

## Syllabus for Engineering Sciences (XE)

### *Section A: Engineering Mathematics (Compulsory)*

**Linear Algebra:** Algebra of matrices, inverse, rank, system of linear equations, symmetric, skew-symmetric and orthogonal matrices. Hermitian, skew-Hermitian and unitary matrices. eigenvalues and eigenvectors, diagonalisation of matrices, Cayley-Hamilton Theorem.

**Calculus:** Functions of single variable, limit, continuity and differentiability, Mean value theorems, Indeterminate forms and L'Hospital rule, Maxima and minima, Taylor's series, Fundamental and mean value-theorems of integral calculus. Evaluation of definite and improper integrals, Beta and Gamma functions, Functions of two variables, limit, continuity, partial derivatives, Euler's theorem for homogeneous functions, total derivatives, maxima and minima, Lagrange method of multipliers, double and triple integrals and their applications, sequence and series, tests for convergence, power series, Fourier Series, Half range sine and cosine series.

**Complex variable:** Analytic functions, Cauchy-Riemann equations, Application in solving potential problems, Line integral, Cauchy's integral theorem and integral formula (without proof), Taylor's and Laurent's series, Residue theorem (without proof) and its applications.

**Vector Calculus:** Gradient, divergence and curl, vector identities, directional derivatives, line, surface and volume integrals, Stokes, Gauss and Green's theorems (without proofs) applications.

**Ordinary Differential Equations:** First order equation (linear and nonlinear), Second order linear differential equations with variable coefficients, Variation of parameters method, higher order linear differential equations with constant coefficients, Cauchy-Euler's equations, power series solutions, Legendre polynomials and Bessel's functions of the first kind and their properties.

**Partial Differential Equations:** Separation of variables method, Laplace equation, solutions of one dimensional heat and wave equations.

**Probability and Statistics:** Definitions of probability and simple theorems, conditional probability, Bayes Theorem, random variables, discrete and continuous distributions, Binomial, Poisson, and normal distributions, correlation and linear regression.

**Numerical Methods:** Solution of a system of linear equations by L-U decomposition, Gauss-Jordan and Gauss-Seidel Methods, Newton's interpolation formulae, Solution of a polynomial and a transcendental equation by Newton-Raphson method, numerical integration by trapezoidal rule, Simpson's rule and Gaussian quadrature, numerical solutions of first order differential equation by Euler's method and 4<sup>th</sup> order Runge-Kutta method.

### *Section B: Fluid Mechanics*

**Fluid Properties:** Relation between stress and strain rate for Newtonian fluids.

**Hydrostatics:** Buoyancy, manometry, forces on submerged bodies.

Eulerian and Lagrangian description of fluid motion, concept of local and convective accelerations, steady and unsteady flows, control volume analysis for mass, momentum and energy.

Differential equations of mass and momentum (Euler equation), Bernoulli's equation and its applications.

Concept of fluid rotation, vorticity, stream function and potential function.

Potential flow: elementary flow fields and principle of superposition, potential flow past a circular cylinder.

**Dimensional analysis:** Concept of geometric, kinematic and dynamic similarity, importance of non-dimensional numbers. Fully-developed pipe flow, laminar and turbulent flows, friction factor, Darcy-Weisbach relation.

Qualitative ideas of boundary layer and separation, streamlined and bluff bodies, drag and lift forces.

Basic ideas of flow measurement using venturimeter, pitot-static tube and orifice plate.

### **Section C: Materials Science**

**Structure:** Atomic structure and bonding in materials. Crystal structure of materials, crystal systems, unit cells and space lattices, determination of structures of simple crystals by x-ray diffraction, miller indices of planes and directions, packing geometry in metallic, ionic and covalent solids. Concept of amorphous, single and polycrystalline structures and their effect on properties of materials. Crystal growth techniques. Imperfections in crystalline solids and their role in influencing various properties.

**Diffusion:** Fick's laws and application of diffusion in sintering, doping of semiconductors and surface hardening of metals.

**Metals and Alloys:** Solid solutions, solubility limit, phase rule, binary phase diagrams, intermediate phases, intermetallic compounds, iron-iron carbide phase diagram, heat treatment of steels, cold, hot working of metals, recovery, recrystallization and grain growth. Microstructure, properties and applications of ferrous and non-ferrous alloys.

**Ceramics:** Structure, properties, processing and applications of traditional and advanced ceramics.

**Polymers:** Classification, polymerization, structure and properties, additives for polymer products, processing and applications.

**Composites:** Properties and applications of various composites.

**Advanced Materials and Tools:** Smart materials, exhibiting ferroelectric, piezoelectric, optoelectric, semiconducting behavior, lasers and optical fibers, photoconductivity and superconductivity, nanomaterials – synthesis, properties and applications, biomaterials, superalloys, shape memory alloys. Materials characterization techniques such as, scanning electron microscopy, transmission electron microscopy, atomic force microscopy, scanning tunneling microscopy, atomic absorption spectroscopy, differential scanning calorimetry.

**Mechanical Properties:** stress-strain diagrams of metallic, ceramic and polymeric materials, modulus of elasticity, yield strength, tensile strength, toughness, elongation, plastic deformation, viscoelasticity, hardness, impact strength, creep, fatigue, ductile and brittle fracture.

**Thermal Properties:** Heat capacity, thermal conductivity, thermal expansion of materials.

**Electronic Properties:** Concept of energy band diagram for materials – conductors, semiconductors and insulators, electrical conductivity – effect of temperature on conductivity, intrinsic and extrinsic semiconductors, dielectric properties.

**Optical Properties:** Reflection, refraction, absorption and transmission of electromagnetic radiation in solids.

**Magnetic Properties:** Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, antiferromagnetism, ferromagnetism, ferrimagnetism, magnetic hysteresis.

**Environmental Degradation:** Corrosion and oxidation of materials, prevention.

### **Section D: Solid Mechanics**

Equivalent force systems; free-body diagrams; equilibrium equations; analysis of determinate trusses and frames; friction; simple relative motion of particles; force as function of position, time and speed; force acting on a body in motion; laws of motion; law of conservation of energy; law of conservation of momentum.

Stresses and strains; principal stresses and strains; Mohr's circle; generalized Hooke's Law; thermal strain; theories of failure.

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

Free vibration of single degree of freedom systems.

### ***Section E: Thermodynamics***

**Basic Concepts:** Continuum, macroscopic approach, thermodynamic system (closed and open or control volume); thermodynamic properties and equilibrium; state of a system, state diagram, path and process; different modes of work; Zeroth law of thermodynamics; concept of temperature; heat.

**First Law of Thermodynamics:** Energy, enthalpy, specific heats, first law applied to systems and control volumes, steady and unsteady flow analysis.

**Second Law of Thermodynamics:** Kelvin-Planck and Clausius statements, reversible and irreversible processes, Carnot theorems, thermodynamic temperature scale, Clausius inequality and concept of entropy, principle of increase of entropy; availability and irreversibility.

**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, equations of state, compressibility chart.

**Thermodynamic Relations:** T-ds relations, Maxwell equations, Joule-Thomson coefficient, coefficient of volume expansion, adiabatic and isothermal compressibilities, Clapeyron equation.

**Thermodynamic cycles:** Carnot vapor power cycle, Ideal Rankine cycle, Rankine Reheat cycle, Air standard Otto cycle, Air standard Diesel cycle, Air-standard Brayton cycle, Vapor-compression refrigeration cycle.

**Ideal Gas Mixtures:** Dalton's and Amagat's laws, calculations of properties, air-water vapor mixtures and simple thermodynamic processes involving them.

### ***Section F: Polymer Science and Engineering***

**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 techniques of polymerization, copolymerization, monomer reactivity ratios and its significance, kinetics, different copolymers, random, alternating, azeotropic copolymerization, block and graft copolymers, techniques for copolymerization-bulk, solution, suspension, emulsion.

**Polymer Characterization:** Solubility and swelling, 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.

**Synthesis 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: 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.

**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 Technology:** Polymer compounding-need and significance, different compounding ingredients for rubber and plastics, crosslinking and vulcanization, vulcanization kinetics.

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

**Polymer processing:** Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, extrusion, pultrusion, calendaring, rotational molding, thermoforming, rubber processing in two-roll mill, internal mixer.

**Polymer testing:** Mechanical-static and dynamic tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness. Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, swelling, ageing resistance, environmental stress cracking resistance.

### ***Section G: Food Technology***

**Food Chemistry and Nutrition:** Carbohydrates: Structure and functional properties of mono- oligo-polysaccharides including starch, cellulose, pectic substances and dietary fibre; Proteins: Classification and structure of proteins in food; Lipids: Classification and structure of lipids, Rancidity of fats, Polymerization and polymorphism; Pigments: Carotenoids, chlorophylls, anthocyanins, tannins and myoglobin; Food flavours: Terpenes, esters, ketones and quinones; Enzymes: Specificity, Kinetics and inhibition, Coenzymes, Enzymatic and non-enzymatic browning; Nutrition: Balanced diet, Essential amino acids and fatty acids, PER, Water soluble and fat soluble vitamins, Role of minerals in nutrition, Antinutrients, Nutrition deficiency diseases.

**Food Microbiology:** Characteristics of microorganisms: Morphology, structure and detection of bacteria, yeast and mold in food, Spores and vegetative cells; Microbial growth in food: Intrinsic and extrinsic factors, Growth and death kinetics, serial dilution method for quantification; Food spoilage: Contributing factors, Spoilage bacteria, Microbial spoilage of milk and milk products, meat and meat products; Foodborne disease: Toxins produced by Staphylococcus, Clostridium and Aspergillus; Bacterial pathogens: Salmonella, Bacillus, Listeria, Escherichia coli, Shigella, Campylobacter; Fermented food: Buttermilk, yoghurt, cheese, sausage, alcoholic beverage, vinegar, sauerkraut and soya sauce.

**Food Products Technology:** Processing principles: Canning, chilling, freezing, dehydration, control of water activity, CA and MA storage, fermentation, hurdle technology, addition of preservatives and food additives, Food packaging, cleaning in place and food laws.; Grain products processing: Milling of rice, wheat, and maize, parboiling of paddy, production of bread, biscuits, extruded products and breakfast cereals, Solvent extraction, refining and hydrogenation of oil; Fruits, vegetables and plantation products processing: Extraction, clarification concentration and packaging of fruit juice, Production of jam, jelly, marmalade, squash, candies, and pickles, pectin from fruit waste, tea, coffee, chocolate and essential oils from spices; Milk and milk products processing: Pasteurized and sterilized milk, cream, butter, ghee, ice-cream, cheese and milk powder; Animal products processing: Drying and canning of fish, post mortem changes, tenderization and freezing of meat, egg powder.

**Food Engineering:** Mass and energy balance; Momentum transfer: Flow rate and pressure drop relationships for Newtonian fluids flowing through pipe, Characteristics of non-Newtonian fluids – generalized viscosity coefficient and Reynolds number, Flow of compressible fluid, Flow measurement, Pumps and compressors; Heat transfer: Heat transfer by conduction, convection, radiation, boiling and condensation, Unsteady state heat transfer in simple geometry, NTU- effectiveness relationship of co-current and counter current double pipe heat exchanger; Mass transfer: Molecular diffusion and Fick's Law,

Steady state mass transfer, Convective mass transfer, Permeability of films and laminates; Mechanical operations: Energy requirement and rate of operations involved in size reduction of solids, high pressure homogenization, filtration, centrifugation, settling, sieving, flow through porous bed, agitation of liquid, solid-solid mixing, and single screw extrusion; Thermal operations: Energy requirement and rate of operations involved in process time evaluation in batch and continuous sterilization, evaporation of liquid foods, hot air drying of solids, spray and freeze-drying, freezing and crystallization; Mass transfer operations: Properties of air-water vapor mixture; Humidification and dehumidification operations.