MT METALLURGICAL ENGINEERING

Section 1: Engineering Mathematics

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

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

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

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

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

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

Section 2: Metallurgical Thermodynamics

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

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

Section 3: Transport Phenomena and Rate Processes

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

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

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

Dimensional Analysis: Significance of dimensionless numbers and their applications.

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

Electrochemical Kinetics: Polarization.

Section 4: Mineral Processing and Extractive Metallurgy

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

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

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

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

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

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

Section 5:	Physical Metallurgy

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

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

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

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

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

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

Corrosion: Basic forms of corrosion and its prevention.

Section 6:	Mechanical Behaviour of Materials

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

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

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

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

Fatigue: Low and high cycle fatigue; crack growth.

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

Section 7:	Manufacturing Processes

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

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

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

Powder Metallurgy: Production of powders, compaction and sintering.

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

Section 8:	**Materials Science and Non-Metallic Materials**

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

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

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

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

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

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