogenesis, glycogen, and fatty acid metabolism; Metabolism of Nitrogen-containing compounds: nitrogen fixation, amino acids, and nucleotides. Photosynthesis, Calvin cycle.

- **Section 3:**

  Biochemical separation techniques: ion exchange, size exclusion, and affinity chromatography, centrifugation; Characterization of biomolecules by electrophoresis; DNA-protein and protein-protein interactions; UV-visible and fluorescence spectroscopy; Mass spectrometry.

- **Section 4:**

  Cell structure and organelles; Biological membranes; Action potential; Transport across membranes; Membrane assembly and Protein targeting; Signal transduction; Receptor-ligand interaction; Hormones and neurotransmitters.

- **Section 5:**

  DNA replication, transcription, and translation; DNA damage and repair; Biochemical regulation of gene expression; Recombinant DNA technology and applications: PCR, site-directed mutagenesis, DNA-microarray; Next-generation sequencing; Gene silencing and editing.

- **Section 6:**

  Immune system: Innate and adaptive; Cell of the immune system; Active and passive immunity; Complement system; Antibody structure, function, and diversity; B cell and T Cell receptors; B cell and T cell activation; Major histocompatibility complex; Immunological techniques: Immunodiffusion, immune-electrophoresis, RIA and ELISA, flow cytometry; monoclonal antibodies and their applications.

44. Botany (XL-R)

- **Section 1: Plant Systematics**

  Botanical nomenclature, history of plant taxonomy, diversity and classification of plants, APG system of plant classification; phylogenetics and cladistics, molecular taxonomy and DNA barcoding; Centers for plant taxonomy and herbaria in India.

- **Section 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 3: Plant development; cell and tissue morphogenesis**

  The 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 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; the 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. Senescence and programmed cell death.

- **Section 5: Genetics and genomics**

  Cell cycle and cell division. Principles of Mendelian inheritance, linkage, recombination, genetic mapping; extrachromosomal 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.

- **Section 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 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 their regulation eg. Bt cotton, Bt brinjal golden rice, etc.

45. Microbiology

- **Section 1: Historical Perspective**

  Discovery of microbial world; Landmark discoveries relevant to the field of microbiology; Controversy over a spontaneous generation; Role of microorganisms in transformation of organic matter and the causation of diseases.

- **Section 2: Methods in Microbiology**

  Pure culture techniques; 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; Next-generation sequencing technologies in microbiology.

- **Section 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 4: Prokaryotic Cells: Structure and Function**

  Prokaryotic Cells: 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 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; Bacterial biofilm and biofouling.

- **Section 6: Control of Micro-organisms**

  Disinfection and sterilization: principles, methods, and assessment of efficacy.

- **Section 7: 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 the synthesis of amino acids; Regulation of major metabolic pathways.

- **Section 8: 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 9: Chemotherapy/Antibiotics**

  General characteristics of antimicrobial drugs; Antibiotics: Classification molecular mechanism of a mode of action and resistance; Antifungal and antiviral drugs.

- **Section 10: 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 phages; mutation in virus genomes, virus recombination, and reassortment; the Basic concept of microbial genomics.

- **Section 11: Microbial Ecology**

  Microbial interactions; Carbon, sulphur, and nitrogen cycles; Soil microorganisms associated with vascular plants; Bioremediation; Uncultivable microorganisms; the basic concept of metagenomics and metatranscriptomics.

46. Zoology (XL-T)

- **Section 1: Animal Diversity**

  Distribution, systematics, and classification of animals, phylogenetic relationships (based on classical and molecular phylogenetic tools).

- **Section 2: Evolution**

  Origin and history of life on earth, theories of evolution, natural selection, adaptation, speciation.

- **Section 3: Genetics**

  Basic Principles of inheritance, the 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 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 5: Cell Biology**

  Basic principles of cellular microscopy, the structure of the cell, cytoskeletal organization, cellular organelles, and their structure and function, cell cycle, cell division, chromosomes, and chromatin structure.

- **Section 6: Gene expression in Eukaryotes**

  Eukaryotic genome organization and regulation of gene expression, transposable elements.

- **Section 7: Animal Anatomy and Physiology**

  Comparative physiology, the respiratory system, Muscular system, circulatory system, digestive system, the nervous system, the excretory system, the endocrine system, the reproductive system, the skeletal system.

- **Section 8: Parasitology and Immunology**

  Nature of parasite, host-parasite relation, protozoan and helminthic parasites, the immune response, cellular and humoral immune response.

- **Section 9: Development Biology**

  Gametogenesis, Embryonic development, cellular differentiation, organogenesis, metamorphosis, Model organisms used in developmental biology, the genetic and molecular basis of development, stem cells.

- **Section 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.

- **Section 11: Animal Behaviour**

  Type of behaviours, courtship, mating and territoriality, instinct, learning and memory, social behaviour across the animal taxa, communication, pheromones, evolution of behavior in animals.

47. Food Technology (XL - U)

- **Section 1: Food Chemistry and Nutrition**

  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, biochemical changes in post mortem, and tenderization of muscles. **Lipids**: Classification and structure of lipids, rancidity, polymerization, and polymorphism. **Pigments**: carotenoids, chlorophylls, anthocyanins, tannins, and myoglobin. **Food flavours**: terpenes, esters, aldehydes, ketones, and quinines. **Enzymes**: specificity, simple and inhibition kinetics, coenzymes, enzymatic

and non-enzymatic browning. **Nutrition**: balanced diet, essential amino acids, and essential fatty acids, protein efficiency ratio, water-soluble and fat-soluble vitamins, the role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases. **Chemical and biochemical changes**: changes occur in foods during different processing.

- **Section 2: Food Microbiology**

  Characteristics of microorganisms: morphology of bacteria, yeast, mold and actinomycetes, spores and vegetative cells, gram-staining. Microbial growth: 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, Shebelle, Escherichia, Bacillus, Clostridium, and Aspergillums genera. Fermented foods and beverages: curd, yoghurt, cheese, pickles, soya-sauce, sauerkraut, idly, dose, vinegar, alcoholic beverages, and sausage.

- **Section 3: Food Products Technology**

  Processing principles: thermal processing, chilling, freezing, dehydration, the addition of preservatives and food additives, irradiation, fermentation, hurdle technology, intermediate moisture foods. Food packaging and storage: packaging materials, aseptic packaging, controlled and modified atmosphere storage. Cereal processing and products: milling of rice, wheat, and maize, parboiling of paddy, bread, biscuits, extruded products, and ready-to-eat breakfast cereals. Oil processing: expelling, solvent extraction, refining, and hydrogenation. Fruits and vegetable 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: drying, canning, and freezing of fish and meat; production of egg powder. Waste utilization: pectin from fruit wastes, uses of by-products from rice milling. Food standards and quality maintenance: FPO, PFA, A-Mark, ISI, HACCP, food plant sanitation, and cleaning in place (CIP).

- **Section 4: Food Engineering**

  Mass and energy balance; Momentum transfer: Flow rate and pressure drop relationships for Newtonian fluids flowing through a pipe, Reynolds number. Heat transfer: heat transfer by conduction, convection, radiation, heat exchangers. Mass transfer: molecular diffusion and Flick'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 sterilization, evaporation of liquid foods, hot air drying of solids, spray and freeze-drying, freezing and crystallization. Mass transfer operations: psychometric, humidification, and de humidification operations.