Assistant Professor

Chemical Engineering

(Syllabus)

FM: 100, PM:40

1 Process Calculations

1.1 Introductory Concepts: System of units, conversion of units, and dimensional consistency, Significant figures and validation of results, Mole and molecular weight, density, specific gravity, and concentration, temperature, pressure, hydrostatic head, and flow rate.

1.2 Ideal and Real Gases: ideal gases, real gases: equations of state and compressibility charts, real gas mixtures, Multiphase Equilibrium: phase diagrams and the phase rule, single-component two-phase systems, two-component gas/ single-component liquid systems

1.3 Material balances: material balances without chemical reaction, stoichiometry and terminology for reaction systems, species mole balances, element material balances, material balances for combustion systems, Material balance involving recycles, bypass and purge systems.

1.4 Energy Balances: Terminology, Types of energy to be included in energy balances, Energy balances without chemical reaction, Energy Balances with chemical reactions, Standard heat of formation, Heat of reaction, Heat of combustion, Humidity.

2 Fluid Mechanics:

2.1 Classification of Fluids and Fluid Properties: Types of Fluids- Ideal and Actual fluids, Compressible and Incompressible Fluids, Newtonian and Non-Newtonian fluids, Newton's law of viscosity, surface tension and its effect, Fluid pressure and its measurement.

2.2 Fluid statics: Kinematics of Fluid Flow, Viscous Flow, Introduction to Compressible flow, Basic Equations of Fluid Flow, Velocity field, Stream function, Irrotational flow, Reynolds' transport theorem, Euler & Bernoulli's equation, Dimensional analysis and similitude.

2.3 Internal and external fluid flow: friction factor, Energy losses in fittings, valves etc., Friction in pipes & Channels, Flow measuring devices, Pumping of fluids, Agitation and mixing of liquids, equipment, agitation of liquids, types of impellers, power consumption in agitated vessels.

3 Mechanical operations:

3.1 Solids, characteristics of solid particles, type of standard screen series, sieve analysis, Size reduction and enlargement, crushers, grinders, disintegrates for coarse & intermediate, wet and dry grinding, energy and power requirements, law of crushers, work index, Conveyers: mechanical and pneumatic conveying, elevators.

3.2 Screening and other separation methods: screen analysis, estimation of particle size, surface area and particle population based on screen analysis, ideal and actual screens, principles of elutriation, flotation, jigging, electrostatics, and magnetic separation processes.

3.3 Sedimentation, settling velocity, flocculation, Fluidizations, dense phase fluidization and boiling beds, Minimum fluidization velocity, minimum porosity of bed and bed

height, batch & continuous fluidization, Filtration, filter media, filter aids, batch and continuous filtration, filtration equipment, vacuum filter, rotary drum filters.

4 Thermodynamics

4.1 Introduction: Thermodynamic system, surroundings, state, process, properties, equilibrium, heat and work. P-V-T surface, Equations of state for ideal and real gases, Virial equation of state, van der Waals equations of state.

4.2 First Law of Thermodynamics: Energy balance, Specific heat, internal energy, enthalpy, and specific heat of ideal gases, isothermal, isobaric, isochoric, and adiabatic processes.

4.3 Second Law of Thermodynamics: Second law, reversible and irreversible processes, Carnot cycle, entropy.

4.4 Production of power from heat: Steam power plant, Rankine Cycle, Otto and Diesel engine

4.5 Refrigeration and Liquefaction: Carnot Refrigerator, Vapor-Compression Cycle, Choice of Refrigerant, Absorption Refrigeration, Heat Pump, Liquefaction Processes

4.6 Thermodynamic Properties: Two phase systems, Phase rule, Vapor/liquid equilibrium, VLE by Raoult's law, Dew point and bubble point calculations, Henty's law, Liquid-liquid equilibrium

4.7 Solutions Thermodynamics and Chemical Reaction: Fundamental property relations, Chemical potential, fugacity and fugacity coefficients, activity coefficients, Reaction coordinate, Multireaction Stoichiometry

5 Energy and Heat Transfer

5.1 Fossil fuels, Combustion and Chemical processes, Fuel calculations: Different forms of energy: renewable vs non-renewable, conventional vs non-conventional, Electrochemical cell, Water splitting, small hydro power plants, Hydrogen energy and Fuels cells, Solar energy (thermal and photovoltaic (PV) applications, Wind energy, Geothermal, Biofuels (solid, liquid and gaseous biofuels), Nuclear energy, Waste to energy, sanitary land fill, gasification.

5.2 Conduction: Fourier conduction equation, Thermal conductivity, Heat conduction equations, Composite wall structure, Insulation and its optimum thickness, Extended surfaces, Steady state heat conduction, Unsteady state conduction.

5.3 Convection: Newton's law of cooling, Heat transfer in laminar and turbulent flows inside tubes, Heat transfer by external flows across: Cylinders, tube bank and spheres, Natural convection, Convection with phase change: Boiling and condensation.

5.4 Radiation: Theories of radiation, electromagnetic spectrum, thermal radiation, spectral emissive power, surface emission, Basic equations, Emissivity, Absorption, Black and gray body, Thermal radiation between two surfaces.

5.5 Heat Exchangers: Types, constructional details and internal components and their functions, condensers, Heat exchangers: Double pipe, shell and tube, air-cooled, plate type, compact heat exchangers, Fouling of heat exchangers.

5.6 Evaporators: Classification, Single and multiple effect evaporators, Performance of evaporators: Capacity and economy, Methods of feeding.

6 Mass Transfer :

6.1 Diffusion: Steady state molecular diffusion in gases and liquids, Fick's Laws of diffusion, Correlation for diffusivity in gases and liquids for binary and multi-component systems, Diffusivity measurement and prediction, Diffusion in solids.

6.2 Mass Transfer by Convection: Concepts of molecular diffusion and mass transfer coefficient, Mass transfer coefficients in laminar flow and turbulent flow, Mass, heat

and momentum transfer analogy, Chilton-Colburn analogy, Reynolds analogy, dimensionless number, Simultaneous heat and mass transfer. Equilibrium curve, Diffusion between phases, Overall mass transfer coefficient, Two film theory in mass transfer, Steady state concurrent and counter current Process, Stages and Multistage cascade.

6.3 Distillation and Extraction: Distillation – types of distillation, Flash distillation, Batch distillation; Binary distillation; introduction to multi-component distillation. Liquid liquid extraction Principles, phase equilibrium diagrams.

6.4 Absorption and Adsorption: Introduction and principles of absorption and desorption, Equilibrium solubility of gases in liquids, isothermal and adiabatic gas liquid contact, Packings and solvent selection, Material balance in absorber, Counter-current multistage operations, Adsorption and principles of adsorption, selection criteria for adsorbent.

6.5 Crystallization and Drying: Nucleation and crystal growth, Batch crystallization, crystallization equipment; Drying Equilibria, drying rate curve and drying time.

6.6 Mass transfer equipment: Gas dispersed: bubble column, Spray tower, Tray tower, Packed tower, Continuous contact equipment, Design of absorption towers-Packed and trayed tower design. Drying equipment and selection, Cooling tower.

7 Chemical Reaction Engineering

7.1 Mole Balances: mole balance equations for batch and continuous reactors, introduction of industrial reactors, mole balance equations in terms of conversion, applications of the conversion equation for reactors, calculation of reactors in series, space time and space velocity.

7.2 Rate Laws and Stoichiometry: expression and interpretation of rate laws, reaction rate constants, expression and interpretation of rate laws, design structure for isothermal reactors, design of batch reactors, design of single CSTR and CSTRs in series, design of tubular reactors, pressure drops in reactors.

7.3 Collection and Analysis of Rate Data: the algorithm for data analysis, determination of rate law parameters by differential and integral methods, determination of rate law parameters by method of initial rates and differential reactors, yield and selectivity in multiple reactions, maximizing desired product in series reactions, algorithm for solution of complex reactions.

7.4 Reaction Mechanisms: pseudo-steady-state hypothesis, searching for a mechanism, chain reactions and reaction pathways, Enzymatic reactions and Bioreactors: - enzymatic reaction fundamentals, inhibition of enzyme reactions, bioreactors, Energy Balances for Non-isothermal Reactors: - derivation of the energy balance equations, application to adiabatic reactors, application to non-adiabatic tubular reactors, application to equilibrium reactors, application to non-adiabatic CSTR reactors, Analysis of two-dimensional non-isothermal reactors.

7.5 Catalysis and Catalytic Reactors: catalysts and steps in a catalytic reaction, reaction mechanism and synthesizing a rate law, heterogeneous data analysis, chemical vapor deposition, catalyst deactivation, Diffusion Effects on Heterogeneous Reactions: - effects of external diffusion, effects of internal diffusion, Residence Time Distributions in Chemical Reactors: - characterization and measurement of RTD, analysis of RTD in different reactors, reactor modeling with RTD.

8 Instrumentation and Process control :

8.1 Introduction to process control, Dynamic behavior of chemical processes, Controller modes (P, PI and PID), control valves.

8.2 Advanced control schemes: Feed forward, Feedback, cascade, ratio, application to equipment such as distillation-columns, reactors.

8.3 Linear Open-loop Systems: First, second and higher order systems, Linearization, Response to step, pulse, impulse and ramp inputs, Level tank U-tube manometer, Interacting and noninteracting systems, Dead time.

8.4 Linear Closed-loop systems: Controllers and final control elements, control valves, block diagram, Transient response of simple control system.

8.5 Frequency response: Frequency domain analysis, control system designed by frequency response, bode stability criteria, different methods of tuning of controllers.

8.6 Instrumentations: Classification of measuring instruments and transducers, (temperature, pressure, flow, liquid level, Moisture and humidity analysis, pH measurements).

9 Chemical Industrial Technology:

9.1 Soda ash, chlorine and caustic soda, CO_2, H_2, N_2, O_2, citric acid, Phosphoric acid (wet process), sulfuric acid, nitric acid.

9.2 Portland cements, Types, compounds in cements, setting and hardening of cements,

9.3 Manufacturing procedure of glass, Types of paints and its raw materials, Manufacture of paints and pigments.

9.4 Normal superphosphate and triple superphosphate, synthetic ammonia, urea, ammonium nitrate and sulfate, potassium chloride, potassium sulfate.

9.5 Pulp and Paper processes, sugar from cane, ethyl alcohol, vegetable oils and animal fats, soaps and detergents, Production of fibers, polyesters, and rayon.

9.6 Constituents of petroleum, crude distillation, Conversion processes, catalytic cracking, Reforming, catalytic reforming, Manufacture of ethylene and propylene, thermoplastic plastic, PE, PP, and PVC, phenol formaldehyde and epoxy resin.

10 Transport Phenomena

10.1 Introduction: Basic principles and equations of change in transport of momentum, heat and mass; Viscosity, thermal conductivity and diffusivity; Shell balance for simple situations to obtain shear stress, velocity, heat flux, temperature, mass flux and concentration distributions.

10.2 Equations of Change for isothermal and non-isothermal systems: Equations of continuity, motion, mechanical energy, angular momentum, energy, and equation of continuity for multicomponent mixture, dimensional analysis of the equation of change.

10.3 Distributions with More than One Independent Variable: Unsteady state flow, creeping flow around a sphere, flow through a rectangular channel, unsteady heat conduction in slabs with and without changing heat flux, heat conduction in laminar in compressible flow

10.4 Interphase Transport in Isothermal and Non-Isothermal Mixtures: Friction factor and heat and mass transfer coefficients, Heat and mass transfer in fluids flowing through closed conduits and packed beds

10.5 Macroscopic Balances: Momentum, heat and mass balances and their application, Cooling and heating of a liquid in stirred tank.

Written Exam Questions [Full Marks: 100, 3Hrs]

Section-A

Chapters	1	2	3	4	5	6	7	8	9	10	Total Marks
MCQ (1 marks each)	2	2	2	2	2	2	2	2	2	2	20
Short [5 marks each]	-	1	1	1	1	1	1	-	-	-	30
Long [10 marks each]	1	-	-	-	-	-	-	1		1	30

Section-B

Chapters	1	2	3	Total Marks
MCQ (1 marks each)	1	2	2	5
Short [5 marks each]	1	1	1	15