SYLLABUS: COMPREHENSIVE EXAM FOR PhD PROGRAMME IN CHEMICAL ENGINEERING

Fluid Particle Mechanics (25 Marks)

Fluid statics, Newtonian and non-Newtonian fluids, fluid flow phenomena, boundary layers, shell-balances including differential form of Bernoulli equation and energy balance, macroscopic friction factors, flow through piping systems, flow meters, manometers, pumps and compressors, turbulent flow: fluctuating velocity, universal velocity profile and pressure drop, agitation and mixing.
Measurement of Particle size and Particle size distribution by sieve analysis, Measurement of Sphericity and Specific surface area for particles, Size reduction by top down method such as ball milling. Flow of fluid past solid. Motion of particles in fluid. Calculation of drag force and drag coefficient, Particle settling in (terminal velocity) Stokes' law and Newton's law. Richardson-Zaki equation for hindered settling. Fluid flow through a packed bed of particles. Determination of bed porosity and Pressure drop calculation using Kozeny-Carman and Ergun's equation. General equation of cake filtration. Constant rate and constant pressure drop filtration. Determination of total filtration time for plate and frame filter. Theory of fluidization, Determination of minimum fluidization velocity and pressure drop and types of fluidization. Drag, flow past immersed bodies including packed and fluidized beds

Heat Transfer Operations (25 Marks)

One-Dimensional, Steady-State Conduction: The Plane Wall, The Cylinder, The Sphere, Thermal Resistance, The Composite Wall; Convection: Convection Correlations: Laminar Flow in Circular Tubes, Turbulent Flow in Circular Tubes, Cylinder in Cross Flow; Boiling and Condensation: Pool Boiling Correlations; Laminar and Turbulent Film Condensation Vertical Plate; Film Condensation on Radial Systems; Dropwise Condensation; Heat Exchanger: The Overall Heat Transfer Coefficient; Log Mean Temperature Difference; Parallel-flow heat exchanger, Counter-flow heat exchanger; Multipass and Cross-Flow Heat Exchangers; Heat Exchanger Analysis: The Effectiveness–NTU Method and Log Mean Temperature Difference Method

Mass Transfer Operations (25 Marks)

Molecular diffusion in fluids: steady state diffusion (both gases and liquids); diffusion through variable cross-sectional area; diffusivity of liquids and gases; multi-component diffusion; diffusion in porous solids; diffusion through crystalline solids; analogy of heat, mass and momentum transfer. Mass transfer coefficients: theories for mass transfer coefficient; mass transfer coefficient in laminar and turbulent flow. Equilibrium conditions for: solvent extraction, absorption, adsorption and drying; estimation of trays using Kremser equation. Distillation: basics of distillation; differential distillation; Continuous rectification; estimation of trays using Fenske equation.

Chemical Reaction Engineering (25 Marks)

Concentration dependent term and temperature dependent terms of rate equation, Elementary and non-elementary reactions, Molecularity and order of reaction, Rate constant, Temperature dependency from Arrhenius' law, Activation energy, Constant volume batch reactor, Variable volume batch reactor, Space-time and space-velocity, Holding time, Types of reactors, PFR, CSTR etc, Size comparison of single reactors, Heats of reaction from thermodynamics, Product distribution, Performance equations for CSTR and PFR; Non ideal flow in reactors, RTD of fluid in reactors, Age distribution, F curve, C curve and E curve, Intensity Function, Effects of RTD on performance of Chemical Process Equipment; Enzyme Kinetics: Kinetics of single substrate enzyme catalysed reaction – Michaelis-Menten equation, significance of km and vmax, modifications of Michaelis-Menten plot; Enzyme inhibition and its kinetics: Types of inhibition-reversible and irreversible inhibition, kinetics of inhibition; Enzyme catalysis: Catalytic efficiency- proximity and orientation effects, distortion or strain, different mechanisms of enzyme catalysis, acid base and covalent catalysis and metal-ion catalysis.

Chemical Engineering Thermodynamics (25 Marks)

Work, Heat, Reversible and Irreversible Processes, internal energy, First Law: Closed and Open Systems, enthalpy, equilibrium state, phase rule, heat capacity specific heat, Equation of state; generalized correlations and accentric factor; Estimation of thermodynamic properties. Heat effects, Second law and entropy, reversible heat engine, Maxwell's relations and fluid property estimation, Residual properties, Single Phase Mixtures and Solutions; Partial molar properties, Gibbs-Duhem equation, fugacity and fugacity coefficient for pure components and for mixture of gases and liquids. Excess properties of mixtures, activity co-efficient, Raoult's Law and Modified Raoult's Law; Application of vapor-liquid equilibrium at low and moderate pressure, activity co-efficient models, and Chemical reaction equilibrium: evaluation of equilibrium conversion for gas phase reaction.

Analytical Techniques (25 Marks)

COD apparatus**:** Definition of COD, Importance and applications of COD, Factors affecting COD, Measurement of COD by close and open reflux method; Define electrochemistry, Electrolytic and galvanic cell, Electrode potential, EMF of a cell, Types and importance of reference electrodes, 2 and 3 electrode system, Nernst equationand its application, Butler Volmer equation, Relation between Gibbs energy and EMF of a cell; UV-Spectrophotometer**:** The Beer-Lambert's law, Introduction to UV spectrophotometer – basics of single and double beam spectrophotometer, Components and applications of UV spectrophotometer; limitations of UV –VISIBLE spectroscopy; pH, conductivity, ORP, TDS and DO meter**:** Working principle of various meters for the measurement of pH, ORP (Oxidation reduction potential), TDS (Total dissolved solids) and DO (Dissolved oxygen), Measurement of TDS by gravimetric analysis and conductivity, standard reduction potential, Factors affecting DO; The principle, applications and limitations of electron microscope The usefulness of DLS (Size measurement and size distribution measurement), TGA, XRD (Amorphous structure vs crystal structure) in nanomaterial/nanocomposite characterization.

FEW REFERENCE BOOKS:

- McCabe W.L., Smith J.C., Harriott P., "Unit Operations of Chemical Engineering", 7th Ed., McGraw-Hill, New York, 2005.
- Smith J. M., Van Ness H. C., Abbott, M.M. "Introduction to Chemical Engineering Thermodynamics", 7th Ed., McGraw-Hill, New York, 2004.
- Treybal R.E., "*Mass-Transfer Operations"*, 3rd Ed., McGraw-Hill, New York, 1980.
- Levenspiel O**., "**Chemical Reaction Engineering", 3rd Ed., John Wiley & Sons, Singapore, 1998.