

## XE Engineering Sciences

### XE0: Engineering Mathematics (Compulsory for all XE candidates)

#### Section XE0.1: Linear Algebra

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

#### Section XE0.2: Calculus

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

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

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

#### Section XE0.3: Vector Calculus

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

#### Section XE0.4: Complex variables

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

#### Section XE0.5: Ordinary Differential Equations

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

#### Section XE0.6: Partial Differential Equations

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

#### Section XE0.7: Probability and Statistics

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

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| <b>Section XE0.8:</b> | <b>Numerical Methods</b> |
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Solution of systems of linear equations using LU decomposition, Gauss elimination method; Lagrange and Newton's interpolations; Solution of polynomial and transcendental equations by Bisection method and Newton-Raphson method; Numerical integration by trapezoidal rule and Simpson's  $1/3^{\text{rd}}$  and  $3/8^{\text{th}}$  rules; Numerical solutions of first order differential equations by Euler's method.

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

## XE2: Materials Science

### Section XE2.1: Classification and Structure of Materials

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

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

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

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

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

**Structure of amorphous materials:** Crystalline and glassy silica; Fused silica and soda-lime glass.

**Solid solutions:** Interstitial and substitutional; Hume-Rothery rules.

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

#### **Defects in Crystalline Materials:**

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

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

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

### Section XE2.2: Thermodynamics, Kinetics and Phase Transformations

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

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

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

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| <b>Section XE2.3:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Properties and Applications of Materials</b>        |
| <p><b>Mechanical properties:</b> elastic and plastic deformation; atomic bonding and elasticity; shear strength of perfect crystals; plastic deformation by slip and dislocation motion; Strengthening mechanisms: strain hardening, solid solution hardening, precipitation hardening, grain size refinement; Griffith theory of fracture; fatigue: cyclic loading, S-N curve, crack initiation and propagation; Creep in crystalline materials: stages and mechanisms of creep; Composites: particle and fibre reinforced composites; elastic modulus (rule of mixtures).</p> <p><b>Electronic Properties:</b> Drude model and classical description of electrical conductivity, Drawbacks of classical theory, Quantum mechanical description including concept of Fermi energy, Fermi surface and density of states. Band Theory to explain insulators, conductors, and semiconductors via allowed and forbidden energy bands, Effective mass concept, Intrinsic and extrinsic semiconductors, temperature dependence of conductivity, Carrier concentration and mobility, drift vs. diffusion current, Hall Effect for a simple metal or semiconductor. Dielectric behavior, piezo- and ferro-electric behavior.</p> <p><b>Magnetic Properties:</b> Origin of magnetism in materials, types of Magnetism: Diamagnetism, Paramagnetism, Ferromagnetism, Ferrimagnetism and Antiferromagnetism, Magnetic Domains &amp; Hysteresis, Hard and soft magnetic materials.</p> <p><b>Thermal Properties:</b> Specific heat, Classical Dulong–Petit Law, Wiedemann-Franz Law, Thermal conductivity of metals and insulators (role of electrons and phonons), Einstein and Debye model, heat conduction, thermal diffusivity, thermal expansion, and thermoelectricity.</p> <p><b>Optical Properties:</b> Refractive index, absorption and transmission of electromagnetic radiation.</p> |                                                        |
| <b>Section XE2.4:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Characterization and Measurements of Properties</b> |
| <p>X-ray diffraction: Bragg's Law, structure factor, indexing of cubic diffraction patterns; spectroscopic techniques: UV-Vis, IR and Raman; band-gap measurement; Microscopy (optical, scanning and transmission electron microscopy): wavelength range, resolution, depth of field; Composition analysis using energy dispersive spectroscopy.</p> <p>Tensile test: engineering and true stress-strain curves, parameters, such as, yield stress, ultimate tensile stress, elongation, area under the curve; Hardness: Brinell, Rockwell and Vickers.</p> <p>Electrical conductivity, carrier mobility and concentrations.<br/>Thermal analysis techniques: thermogravimetry and calorimetry.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                        |
| <b>Section XE2.5:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Processing of Materials</b>                         |
| <p><b>Heat Treatment of steels:</b> TTT and CCT diagram: coarse and fine pearlite, martensite and bainite; Annealing, normalizing, quenching, tempering.</p> <p><b>Heat treatment of aluminium alloys:</b> Precipitation hardening: Solutionising, quenching and ageing. Hardness vs. aging time and its dependence on aging temperature.</p> <p><b>Silicon processing:</b> production of metallurgical and semiconductor grade, zone refining, single crystal growth, silicon oxidation, doping, photolithographic process</p> <p>Preparation of powders; sintering.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                        |
| <b>Section XE2.6:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Degradation of Materials</b>                        |
| <p>Electrochemical basis of corrosion of metals: standard electrode potential, galvanic series, Nernst equation, polarization and passivation; forms of corrosion; corrosion prevention</p> <p>Polymer degradation: swelling and dissolution; bond rupture: radiation, chemical and thermal effects; weathering.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                        |

**XE3: Solid Mechanics****Section XE3.1      Mechanics of Rigid Bodies**

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

**Section XE3.2      Mechanics of Deformable Bodies**

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

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

**Section XE3.3      Vibrations**

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

**XE4: Thermodynamics****Section XE4.1: Basic Concepts**

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

**Section XE4.2: Properties of Pure Substances**

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

**Section XE4.3: First Law of Thermodynamics**

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

**Section XE4.4: Second Law of Thermodynamics**

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

**Section XE4.5: Entropy**

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

**Section XE4.6: Thermodynamic Relations**

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

**Section XE4.7: Thermodynamic Cycles**

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

**Section XE4.8: Mixtures of Ideal Gases**

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

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| <b>XE5</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Polymer Science and Engineering</b>         |
| <b>Section XE5.1:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Polymer Chemistry</b>                       |
| Monomers; Degree of polymerization; Classification of polymers; Polymerization reactions: addition and condensation, their kinetics; Metallocene polymers and other newer methods of polymerization; Copolymerization; Monomer reactivity ratios and its significance; Kinetics; Different copolymers; Random, alternating, azeotropic copolymerization; Block and graft copolymers; Techniques for polymerization-bulk, solution, suspension, emulsion.                                                                                                                                                                         |                                                |
| <b>Section XE5.2:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Polymer Characterization</b>                |
| Solubility and swelling; Concept of molecular weight distribution and its significance; Concept of average molecular weight; Determination of number average, weight average, viscosity average and Z-average molecular weights; Glass transition; Melting transition; Amorphous and crystalline states of polymers; Orientation in polymers and polymer crystallinity; Factors affecting crystallinity; Analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA); Microscopic (optical and electronic) techniques; GPC; Mooney viscosity; Morphology and microstructure (SEM, TEM, AFM).                                    |                                                |
| <b>Section XE5.3:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Synthesis, Manufacturing and Properties</b> |
| Commodity and general-purpose thermoplastics: PE, PP, PS, PVC; Polyesters; Acrylic; PU polymers; Engineering Plastics: Nylon, PC, PBT, Polyphenylene oxide, ABS, Fluoropolymers; Thermosetting polymers: Polyurethane, PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds; Natural and synthetic rubbers: recovery of NR hydrocarbon from latex; SBR; Nitrile; CR; CSM; EPDM; IIR; BR; Silicone; TPE; Specialty plastics: PEK, PEEK, Polyphenylene sulfide, Polysulfone, Polyethersulfone, etc.; Bio-compostable polymers such as PCL, PLA, PBAT, PHA/PHB, natural and biodegradable polymers such as cellulose, starch, alginate. |                                                |
| <b>Section XE5.4:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Polymer Blends and Composites</b>           |
| Polymer blends and composites, their significance; Choice of polymers for blending, blend miscibility: miscible and immiscible blends; Thermodynamics; Phase morphology; Polymer alloys; Polymer eutectics; Plastic-plastic, rubber-plastic and rubber-rubber blends; FRP, particulate, long and short fibre reinforced composites; Polymer reinforcement, reinforcing fibres – natural and synthetic.                                                                                                                                                                                                                           |                                                |
| <b>Section XE5.5:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Additives, Compounding and Formulations</b> |
| Polymer compounding-need and significance; Different compounding ingredients for rubber and plastics (crosslinkers, antioxidants, heat stabilizers, UV stabilizers, lubricants, processing aids, impact modifiers, flame retardant, antistatic agents. PVC stabilizers and plasticizers) and their function; Use of carbon black; Polymer mixing equipment; Vulcanization and kinetics.                                                                                                                                                                                                                                          |                                                |
| <b>Section XE5.6:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Polymer Rheology</b>                        |
| Flow of Newtonian and non-Newtonian fluids, different flow equations, dependence of shear modulus on temperature, molecular/segmental deformations at different zones and transitions; Measurements of rheological parameters by capillary, parallel plate, cone-plate rheometer. viscoelasticity, creep and stress relaxation, oscillatory or dynamic testing, mechanical models, control of rheological characteristics through compounding, rubber curing in parallel plate viscometer, ODR and MDR.                                                                                                                          |                                                |
| <b>Section XE5.7:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Polymer Processing</b>                      |
| Spin coating; Electrospinning; Solution and melt spinning; Film casting; Compression molding; Transfer molding; Injection molding; Blow molding; Reaction injection molding; Filament winding; SMC; BMC; DMC; Extrusion;                                                                                                                                                                                                                                                                                                                                                                                                         |                                                |

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

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

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

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| <b>XE6</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Food Technology</b>              |
| <b>Section XE6.1:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Food Chemistry and Nutrition</b> |
| <p><b>Food Components Characterization and quantification techniques</b></p> <p><b>Carbohydrates:</b> Structure and functional properties of mono-, oligo-, &amp; poly- saccharides including starch, cellulose, pectic substances and dietary fibre, gelatinization and retrogradation of starch.</p> <p><b>Proteins:</b> classification and structure of proteins in food, Protein denaturation, functional properties of proteins and starch.</p> <p><b>Lipids:</b> Classification and structure of lipids, rancidity, polymerization and polymorphism.</p> <p><b>Pigments:</b> carotenoids, chlorophylls, anthocyanins, tannins and myoglobin. Curcumin, betalains.</p> <p><b>Food Flavours:</b> Terpenes, esters, aldehydes, ketones and quinines. Enzymes: specificity, simple and inhibition kinetics, coenzymes, enzymatic and non- enzymatic browning, Food enzymology.</p> <p><b>Nutrition:</b> Balanced diet, essential amino acids and essential fatty acids, protein efficiency ratio, water soluble and fat soluble vitamins, role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases. Food Supplements, Concept of nutrigenomics.</p> <p>Food adulteration (types of adulterants and their detection)</p> <p><b>Chemical and Biochemical Changes:</b> Changes occurring in foods during different processing. Changes occur in foods and food biopolymers (carbohydrates, proteins, lipids) during different processing.</p> |                                     |
| <b>Section XE6.2:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Food Microbiology</b>            |
| <p><b>Characteristics of Microorganisms:</b> Morphology of bacteria, yeast, mold and actinomycetes, spores and vegetative cells, gram-staining, Resistant bacteria.</p> <p><b>Microbial Growth:</b> D-value, Z-value, F-value, Growth and death kinetics, serial dilution technique.</p> <p><b>Food Spoilage:</b> Spoilage microorganisms in different food products including milk, fish, meat, egg, cereals and their products.</p> <p><b>Toxins from Microbes:</b> Pathogens and non-pathogens including Staphylococcus, Salmonella, Shigella, Escherichia, Bacillus, Clostridium, and Aspergillus genera, Food borne diseases.</p> <p><b>Fermented Foods and Beverages:</b> Curd, yoghurt, cheese, pickles, soya-sauce, sauerkraut, idli, dosa, vinegar, alcoholic beverages, and sausage.</p> <p><b>Probiotic foods:</b> probiotic microorganisms, their benefits, prebiotics, synbiotics.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                     |
| <b>Section XE6.3:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Food Products Technology</b>     |
| <p><b>Processing Principles:</b> Food Components Characterization and quantification techniques. Quality analysis of raw and processed food products. Thermal processing (blanching, pasteurization, sterilization), chilling, freezing, dehydration, addition of preservatives and food additives, Microwave, radiowave, and Infrared</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                     |

processing, irradiation, fermentation, hurdle technology, intermediate moisture foods.

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

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

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

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

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

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

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

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

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

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| <b>Section XE6.4:</b> | <b>Food Engineering</b> |
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Mass and energy balance.

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

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

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

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

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

**Mass Transfer Operations:** Psychometric, humidification and dehumidification operations.

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| <b>XE7</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>Atmospheric and Oceanic Sciences</b> |
| <b>Section XE7.1:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Atmospheric Science</b>              |
| <p>Vertical Structure and Composition of the Atmosphere; Blackbody Radiation and Radiation Balance; Modes of Heat Transfer in the Atmosphere; Greenhouse Effect; Cloud Types; Laws of Thermodynamics; Gas Laws; Hydrostatic Equation; Clausius Clapeyron Equation; Adiabatic Processes, Humidity in the Atmosphere, Atmospheric Stability; Global Radiation Budget, Role of Greenhouse Gases.</p> <p>Navier-Stokes and Continuity Equations; Compressible and Incompressible Fluids; Pressure Gradient, Centripetal, Centrifugal and Coriolis Forces; Geostrophic, Gradient and Cyclostrophic Balances; Circulations and Vorticity, General Circulation of the Atmosphere. Broad Features of Indian Monsoons; Fundamentals of Tropical Cyclones.</p> |                                         |
| <b>Section XE7.2:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Ocean Sciences</b>                   |
| <p>Vertical Profiles of Temperature and Salinity; Stability and Double Diffusion; Equation of State, Equations for Conservation of Mass, Momentum, Heat and Salt; Inertial Currents; Geostrophic Motion; Air-Sea Surface Fluxes; Wind-driven Circulation, Ekman and Sverdrup Transports; Storm Surges, Tides, Tsunamis and Wind Waves; Eddies and Gyres; Thermohaline Circulation.</p> <p>Chemical Properties of Seawater, Major and Minor Elements, Ocean Acidification, Biogeochemical Cycling of Nutrients; Biological Pump; Primary and Secondary Biological Productivity; Marine Ecology.</p>                                                                                                                                                   |                                         |

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| <b>XE8</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>Energy Science</b>                                         |
| <b>Section XE8.1:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <b>Energy Resources and Conversion Technologies</b>           |
| <p><b>Fossil energy resources:</b> R/P ratio, estimation of reserves, unconventional fossil resources (coal bed methane, shale gas, gas hydrates, frozen methane), peak oil theory.</p> <p><b>Nuclear energy resources:</b> Energy-mass relation, nuclear reaction conservation laws, binding energy and Q-values, radioactive decay, fission and fusion.</p> <p><b>Solar thermal systems:</b> Solar radiation distribution and measurement, solar geometry, optical efficiency, thermal efficiency, energy conservation for solar thermal collectors, flat plate collectors, evacuated tube collectors, solar air heaters, concentrating collectors.</p> <p><b>Solar photovoltaic (PV) systems:</b> I-V characteristics, efficiency, fill factor, series and parallel connections, sizing of PV systems (load factor, days of autonomy, battery size, inverter size, PV array size), maximum power point tracking.</p> <p><b>Biomass:</b> Biomass resources, biomass composition, characterisation, conversion methods (pyrolysis, gasification, steam reforming), biofuels.</p> <p><b>Wind energy conversion systems:</b> Wind resource analysis, types and characteristics of wind turbines, Betz limit, wind turbine motor design considerations, blade profile, wind energy generators.</p> <p><b>Hydropower:</b> Hydro resources, hydro power plants, turbines (Pelton, Kaplan, Francis), small hydro systems.</p> |                                                               |
| <b>Section XE8.2:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <b>Energy Storage, Economics, Environment, and Efficiency</b> |
| <p><b>Energy storage systems:</b> Batteries (capacity, C-rate, state of charge, state of health, depth of discharge, energy and power densities); conservation of energy and mass for thermal energy storage, pumped hydro storage, and compressed air storage; charging, discharging, and roundtrip efficiency.</p> <p><b>Economic analysis of energy systems:</b> Simple Payback Period, Time Value of Money, Discount rate, Present Worth Factor, Capital Recovery Factor, Life Cycle Costing, Internal Rate of Return, Net Present Value, Annual Worth, Cost of Saved Energy, Levelized Cost of Energy.</p> <p><b>Environmental impacts of energy use:</b> Air pollution (SO<sub>x</sub>, NO<sub>x</sub>, CO, particulates), greenhouse gas emissions and their sources, emission factors and inventories.</p> <p><b>Energy management:</b> Energy auditing (methodology, analysis of past trends plants data), electrical systems (demand side management, power factor correction), motor efficiency testing, energy efficient motors, lighting (lighting levels, efficient options, fixtures, daylighting, timers), thermal and mechanical systems (insulation, compressors, pumps, boiler, heating and cooling systems).</p>                                                                                                                                                                                     |                                                               |

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| <b>XE9</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Textile Engineering and Fibre Science</b>           |
| <b>Section XE9.1:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Textile Fibres</b>                                  |
| <p>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.</p> <p>Molecular architecture, amorphous and crystalline phases, glass transition, plasticization, crystallization, melting, factors affecting T<sub>g</sub> and T<sub>m</sub>; 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.</p> <p>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.</p> |                                                        |
| <b>Section XE9.2:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Yarn Manufacture, Yarn Structure and Properties</b> |
| <p>Principles of ginning; Principles of opening, cleaning and blending; Working principles of modern blowroom machines; Fundamentals of carding; Conventional vs. modern carding machine; Card setting; Card clothing; Periodic mass variation in card sliver; Card autoleveller; Principles of roller drawing; Roller arrangements in drafting systems; Periodic mass variation in drawn sliver; Drawframe autoleveller; Principles of cotton combing; Combing cycle and mechanisms; Recent developments in combing machine; Principles of drafting, twisting, and bobbin building in roving formation; Modern developments in roving machine; Principles of drafting, twisting and cop building in ring spinning; Causes of end breakages; Modern developments in ring spinning machine; Working principles of ring doubler and two-for-one twister; Relationship between single yarn twist and folded yarn twist; Principles of compact, rotor, air-jet, air-vortex, friction, core, wrap and twist-less spinning processes. Influence of fibre geometry, fibre configuration and fibre orientation in yarn; Fibre packing density of yarn; Yarn diameter; Yarn twist and its relation to yarn strength; Helical arrangement of fibres in yarns; Yarn contraction; Fibre migration in yarns; Stress-strain relation in yarn; Mass irregularity of yarn; Structure-property relationship in ring, compact, rotor, air-jet and friction spun yarns.</p>                                                                     |                                                        |
| <b>Section XE9.3:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Fabric Manufacture, Structure and Properties</b>    |
| <p>Principles of winding processes; Classification of winding methods; Patterning mechanism; Yarn clearers and tensioners; Different systems of yarn splicing; Warping objectives and classification; Different types of warping creels; Features of beam and sectional warping machines; Different sizing systems; Sizing of spun and filament yarns; Drawing-in process; Principles of pirn winding. Primary and secondary motions of loom; Shedding motion; Positive and negative shedding mechanisms; Type of sheds; Tappet, dobby and jacquard shedding; Weft insertion; Mechanics of weft insertion with shuttle; Shuttle picking and checking; Beat-up; Kinematics of sley; Loom timing diagram; Cam designing; Effect of sley setting and cam profile on fabric formation; Take-up and Let-off motions; Warp and weft stop motions; Warp protection; Weft replenishment; Principles of weft insertion systems of shuttle-less weaving machines such as projectile, rapier, water-jet and air-jet; Principles of functioning of multiphase and circular looms; Types of selvages; Basic woven fabric constructions and their derivatives, such as crepe, cord, terry, gauze, leno, double cloth and other constructions; Drawing and lifting plans.</p> <p>Fundamentals of weft knitting; Classification of weft knitting technologies; Weft knitted constructions such as plain, rib, interlock, purl and others; Different knit stitches such as loop, tuck, float and others; Principle of warp</p>                |                                                        |

knitting; Classification of warp knitting technologies; Swinging and shogging motion of guide bar; Basic warp knit constructions such as pillar, tricot, atlas, inlay nets and others; Fibre preparation processes for nonwovens; Web formation and bonding processes; Spun-bonding and melt-blowing technologies; Applications of nonwoven fabrics; Principles of braiding; Type of braids; Maypole braiding technology;

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

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| <b>Section XE9.4:</b> | <b>Textile Testing</b> |
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Sampling techniques for fibres, yarns and fabrics; Sample size and sampling errors.

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

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

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

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| <b>Section XE9.5:</b> | <b>Chemical Processing</b> |
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Impurities in natural fibre; Singeing; Chemistry and practice of preparatory processes for cotton; Preparatory processing of wool and silk; Mercerization of cotton; Preparatory processes for manmade fibres and their blends; Optical brightening agent.

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

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

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

Pollution control and treatment of effluents.