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; Stokes, Gauss and Green's theorems.

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

Probability and Statistics: Definitions of probability and sampling theorems, conditional probability, Mean, median, mode and standard deviation; Random variables; Poisson, normal and binomial distributions; Analysis of experimental data; linear least squares method.

Numerical Methods: Solutions of linear and non-linear (Bisection, Secant, Newton- Raphson methods) algebraic equations; integration by trapezoidal and Simpson's rule; single and multi- step methods for differential equations.

Section 2: Metallurgical Thermodynamics

Laws of Thermodynamics: First law – energy conservation, Second law - entropy; Enthalpy, Gibbs and Helmholtz free energy; Maxwell's relations; Chemical potential; Applications to metallurgical systems, solutions, ideal and regular solutions; Gibbs phase rule, phase equilibria, binary phase diagram and lever rule, free-energy vs. composition diagrams; Equilibrium constant, Activity, Ellingham and phase stability diagrams; Thermodynamics of point defects, surfaces and interfaces, adsorption and segregation phenomena.

Electrochemistry: Single electrode potential, Electrochemical cells, Nernst equation, Potential-pH diagrams.

Section 3: Transport Phenomena and Rate Processes

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

Heat transfer: Conduction, Fourier's Law, 1-D steady state conduction. Convection: Heat transfer coefficient relations for forced convection. Radiation: Black body radiation, Stefan-Boltzmann Law, Kirchhoff's Law.

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

Dimensional Analysis: Buckingham Pi theorem, Significance of dimensionless numbers.

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

Electrochemical Kinetics: Polarization.

Section 4: Mineral Processing and Extractive Metallurgy

Comminution techniques, Size classification, Flotation, Gravity and other methods of mineral beneficiation; Agglomeration: sintering, pelletizing and briquetting. Material and Energy balances in metallurgical processes; Principles and processes for the extraction of non-ferrous metals – aluminium,

copper and titanium.

Iron and Steel Making: Material and heat balance in blast furnace; Structure and properties of slags and molten salts – basicity of slags - sulphide and phosphate capacity of slags; Production of metallurgical coke. Other methods of iron making (COREX, MIDRE).

Primary Steel Making: Basic oxygen furnace, process dynamics, oxidation reactions, electric arc furnace.

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

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

Section 5: Physical Metallurgy

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

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

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

Diffusion in Solids: Diffusion equation, steady state and error function solutions; Examples-homogenization and carburization; Kirkendall effect; Uphill diffusion; Atomic models for interstitial and substitutional diffusion; Pipe diffusion and grain boundary diffusion.

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

Solid-state Transformations: Precipitation, spinoidal decomposition, ordering, massive transformation, discontinuous precipitation, eutectoid transformation, diffusionless transformations; Precipitate coarsening, Gibbs-Thomson effect.

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

Electronic, magnetic and optical properties of materials.

Basic forms of corrosion and its prevention.

Section 6: Mechanical Metallurgy

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

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

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

Fracture behavior, Griffith theory, linear elastic fracture mechanics, fracture toughness, fractography, ductile to brittle transition.

Fatigue: Cyclic stress strain behavior - low and high cycle fatigue, crack growth. Mechanisms of high temperature deformation and failure; creep and stress rupture, stress exponent and activation energy.

Section 7: Manufacturing Processes

Metal Casting: Mould design involving feeding, gating and 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.