Chemical Reaction Engineering I
EC 605

Lecture : 3 **Year: III**
Tutorial : 1 **Part: I**

Course Objective:

i. Design and simulate various chemical reactors such as batch, CSTR and tubular reactors.
ii. Understand fundamentals of isothermal chemical reaction engineering and design isothermal reactors.
iii. Design reactors using numerical software such as Polymath as well as process simulator such as Aspen.

1. Mole Balances **(4 hours)**

1.1 Rate of reaction
1.2 General mole balance equation
1.3 Batch and continuous flow reactors

2. Conversion and reactor sizing **(5 hours)**

2.1 Definition of conversion
2.2 Design equations for batch and flow reactors
2.3 Reactors in series
2.4 Introduction of Polymath for problem solving

3. Rate laws and stoichiometry **(9 hours)**

3.1 Introduction of rate laws
3.2 Reaction order and rate constants
3.3 Stoichiometry of batch and flow reactors
3.4 Problem solving with Polymath

4. Isothermal reactor design **(4 hours)**

4.1 Mole balance in terms of conversion
4.2 Introduction to energy balance
4.3 Design of batch and flow isothermal reactors

5. Isothermal reactor design w Pressure change **(5 hours)**

5.1 Pressure drop in reactors
5.2 Mole balances in terms of concentration
5.3 Mole balances in terms of molar flow rate
5.4 Introduction of Aspen for reactor design

6. Collection and analysis of rate data **(9 hours)**

6.1 Algorithm for data analysis
6.2 Differential and integral method of analysis
6.3 Method of initial rates and half lives
6.4 Evaluation of laboratory reactors

7. Multiple reactions **(9 hours)**

7.1 Yield and selectivity
7.2 Maximizing desired product in multiple reactions
7.3 Algorithm for solving multiple reactions in flow reactors
7.4 Algorithm for solving multiple reactions in membrane reactors
7.5 Multiple reaction problems elucidated with the help of Polymath and Aspen Plus

References:

1. H. S. Fogler, "Elements of Chemical Reaction Engineering", Prentice Hall International.
2. O. Levenspiel, "Chemical Reaction Engineering", John Wiley & Sons.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Unit	Chapter	Topics	Marks
1	1 & 2	all	16
2	3	all	16

3	4 & 5	all	16
4	6	all	16
5	7	all	16
Total			**80**

MECHANICAL OPERATION
EC 604

Lecture : 3 **Year: III**
Tutorial : 1 **Part: I**
Practical:3

Course Objective:

i To understand particulate solid characterization, storage, and transportation of solids.
ii To understand principles of size reduction and equipment for size reduction
iii To understand solid – liquid, gas – solid and solid – solid mechanical separation processes and equipment.

1 Particles properties (6 hours)

1.1 Characterization of solid particle, Particles shape and size, Mixed particle sizes and size analysis, Number of particles in mixtures
1.2 Screen analysis, Standard screen series, Size measurement with fine particles
1.3 Properties of particulate masses, Pressures in masses of particles, Angle of internal friction and angle of repose

2 Storage and Mixing of solids (6 hours)

2.1 Bulk storage, Bin storage, Flow out of bins
2.2 Types of mixtures
2.3 Mixers for cohesive solids
2.4 Criteria of mixer effectiveness: mixing index
2.5 Mixing index in blending granular solids
2.6 Rate of mixing

3 Size Reduction (8 hours)

3.1 Comminution: principles and characterization
3.2 Crushing efficiency
3.3 Empirical Relationship: Rittinger's and Kick's Law
3.4 Bond crushing law and work index
3.5 Computer simulation of milling operations
3.6 Size Reduction Equipment, Crushers, Grinders, and Cutting machines
3.7 Open-circuit and closed-circuit operation

4 Mechanical Separation (4 hours)

4.1 Screening equipment
4.2 Comparison of ideal and actual screens
4.3 Material balances over screen
4.4 Capacity and effectiveness of screens

5 Filtration (6 hours)

5.1 Theory of solid-liquid filtration
5.2 Cake filters, filter media, filter aids
5.3 Principles of cake filtration
5.4 Pressure drop through filter cakes
5.5 Constant-pressure filtration
5.6 Constant-rate filtration
5.7 Principle of centrifugal filtration

6 Filtration equipment (4 hours)

6.1 Discontinuous pressure filters, Filter press, Shell-and-leaf filters
6.2 Continuous vacuum filters, Rotary-drum filter, Horizontal belt filter
6.3 Centrifugal filters, Suspended batch centrifuges

7 Clarifiers (2 hours)

7.1 Clarifying equipment
7.2 Principles of clarification

8 Settling (5 hours)

8.1 Gravity settling process
8.2 Gravity and sorting classifiers
8.3 Clarifiers and thickeners
8.4 Flocculation and sedimentation
8.5 Clarifier and thickener design
8.6 Centrifugal settling process: Cyclones, cyclone design

9 Agitation and mixing of liquids (4 hours)

9.1 Principles of agitation, agitation equipments
9.2 Flow pattern in agitated vessels, prevention of swirling, draft tubes
9.3 Standard turbine design
9.4 Blending and mixing

References:

1. W. L. McCabe, J. C. Smith, P. Harriott, "Unit Operations of Chemical Engineering", McGraw-Hill Inc.
2. J. M. Coulson, J. F. Richardson, "Chemical Engineering" Vol – II, and VI, Butterworth – Heinemann, Elsevier. Pergamon Press.
3. M. J. Rhodes, "Introduction to Particle Technology", Wiley.
4. R. G. Holdich. "Fundamentals of Particle Technology", Midland Information Technology & Publishing.
5. H. Rumpf, "Particle Technology", Springer Netherlands.

Practical:

1. To verify the laws of crushing and size reduction ratio in Jaw crusher. (3h)
2. Determining the critical speed of ball mill. (3h)
3. To report the result of screen analysis for the product obtained from ball mill in the form of cumulative & fractional distribution plots. (3h)
4. To determine the average diameter of a different size solid particle mixture. (3h)
5. To study the separation of fine solid dust particle from the air. (3h)
6. To find out the efficiency of magnetic separator. (3h)
7. Analyzing effect of different concentration and initial height over the sedimentation characteristics. (3h)
8. To study the batch setting & design of thickener for given under-sludge concentration. (3h)
9. To study the separation of sludge by applying centrifugal force. (3h)
10. To study batch filtration in plate & frame filter press. (3h)
11. Demonstration of various flow patterns exhibited by different types of impellers with using baffles in the mixing tank. (3h)
12. To plot power number vs Reynolds number for the given set of impeller with baffled/unbaffled mixing. (3h)

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Unit	Chapter	Topics	Marks
1	1 & 4	all	16
2	2 & 6	all	16
3	3	all	16
4	5 & 7	all	16
5	8 & 9	all	16
Total			80

THERMODYNAMICS II
EC 501

Lecture : 3 **Year: III**
Tutorial : 1 **Part: I**

Course Objective:

i Understand the theories of phase equilibria, phase diagram, and to determine the activity coefficient to modify Raoult's law in real-phase equilibria.

ii Understand the principles of chemical reaction equilibria, equilibrium constant, and learn how to determine equilibrium composition for gas and liquid phase reactions.

1 Thermodynamic Properties of Fluids (8 hours)

1.1 Property relations for homogeneous phases
1.2 Residual properties
1.3 Residual properties by equation of state
1.4 Two phase systems
1.5 Thermodynamic diagrams
1.6 Generalized property correlations for gases

2 Vapor/Liquid Equilibrium: Introduction (8 hours)

2.1 The phase rule: Duhem's theorem
2.2 VLE: qualitative behavior
2.3 Simple models for vapor/liquid equilibrium
2.4 VLE by modified Raoult's law
2.5 VLE from K-value correlations

3 Solutions Thermodynamics: Theory (8 hours)

3.1 Fundamental property relation
3.2 Chemical potential and phase equilibria
3.3 Partial properties
3.4 Ideal-gas mixture model
3.5 Fugacity and fugacity coefficient: Pure species
3.6 Fugacity and fugacity coefficient: Species in solution
3.7 Generalized correlations for the fugacity coefficient
3.8 The ideal solution model
3.9 Excess properties

4 Solutions Thermodynamics: Applications (6 hours)

4.1 Liquid-phase properties from VLE data
4.2 Models for the excess Gibbs energy
4.3 Property changes of mixing
4.4 Heat effects of mixing processes

5 Chemical Reaction Equilibria (10 hours)

5.1 The reaction coordinate
5.2 Application of equilibrium criteria to chemical reactions
5.3 The standard Gibbs energy change and the equilibrium constant
5.4 Effect of temperature on the equilibrium constant
5.5 Evaluation of equilibrium constant
5.6 Relation to equilibrium constants to composition
5.7 Equilibrium conversions for single reactions
5.8 Phase rule and Duhem's theorem for reacting systems
5.9 Multireaction equilibria

6 Topics in phase equilibria (5 hours)

6.1 Equilibrium and stability

6.2 Liquid/liquid equilibrium

6.3 Solid/liquid equilibrium

References:

1. J. M. Smith, H. C. Van Ness, M. M. Abbott, "Chemical Engineering Thermodynamics," McGraw-Hill International Edition.
2. Y. A. Cengel, M. A. Boles, "Thermodynamics: An Engineering Approach", McGraw-Hill.
3. T. E. Daubert, "Chemical Engineering Thermodynamics", McGraw-Hill Book Company.
4. S. I. Sandler, "Chemical and Engineering Thermodynamics", John Wiley and Sons, Inc.
5. B. G. Kyle, "Chemical and Process Thermodynamics", Prentice Hall.
6. M. D. Koretsky, "Engineering and Chemical Thermodynamics", Wiley.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Unit	Chapter	Topics	Marks
1	1	all	16
2	2	all	16
3	3	all	16
4	4 & 6	all	16
5	5	all	16
Total			80

CHEMICAL PROCESS INDUSTRIES II
EC 603

Lecture : 3 **Year: III**
Tutorial : 1 **Part: I**

Course Objective:

i. Understand major industrial manufacturing processes of organic chemicals.
ii. Learn flowsheeting of processes.

1 Natural product processing **(8 hours)**

1.1 Historical, uses and economics
1.2 Manufacturing procedure of pulp, pulping processes, recovery of the black liquor
1.3 Manufacturing procedure of paper
1.4 Manufacture procedure of sugar from cane, cane sugar refining
1.5 Manufacture of starch
1.6 Gasification of coal and chemicals from coal

2 Industrial microbial processes and edible oils **(6 hours)**

2.1 Historical, uses and economics
2.2 Manufacture procedure of ethyl alcohol
2.3 Manufacture procedure of citric acid
2.4 Extraction and processing of vegetable oils, and animal fats

3 Soaps and detergents **(4 hours)**

3.1 Historical, uses and economics
3.2 Manufacture procedure of soap and toilet bar soap, glycerine removal
3.3 Manufacture procedure of detergent

4 Petroleum refining **(8 hours)**

4.1 Historical, uses and economics
4.2 Exploration, constituents of petroleum
4.3 Refinery processes, crude distillation
4.4 Conversion processes, catalytic cracking
4.5 Reforming, catalytic reforming

5 Petrochemical industries **(4 hours)**

5.1 Historical, uses and economics
5.2 Precursors of petrochemicals
5.3 Manufacture of ethylene and propylene

6 Polymer based Industries **(7 hours)**

6.1 Historical, uses and economics
6.2 Engineering plastics
6.3 Classification of polymers and commercial resins
6.4 Production of thermoplastic plastic, polyethylene, polypropylene, and polyvinyl chloride
6.5 Production of resins, phenol formaldehyde, urea formaldehyde, melamine formaldehyde, and epoxy resin

7 Fiber and rubber industries **(4 hours)**

7.1 Historical, uses and economics
7.2 Classification of synthetic fiber and rubber
7.3 Production of fibers, polyamides, polyesters, and rayon
7.4 Production of styrene butadiene rubber (SBR)

8 Dyes and Pesticides **(4 hours)**

8.1 Classification of dyes and pesticides
8.2 Manufacture of dyes
8.3 Characteristics of pesticides, biopesticides

References:

1. G. T. Austin, "Shreve's Chemical Process Industries", Mc Graw Hill Book Co., New York.
2. S. D. Shukla, G. N. Pandey, "Text book of Chemical Technology", Vol 1 – II, Vikas Publishing, India.
3. R. Gopal and M. Sittig, "Dryden's Outline of Chemical Technology: For The 21st Century", Affiliated East – West Publishers.
4. W. V. Mark, S. C. Bhatia, "Chemical Process Industries Vol I – II", CBS Publishers & Distributors Pvt. Ltd.
5. E. R. Riegel, J. A. Kent, "Riegel's Handbook of Industrial Chemistry", Springer Science & Business Media.
6. K. Othmer, "Encyclopedia of Chemical Technology", Wiley Interscience: New York, Inter Science Publishers.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Unit	Chapter	Topics	Marks
1	1	all	**16**
2	2 & 5	all	**16**
3	3 & 7	all	**16**
4	4	all	**16**
5	6 & 8	all	**16**
Total			**80**

Mass Transfer I
EC 602

Lecture: 3 **Year: III**
Tutorial: 1 **Part: I**
Practical: 3

Course Objectives:

i. Demonstrate effective approaches to solving 1D/2D mass transfer problems by hand and by using computing tools such as Python or Matlab and process simulation tools like Aspen Plus.
ii. Apply mass balance equations and rate laws to solve diffusion and convection mass transfer problems
iii. Design packed or plate columns for mass transfer processes such as absorption/desorption and distillation.

1 Mass transfer by diffusion (8 hours)

1.1 Fick's law
1.2 Mass transfer in nonstationary media
1.3 Stationary medium approximation
1.4 Conservation of species for a stationary medium
1.5 Mass diffusion with chemical reactions

2 Mass transfer by convection (6 hours)

2.1 Heat and mass analogy: Chilton-Colburn analogy, Reynolds analogy, dimensionless numbers
2.2 Introduction to mass transfer coefficients, boundary layer equations, laminar and turbulent flow
2.3 Film theories: film, boundary layer, penetration, two film

3 Gas Absorption (8 hours)

3.1 Introduction to absorption and desorption
3.2 Packings and solvent selection
3.3 Packed and trayed tower design
3.4 Principles of absorption and desorption
3.5 Mass transfer correlations
3.6 Reactive mass transfer elucidated with Aspen Plus

4 Humidification Operations (6 hours)

4.1 Humidity terminologies and humidity chart
4.2 Wet bulb and dry bulb temperatures
4.3 Cooling tower fundamentals

5 Equilibrium Stage Operations (4 hours)

5.1 Equipment for stage contacts
5.2 Principles for stage processes

6 Distillation (8 hours)

6.1 Flash distillation
6.2 Continuous distillation with reflux: material balances in plate columns, number of ideal plates, McCabe-Thiele Method
6.3 Design of sieve plate columns, plate efficiencies
6.4 Azeotropic and extractive distillation
6.5 Distillation elucidated with Aspen Plus

7 Multicomponent Distillation (5 hours)

7.1 Introduction to multicomponent distillation
7.2 Multicomponent phase equilibria & flash distillation
7.3 Multicomponent distillation process elucidated with Aspen Plus

Practical:

1. Study the operation of sieve plate distillation column to obtain a desired separation of an alcohol water feed product.
2. Study extraction of benzoic acid from toluene by water in a packed bed to understand concepts of liquid- liquid extraction.
3. To determine the diffusion coefficient of a gas by evaporation from a liquid surface.

4. Study the basic principles of absorption of gas into a liquid using a packed column.
5. Determine the surface area (adsorption area) of activated charcoal catalyst
6. Study the drying rate curves for drying a wet solid with air of fixed temperature and humidity.
7. Determination of drying curves to assess the feasibility of fluidised bed drying of a material.
8. Study the heat and mass transfer processes in cooling tower for different flow and thermodynamic conditions.
9. Study the crystallization process.
10. To study the fundamental of solid-liquid extraction process.
11. To determine the exchange capacity and regeneration efficiency of a cationic and anionic resins in the softening of water.

References:

1. W. L. McCabe, J. C. Smith, P. Harriott, "Unit Operations of Chemical Engineering", McGraw Hill Education Private Limited.
2. R. E. Treybal, "Mass Transfer Operations", McGraw Hill Education Private Limited.
3. J. D. Seader, E. J. Henley, D. K. Roper, "Separation Process Principles", John Wiley & Sons, Inc.
4. F. P. Incropera, D. P. DeWitt, T. L. Bergman, A. S. Lavine, "Incropera's Principles of Heat and Mass Transfer", John Wiley & Sons.
5. Y. A. Cengel, A. J. Ghajar, "Heat and Mass Transfer: Fundamentals and Applications", McGraw Hill Education Private Limited.

Evaluation Scheme:

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as follows:

Unit	Chapter	Topics	Marks
1	1	all	**16**
2	3	all	**16**
3	4 & 5	all	**16**
4	6	all	**16**
5	2 & 7	all	**16**
Total			**80**

PROBABILITY AND STATISTICS
SH 552

Lecture : 3 **Year : II**
Tutorial : 1 **Part : II**
Practical : 0

Course Objective:

To provide students practical knowledge of the principles and concept of probability and statistics and their application in engineering field.

1. Descriptive statistics and Basic probability (6 hours)
- 1.1. Introduction to statistics and its importance in engineering
- 1.2. Describing data with graphs (bar, pie, line diagram, box plot)
- 1.3. Describing data with numerical measure(Measuring center, Measuring variability)
- 1.4. Basic probability, additive Law, Multiplicative law, Baye's theorem.

2. Discrete Probability Distributions (6 hours)
- 2.1. Discrete random variable
- 2.2. Binomial Probability distribution
- 2.3. Negative Binomial distribution
- 2.4. Poison distribution
- 2.5. Hyper geometric distribution

3. Continuous Probability Distributions (6 hours)
- 3.1. Continuous random variable and probability densities
- 3.2. Normal distribution
- 3.3. Gama distribution
- 3.4. Chi square distribution

4. Sampling Distribution (5 hours)
- 4.1. Population and sample
- 4.2. Central limit theorem
- 4.3. Sampling distribution of sample mean
- 4.4. Sampling distribution of sampling proportion

5. Inference Concerning Mean (6 hours)
- 5.1. Point estimation and interval estimation
- 5.2. Test of Hypothesis
- 5.3. Hypothesis test concerning One mean
- 5.4. Hypothesis test concerning two mean
- 5.5. One way ANOVA

6. Inference concerning Proportion (6 hours)
- 6.1. Estimation of Proportions
- 6.2. Hypothesis concerning one proportion
- 6.3. Hypothesis concerning two proportion
- 6.4. Chi square test of Independence

7. Correlation and Regression (6 hours)
- 7.1. Correlation
- 7.2. Least square method
- 7.3. An analysis of variance of Linear Regression model
- 7.4. Inference concerning Least square method
- 7.5. Multiple correlation and regression

8. Application of computer on statistical data computing (4 hours)
- 8.1. Application of computer in computing statistical problem. eq scientific calculator, EXCEL, SPSS , Matlab etc

References:

1. Richard A. Johnson, "Probability and Statistics for Engineers", Miller and Freund's publication.
2. Jay L. Devore, "Probability and Statistics for Engineering and the Sciences" , Brooks/Cole publishing Company, Monterey, California.
3. Richard I. Levin, David S Rubin, " Statistics For Management", Prentice Hall publication.
4. Mendenhall Beaver Beaver, " Introduction Probability and statistics ", Thomson Brooks/Cole.

Evaluation scheme

The questions will cover all the chapters of the syllabus. The evaluation scheme will be as indicated in the table below:

Unit	Chapter	Topics	Marks
1	1	all	16
	2	2.1 to 2.2	
2	2	2.3 & 2.5	16
	3	all	
3	4 & 5	all	16
4	6	all	16
	7	7.1 and 7.5	
5	7	7.2 to 7.4	16
	8	all	
Total			80