



## MT Metallurgical Engineering

### Section 1: Engineering Mathematics

**Linear Algebra:** Matrices and Determinants, Systems of linear equations, Eigen values and Eigen vectors.

**Calculus:** Limit, Continuity and Differentiability; Partial derivatives; Maxima and minima; Sequences and series; Test for convergence; Fourier series.

**Vector Calculus:** Gradient; Divergence and Curl; Line, Surface and volume integrals; Stokes, Gauss and Green's theorems.

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

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

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

### Section 2: Metallurgical Thermodynamics

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

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

### Section 3: Transport Phenomena and Rate Processes

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

**Heat transfer:** Conduction, Fourier's Law, 1-D steady state conduction.

**Convection:** Heat transfer coefficient relations for forced convection.

**Radiation:** Black body radiation, Stefan-Boltzman Law, Kirchhoff's Law.

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

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



**Basic Laws of Chemical Kinetics:** First order reactions, 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 behaviour, Griffith theory, linear elastic fracture mechanics, fracture toughness, fractography, ductile to brittle transition.

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

### **Section 7: Manufacturing Processes**

**Metal Casting:** Mould design involving feeding, gating and 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.