DEPARTMENT OF CHEMICAL ENGINEERING
B.Tech (Chemical Engineering)
COURSE STRUCTURE

B.Tech. 5th Semester

Code	Name of the Subject	L	T	P	C
HS 3405	Engineering Economics and Project Management	3	1	-	4
CHEM 3412	Chemical Reactor Theory	3	1	-	4
CHEM 3413	Chemical Technology	3	1	-	4
CHEM 3414	Principles of Mass Transfer	3	1	-	4
CHEM 3415	Process Dynamics & Control	3	1	-	4
CHEM 3416	Chemical Technology Lab	-	-	3	2
CHEM 3217	Computer Applications in Chemical Engg (CACE) Lab	-	-	3	2
CHEM 3218	Process Dynamics & Control Lab	-	-	3	2
Total		**15**	**5**	**09**	**26**

B.Tech. 6th Semester

Code	Name of the Subject	L	T	P	C
CHEM 3419	Applications of Mass Transfer	3	1	-	4
CHEM 3420	Chemical & Catalytic Reaction Engineering	3	1	-	4
CHEM 3421	Petroleum Refining and Petrochemicals	3	1	-	4
Elective-1		3	1	-	4
CHEM 3422	Clean Process Technologies				
CHEM 3423	Fertilizer Technology				
CHEM 3424	Polymer Technology				
Elective - II (Open Elective)		3	1	-	4
IT 3418	Cloud Computing (IT)				
CE3428	Disaster Management (Civil)				
ECE 3425	Fundamentals of Global Positioning System (ECE)				
CHEM 3425	Industrial Safety and Hazards Management (Chem.)				
ME 3431	Operations Research (Mech.)				
EEE 3427	Renewable Energy Resources(EEE)				
CSE 3416	Soft Computing (CSE)				

CHEM 3226	Chemical Reaction Engineering Lab	-	-	3	2
CHEM 3227	Mass Transfer Operations Lab	-	-	3	2
GMR 30206	Term Paper	-	-	-	2
GMR 30001	Audit Course	-	-	-	-
		15	**5**	**06**	**26**

Department of Chemical Engineering

B.Tech (CHEM)- 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: Engineering Economics and Project Management Subject code: **HS 3405**

L	T	P	C
3	1	0	4

Course Objectives:
The course content enables students to:

1. To acquaint the basic concepts of Engineering Economics and its application
2. To know various methods available for evaluating the investment proposals
3. To gain the relevant knowledge in the field of management theory and practice
4. To understand the project management lifecycle and be knowledgeable on the various phases from project initiation through closure

Course Outcomes:
At the end of the course students are able to:

1. Understand basic principles of engineering economics.
2. Evaluate investment proposals through various capital budgeting methods.
3. Analyze key issues of organization, management and administration.
4. Evaluate project for accurate cost estimates and plan future activities.

UNIT-I:
Introduction to Engineering Economics: **10 + 3***
Concept of Engineering Economics – Types of efficiency – Theory of Demand - Elasticity of demand-Supply and law of Supply – Indifference Curves.

Demand Forecasting & Cost Estimation:
Meaning – Factors governing Demand Forecasting – Methods – Cost Concepts – Elements of Cost – Break Even Analysis.

UNIT-II
Investment Decisions & Market Structures: **11 +6***
Time Value of Money – Capital Budgeting Techniques - Types of Markets – Features – Price Out-put determination under Perfect Competition, Monopoly, Monopolistic and Oligopoly

Financial Statements & Ratio Analysis:
Introduction to Financial Accounting - Double-entry system – Journal – Ledger - Trail Balance – Final Accounts (with simple adjustments) – Ratio Analysis (Simple problems).

UNIT-III

Introduction to Management: **12 + 2***

Concepts of Management – Nature, Importance – Functions of Management, Levels - Evolution of Management Thought – Decision Making Process - Methods of Production (Job, Batch and Mass Production) - Inventory Control, Objectives, Functions – Analysis of Inventory – EOQ.

UNIT-IV

Project Management: **12 +4***

Introduction – Project Life Cycle – Role Project Manager - Project Selection – Technical Feasibility – Project Financing – Project Control and Scheduling through Networks - Probabilistic Models – Time-Cost Relationship (Crashing) – Human Aspects in Project Management.

Text Books:

1. Fundamentals of Engineering Economics by Pravin Kumar, Wiley India Pvt. Ltd. New Delhi, 2012.
2. Project Management by Rajeev M Gupta, PHI Learning Pvt. Ltd. New Delhi, 2011.

Reference Books:

1. Engineering economics by PanneerSelvam, R, Prentice Hall of India, New Delhi, 2013.
2. Engineering Economics and Financial Accounting (ASCENT Series) by A. Aryasri&Ramana Murthy, McGraw Hill, 2004.
3. Project Management by R.B.Khanna, PHI Learning Pvt. Ltd. New Delhi, 2011.
4. Project Management by R. PanneerSelvam&P.Senthil Kumar, PHI Learning Pvt. Ltd. New Delhi, 2009.
5. Management Science by A.Aryasri, Tata McGraw Hill, 2013
6. Koontz & Weihrich: Essentials of Management, 6/e, TMH, 2007

Department of Chemical Engineering

B.Tech (CHEM)- 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Chemical Reactor Theory**

Subject code: **CHEM 3412**

L	T	P	C
3	1	0	4

Course Objectives:

1. The emphasis of this course is on the fundamentals of chemical reaction kinetics and chemical reactor operation.
2. Heat transfer, mass transfer, thermodynamics and chemical kinetics all play an important role in chemical reactor analysis and design and will be discussed in detail.
3. The overall goal of this course is to develop a critical approach toward understanding complex reaction systems and elucidating chemical reactor design.
4. Integrate concepts from science & engineering to constitute a basis for the design of chemical reactor, a key element in the design of chemical process.

Course outcomes:

At the end of the course, the student will be able to:

1. Analyze and interpret experimental data from batch reactors and determine the order of simple chemical reactions.
2. Compare ideal reactor types (batch, CSTR and PFR) and apply quantitative methods to design and size reactors for simple chemical reaction schemes.
3. Determine optimal ideal reactor design for multiple reactions for yield or selectivity.
4. Predict reactor performance for reactors when the temperature is not uniform within the reactor.

UNIT- I: KINETICS OF HOMOGENEOUS REACTIONS 12Hrs

Classification of reactions, Rate equations of elementary and non-elementary reactions, variables affecting the rate of reaction, reaction rate constant, reaction order and molecularity, reversible reactions, non-elementary reactions; Concentration dependent term of rate equation, Temperature dependent term of rate equation, predictability of reaction rate from theory.

UNIT-II: INTERPRETATION OF BATCH REACTOR DATA 18Hrs

Constant and variable volume reaction systems, integral and differential methods of kinetic analysis, half-lives, fractional life method – general procedure, irreversible unimolecular type first order, bimolecular type second order, and trimolecular type third order reactions, empirical reactions of n^{th} order, zero-order reactions, overall order of irreversible reactions, irreversible reactions in series and parallel, Analysis of total pressure data obtained in a constant-volume system, First and second order reversible reactions, reactions of shifting order, Biochemical Reaction systems (Enzymatic reactions); Non-elementary Homogeneous Reactions - reaction mechanisms, pseudo-steady state hypothesis, and search for a rate equation.

UNIT- III: ISOTHERMAL REACTOR DESIGN 12Hrs

Ideal reactors for a single reaction - Ideal batch reactor, Steady-state mixed flow reactor, Steady-state plug flow reactors; Design for single reactions - Size comparison of single reactors, Multiple reactor systems, Recycle reactor, Autocatalytic reactions.

UNIT IV: DESIGN FOR MULTIPLE REACTIONS AND TEMPERATURE & PRESSURE EFFECTS 18 Hrs

Introduction to multiple reactions, qualitative discussion and quantitative treatment of product distribution and of reactor size, Irreversible first order reactions in series, quantitative discussion about product distribution, quantitative treatment - plug flow or batch reactor, mixed flow reactor, first-order followed by zero order reaction, zero order followed by first order reaction.

Non-isothermal operation of reactors: Optimum temperature progression; Adiabatic and non-adiabatic batch, mixed flow and plug flow reactors; Exothermic reactions in mixed flow reactors; Multiple reactions: Yield and selectivity.

Text Books:

1. O. Levenspiel, Chemical Reaction Engineering, 3rd ed. John Wiley & Sons, 2007.

Reference Books:

1. H. S. Fogler, Elements of Chemical Reaction Engineering, 4th ed., PHI, 2005.
2. K A Gavhane, Chemical Reaction Engineering – I, Nirali Prakashan, 2004.
3. K.G. Denbigh, J.C.R Turner, Chemical Reactor Theory: An introduction, Cambridge University Press, 3rd ed., 1984.

B.Tech (CHEM)- 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Chemical Technology** Subject code: **CHEM 3413**

L	T	P	C
3	1	0	4

Course Objectives:

The course enables to:

- Understand the schematic representation of important unit operation/ unit processes involved in plant operations.
- Develop skills in preparing /presenting a neat Engineering drawing for Chemical Process Industries such as chloro-alkali industries, Pulp, Paper, and Fermentation Industries.
- Impart clear description of one latest process along with its Chemistry, Process parameters, Engineering Problems and Optimum Conditions.
- Demonstrate the importance of updating the latest technological developments in producing products economically and environment friendly.
- Appreciate the usage of other engineering principles such as Thermodynamics, Heat, mass and momentum transfer in operation and maintain the productivity.

Course outcomes:

Upon successful completion of the course the students will be able to:

1. Make a neat and easy to understand the plant process flow sheet.
2. Keeps up the productivity while maintaining all safety norms stipulated, during their job.
3. Solve Engineering problems that are likely to come across during the operation of plants.
4. Suggest alternative manufacturing process in terms of Economic viability of the product.

UNIT-I **18 Hrs**

Schematic representation of Unit operations and Unit processes, Soda ash, Caustic soda, Chlorine, Industrial gases: Hydrogen , Oxygen, Nitrogen industries: Synthetic ammonia, Urea and Nitric acid.

UNIT –II **14 Hrs**

Sulfur and sulfuric acid, manufacture of glass, manufacture of Cements, Special cements,

UNIT –III **14 Hrs**

Manufacture of Phenol, formaldehyde, phenol-formaldehyde resin, SBR

Oils: expression and extraction of vegetable oils, hydrogenation of oils, Ethanol by fermentation

UNIT –IV **14 Hrs**

Soaps: continuous process for productions of fatty acids, glycerin, and soap, Pulp & Paper industry: production of pulp by sulfate, sulfite process, black liquor recovery and production of paper by wet process,

TEXT BOOKS:

1. George T Austin, Shreve's Chemical Process Industries - International Student Ed., 5th ed., McGraw Hill Inc., 1998.
2. Sittig M. and Gopala Rao M., Dryden's Outlines of Chemical Technology for the 21st Century, 3rd ed., WEP East West Press, 2010.

REFERENCE BOOKS:

1. Sharma, B.K., Industrial Chemistry, Goel Publishing House, Meerut, 1997.

Department of Chemical Engineering

B.Tech (CHEM)- 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Principles of Mass Transfer** Subject code: **CHEM 3414**

L	T	P	C
3	1	0	4

Course Objectives: The course content enables the students

1. To discuss the fundamental concepts of mass transfer principles and to apply those concepts to real engineering problems.
2. Applies the concepts of diffusion mass transfer, mass transfer coefficients, convective mass transfer, inter-phase mass transfer, equipment for gas-liquid operations.

Course outcome(s):

At the end of the course students will be able to:

1. Recognize the various modes of mass transfer, Determine mass transfer rates using Fick's Law
2. Estimate diffusion coefficients, Solve unsteady state diffusion problems
3. Determine convective mass transfer rates & mass transfer coefficients
4. Determine the number of transfer units and height requirements for a packed column
5. Differentiate various membrane processes and their applications

UNIT- I: (Introduction to Mass Transfer Operations & Molecular Diffusion) 15 Hrs

Introduction to Mass Transfer Operations: Classification of the Mass-Transfer Operations

Molecular Diffusion In Fluids: Molecular Diffusion, Equation of Continuity, binary solutions, Steady State Molecular Diffusion in Fluids at Rest and in Laminar Flow, estimation of diffusivity of gases and liquids, Molecular Diffusion In solids: Diffusion in Solids, Fick's Diffusion, Unsteady State Diffusion, Types of Solid Diffusion, diffusion through polymers, diffusion through crystalline solids, Diffusion through porous solids & hydrodynamic flow of gases

UNIT-II: (Mass Transfer Coefficients & Inter Phase Mass Transfer) 15 Hrs

Mass Transfer Coefficients: Mass Transfer Coefficients in Laminar Flow (Explanation of equations only and no derivation), Mass Transfer Coefficients in Turbulent Flow, eddy diffusion, Film Theory, Penetration theory, Surface-renewal Theory, Combination Film-Surface-renewal theory, Surface-Stretch Theory, Mass, Heat and Momentum Transfer Analogies, Turbulent Flow in Circular Pipes. Mass transfer data for simple situations.

Inter Phase Mass Transfer: Concept of Equilibrium, Diffusion between Phases, Material Balances in steady state co-current and counter current stage processes, Stages, Cascades, Kremser – Brown equation.

UNIT- III: (Equipment for Gas-Liquid Operations) 15 Hrs

Equipment for Gas-Liquid Operations:

Gas dispersed - sparged vessels (bubble columns), mechanical agitated equipments, tray towers - general characteristics, sieve tray design for absorption and distillation, different types of tray efficiencies.

Liquid dispersed - venturi scrubbers, wetted-wall towers, packed towers - counter current flow of liquid & gas, mass transfer coefficients, end effects and axial mixing, design of packed column- HTU concept, tray towers vs packed towers.

UNIT- IV: (Membrane Separation Processes) 15 Hrs

Membrane Separation Processes (qualitative treatment only): Basic principles of membrane separation, classification of membrane processes – pressure driven, concentration gradient driven, electric potential driven processes – brief introduction on reverse osmosis, nanofiltration, ultrafiltration, microfiltration, pervaporation, dialysis, membrane extraction, electrodialysis. Types of synthetic membranes – microporous, asymmetric, thin-film composite, electrically charged and inorganic membranes. Membrane modules - industrial applications

TEXT BOOKS:

1. Mass transfer operations by R.E. Treybal, 3rd ed., McGraw Hill, 1980.
2. Membrane Separation Processes, Kaushik Nath, PHI, 2008

REFERENCE BOOKS:

1. Unit Operations of Chemical Engineering, W.L. McCabe, J.C. Smith & Peter Harriott, McGraw-Hill, 6th Edition, 2001
2. Principles of Mass Transfer and Separation Processes, Binay K. Datta, PHI Learning Pvt. Ltd., 2009.
3. Equilibrium Staged Separations, Phillip C.Wankat, Prentice-Hall PTR, 1988.

Department of Chemical Engineering

B.Tech (CHEM)- 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Process Dynamics & Control** Subject code: **CHEM 3415**

L	T	P	C
3	1	0	4

Course objectives:

1. Ability to develop mathematical and transfer function models for dynamic processes.
2. Ability to analyze process stability and dynamic responses.
3. Ability to empirically determine process dynamics for step response data.
4. Familiarity with different types of PID feedback controllers.
5. Ability to read block diagrams and process and instrumentation diagrams.
6. Ability to understand feed forward control, cascade control and Smith predictors and their applications.
7. Knowledge of real time applications of process control implementation.

Course outcomes:

At the end of the course, students will be able to:

1. Solve simple linear differential equations using Laplace transforms
2. Linearize nonlinear differential equations
3. Identify, formulate, and solve linear chemical process dynamics problems,
4. Develop dynamic mass and energy balance equations
5. Design a control system to meet desired needs for a given process
6. Analyze stability of transfer functions
7. Develop and analyze a feedback control schemes
8. Familiarize with advanced control strategies like cascade, smith predictor, feed forward control to implement in operating decisions through DCS

UNIT-I **15Hrs**

Introductory Concepts of Process Control- Introduction , An Industrial Perspective of a Typical Process Control Problem, Process Variables, The Concept of a Process Control System, Overview of Control System Design

Introduction to Control System Implementation- Evolution of control system implementation, Elements of a digital computer Control System, Transducers for Data Acquisition and Control, final control elements - Control valves, Modes of Computer Control - direct digital control, elements of a distributed control system network

UNIT-II **15Hrs**

Tools of Dynamic Analysis -Formulating Process Models, The Concept of a Transfer Function Laplace Transform-Domain Models, Linearization

Dynamic Behavior of Linear Low Order-Systems First Order Systems Response of First-Order Systems to step and impulse Inputs, Pure Gain Systems Pure Capacity Systems

Dynamic Behavior of Linear Higher Order Systems Two First-Order Systems in Series Second-Order Systems, Response of Second-Order Systems to step and impulse Inputs, *N* First-Order Systems in Series

UNIT-III **15Hrs**

Control systems analysis - Properties of Closed-loop transfer functions. Properties of Block diagram, Choice of controller type P, PI, PD, PID. Specifications and performance criteria

Controller tuning Tune PID controllers using the classical, Ziegler-Nichols, and Cohen-Coon methods

UNIT-IV **15Hrs**

Stability of a dynamic process Analysis Definitions of Stability, Routh-Hurwitz's stability criterion, Routh test, root locus

Frequency Response Analysis The frequency response for a stable system, Graphical frequency-response representation, bode stability criterion, bode plots, Stability margins

Process Applications Cascade Control, Feed-Forward Control, Ratio Control, Selective and Override Control, Split-Range Control, control of distillation towers and heat exchangers

Textbooks

1. Process System Analysis and Control, 3rd ed., Donald R.Coughnowr, McGraw-Hill Inc., 2013.

Reference Books:

1. George Stephanopoulos, Chemical Process Control: An Introduction to Theory & Practice, Prentice - Hall of India Pvt. Ltd., New Delhi, 1993.
2. Duncan A. Mellichamp, Dale Seborg, Thomas F. Edgar, Process Dynamics and Control Francis Doyle, John Wiley & Sons Inc, 3rd ed., 2010,
3. Carlos A. Smith and Armando B. Corripio, Principles and Practice of Automatic Process Control, John Wiley & Sons, New York, 1985.

Department of Chemical Engineering

B.Tech (CHEM)- 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Chemical Technology lab** Subject code: **CHEM 3216**

L	T	P	C
0	0	3	2

Course Objectives:

1. Introduce the fundamental principles of chemistry lab experiments to students which include analysis of oils, urea glucose, and sucrose.
2. Enable student to become skilled at and in conducting analysis using chromatographic and spectrophotometers.
3. Offers understanding of the water analysis& how to carry out some of the important characteristics of water analysis required for engineering industry.
4. Make the students aware of basic safety considerations during handling of chemicals, glass ware usage, instruments used in analysis, production activities.

Course Outcomes:

At the end of the course, the students will be able to:

1. Handle different analytical apparatus and learn the skill in using chromatographic and spectrophotometers for analysis.
2. Conduct experimental procedure for manufacture of soap, Organic chemicals: nitrobenzene, acetanilide, methyl orange, aspirin.
3. Learn the desirable limits of various constituents in water analysis and its importance.
4. Handle modern instruments like ion selective electrodes for fluoride and chloride ion-determination.

The student should perform minimum of 11 experiments, choosing at least one from the following group.

1. Preparation of Industrial Chemicals :
   a. nitrobenzene,
   b. acetanilide,
   c. methyl orange,

d. aspirin.

2. Estimation of Organic compounds, using chemical methods

a. formaldehyde,

b. urea,

c. glucose and

d. sucrose.

3. Solvent extraction of oil

4. Analysis of oils and fats:

a. acid value,

b. saponification value and

c. iodine value

5. Estimation of hydroxyl groups in alcohols and phenols

6. Physico-chemical methods of analysis

a. Separation and estimation of anionic mixture by Ion chromatographic method

b. Estimation of finished product: paracetamol by spectro-photometric method

7. Analysis of Raw material/finished product:

a. limestone,

b. Soda ash and

c. fertilizers.

8. Soap manufacture

Department of Chemical Engineering

B.Tech (CHEM) - 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Computer Applications in Chemical Engg. (CACE) Lab** Subject code: **CHEM 3217**

L	T	P	C
0	0	3	2

Objectives:

- To familiarize students with basic programming skills required for solving chemical engineering problems.
- To analyze the data obtained from simulation with theoritcal concepts.
- To compare different thermodynamic property estimation methods and analysing the results.
- To familiarize students with fundamental applications of chemical engineering in ASPEN PLUS.

Outcomes:

At the end of the laboratory course, the students will be able to:

1. Develop basic programming skills required to solve chemical engineering problems.
2. Make comparison of different thermodynamic property estimation methods .
3. Use ASPEN PLUS for solving basic material balance problems.
4. Analyze the results from simulation with that obtained from basic theory.

Following problems are to be solved in EXCEL/C/MATLAB

1. Solving Equation of State
2. Property Estimation for a Given Compound
3. Mass Balances Without Recycle Streams
4. Mass Balances With Recycle Streams
5. Bubble Point Calculations
6. Dew Point Calculations

Following problems are to be solved in ASPEN PLUS

7. Simulation of a Mixer
8. Simulation of a flow splitter
9. Simulation of a Gravity Flow tank
10. T-x-y diagram of a binary mixture using ASPEN PLUS
11. P-x-y diagram of a binary mixture using ASPEN PLUS
12. Solving material balances using ASPEN PLUS

Department of Chemical Engineering

B.Tech (CHEM)- 5th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Process Dynamics & Control Lab** Subject code: **CHEM 3218**

L	T	P	C
0	0	3	2

Course Objectives:

1. To understand the dynamic behavior of the systems
2. To evaluate response of fist and higher order characteristics.
3. Study the installed characteristics of the valve.
4. Study if there is a hysteresis in the control valve and sensor.
5. Evaluate the tuning of a PID control via manual and automatic tuning.
6. Evaluate the effect controller on the control system

Course Outcomes:

At the end of the course, the students will be able to:

1. Estimate the dynamic behavior of the control systems
2. Understand the controllability, speed of response the control systems.
3. Select proper control valve to meet process needs.
4. Understand direct digital control systems handling and operation.
5. tuning of a PID control via manual and automatic tuning.
6. choose PID modes that effect controllability, speed of response the control systems

Experiments: (Students would perform any 12 experiments out of the following 16 experiments)

1. Study of step response of Mercury-in-Glass thermometer
2. Study of control valve flow coefficient
3. Study of installed characteristics of control valve
4. Study of hysteresis of control valve
5. Study of step response of manometer

6. Step response of first order systems arranged in non- interacting mode
7. Step response of first order systems arranged in interacting mode
8. To study impulse response of first order systems arranged in non-interacting mode
9. To study impulse response of first order systems arranged in interacting mode
10. Step response of single capacity system
11. Study of open loop response control system
12. Study of response of Temperature controller with proportional integral derivative controller mode
13. Study of response of Level controller with proportional integral controller mode
14. Study of response of pressure controller with proportional integral derivative controller
15. Study of response of Flow controller with proportional controller mode
16. Closed loop method Tuning of cascade controllers

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: Applications of Mass Transfer Subject code: **CHEM 3419**

L	T	P	C
3	1	0	4

COURSE OBJECTIVES: This course deals with:

1. Various chemical engineering separation processes
2. Design of equilibrium-based multistage separations such as absorption, extraction and leaching.
3. Design of distillation column using McCabe-Thiele and Ponchon-Savarit methods.
4. Principles and applications of Fluid –solid separation processes (drying and adsorption).

COURSE OUTCOME(S):

At the end of the course students will be able to:

1. Describe and differentiate various separation processes
2. Design multistage separation systems for specific operations involving absorption, extraction, leaching, drying and adsorption.
3. Construct McCabe-Thiele, Ponchon-Savarit diagrams for distillation
4. Construct triangular diagrams for multiple contact or counter current liquid-liquid extraction
5. Analyze and design constant rate drying systems

UNIT- I: **15Hrs**

Humidification Operations: Vapor pressure curve, definitions, psychometric charts, enthalpy of gas-vapor mixtures, humidification and dehumidification, operating lines and design of packed humidifiers, dehumidifiers and cooling towers, spray chambers.

Absorption and Stripping: Absorption equilibrium, ideal and non ideal solutions selection of a solvent for absorption, one component transferred: material balances. Determination of number of plates (graphical), absorption Factor, estimation of number of plates by Kremser Brown equation.

UNIT- II **15Hrs**

Distillation: Fields of applications, VLE for miscible liquids, immiscible liquids, steam distillation, Positive and negative deviations from ideality, enthalpy-concentration diagrams, Flash vaporization and differential distillation for binary mixtures.

Continuous rectification-binary systems, multistage tray towers–method of McCabe and Thiele and Ponchon and Savarit method, enriching section, exhausting section, feed introduction, total reflux, minimum and optimum reflux ratios, use of steam, condensers, partial condensers, cold reflux, tray efficiencies, Azeotropic distillation, extractive distillation, comparison of azeotropic and extractive distillation.

UNIT- III: **15Hrs**

Extraction: fields of usefulness, liquid-liquid equilibrium, equilateral triangular co-ordinates, choice of solvent, stage wise contact, multistage cross-current extraction, Multi stage counter current without reflux- multi stage counter current with reflux.

Extraction Equipment: Differential (continuous contact) extractors, spray towers, packed towers, mechanically agitated counter-current extractors, centrifugal extractors

Leaching: Fields of applications, preparation of solid for leaching, types of leaching, leaching equilibrium, single stage and multi stage leaching calculations, constant under flow conditions, equipment for leaching operation.

UNIT-IV: **15Hrs**

Drying: Equilibrium, definitions, drying conditions- rate of batch drying under constant drying conditions, mechanisms of batch drying, drying time through circulation drying.

Batch and continuous drying equipment, material and energy balances of continuous driers, rate of drying for continuous direct heat driers

Adsorption: adsorption equilibrium- single gases and vapors, vapor and gas mixtures- one component adsorbed, Liquids- adsorption of solute from dilute solution, the Freundlich equation, adsorption operations- stage wise operation, application of Freundlich equation to single and multistage adsorption (cross current & counter current). Adsorption of vapor from a gas - fluidized bed, continuous contact, unsteady state–fixed bed adsorbers (break through curve)

TEXT BOOKS:

1. Mass Transfer Operations by R.E. Treybal, 3rd ed., McGraw Hill, 1980.

REFERENCE BOOKS:

1. Unit Operations of Chemical Engineering, W.L. McCabe, J.C. Smith & Peter Harriott, McGraw-Hill, 6th ed., 2001.
2. Principles of Mass Transfer and Separation Processes, Binay K. Datta, PHI Learning Pvt. Ltd., 2009.
3. Equilibrium Staged Separations, Phillip C.Wankat, Prentice-Hall PTR, 1988.

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Chemical and Catalytic Reaction Engineering**

Subject code: **CHEM 3420**

L	T	P	C
3	1	0	4

Course Objectives:

1. To impart the knowledge of deviations in chemical reactors and to understand the parameters that influences the models of non-ideal reactors.
2. To develop the rate equation for heterogeneous reactions and study about the properties and preparation of solid catalysts
3. To discuss the effects of diffusion, mass and heat transfer in catalyst pellet in reaction rates and the significance of Thiele modulus.
4. To develop the rate-controlling model for heterogeneous reactions, in which diffusion, and reactions controlling the reaction rate influence the rate of reaction and to arrive at the relationship for complete conversion for the different types of reactors.

Course Outcomes:

At the end of the course, the students will be able to:

1. Predict reactor performance under non-ideal flow situations using RTD data.
2. Develop rate equation for heterogeneous reactions.
3. Estimate the effects of diffusion, mass and heat transfer in catalyst pellet on reaction rates.
4. Develop the rate-controlling model for heterogeneous catalytic reactions.

UNIT- I: BASICS OF NON-IDEAL FLOW **15Hrs**

Non-ideal flow, Residence time distribution (Importance and interpretation of RTD curve, E, F and C curves and relationship between them in reactor, Statistical Interpretation, RTD measurement, Conversion in non-ideal flow reactors, Diagonizing reactor ills, Dispersion model), Tanks-in-series model, Mixing of fluids; Degree of segregation; Laminar flow reactor; Conversion in segregated flow; Early and late mixing.

UNIT-II: HETEROGENEOUS REACTIONS AND SOLID CATALYSIS **15Hrs**

Heterogeneous processes, Rate equations for heterogeneous reactions, adsorption isotherm and rates of adsorption, desorption and surface reaction, concept of rate controlling steps and analysis of rate equation. Classification and preparation of catalysts, Promoters and inhibitors, Catalyst characterization: Surface area and pore size distribution, Poisoning of catalysts.

UNIT- III: SOLID CATALYZED REACTIONS **15 Hrs**

Characteristics of catalyzed reaction, Mechanism, Pore diffusion resistance combined with surface kinetics, Single cylindrical pore + first order reaction, Effectiveness factor, Porous catalyst particles, Heat effects during reaction, Performance equation for reactors containing porous catalyst particles, Experimental methods for finding rates, Deactivation of catalysts and mechanism - the rate and performance equations.

UNIT IV: FLUID--PARTICLE REACTIONS **15 Hrs**

Introduction to fluid particle reactions, The rate Equations, Selection of kinetic model, Shrinking core model for spherical particles of unchanging size: Diffusion through gas film controls, Diffusion through ash layer controls, Chemical reaction controls; Rate of reaction for shrinking spherical particles: Chemical reaction controls, Diffusion through gas film controls, SCM for cylindrical particles of unchanging size, determination of rate controlling step.

Text Books:

1. O.Levenspiel, Chemical Reaction Engineering, 3rd ed. John Wiley & Sons,1999.
2. H.S.Fogler, Elements of Chemical Reaction Engineering, 2nd ed., PHI, 1992.
3. J.M.Smith, Chemical Engineering Kinetics, 3rd ed., McGraw Hill, 1981.

Reference Book:

1. K.A. Gavhane, Chemical Reaction Engineering – II, Nirali Prakashan, 2008.

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Petroleum `Refining and Petrochemicals**

Subject code: **CHEM 3421**

L	T	P	C
3	1	0	4

COURSE OBJECTIVE(S):

The course content enables students to:

1. Learn the formation, refining of crude oil and products of refinery.
2. Understand the means of processing data including thermal properties, important products characteristics.
3. Develop skills in drawing neat flow diagrams of different petroleum refining processes (cracking/reforming/alkylation/isomerization / hydrocracking etc.,) that are aimed at producing high value/demand products.
4. Understand final product treating/finishing operations.
5. Identify important testing methods for important petroleum products.
6. Have idea on Indian standards for major petroleum products

COURSE OUTCOME(S):

At the end of the course students are able to:

1. Describe the formation of crude oil, its refining techniques.
2. Describe the chemical composition and physical properties of crude oil
3. Understand various processes employed in petroleum refinery such that we can meet customer demand in terms of quality & quantity.
4. Demonstrate the different methods available for removal of impurities from crude and products manufacture
5. Understand, draw and describe the process flow diagrams of various refinery processes like distillation, cracking and reforming etc.,

UNIT-I **15 Hrs**

Origin, formation and composition of petroleum: Origin and formation of petroleum, theories explaining crude formation,

Fractionation of petroleum: Dehydration and desalting of crudes, heating of crude-pipe still heaters, distillation of petroleum.

UNIT –II **15 Hrs**

Petroleum processing data: Evaluation of petroleum, thermal properties (viscosity index, flash, fire points, of petroleum fractions), important products, properties and test methods.

Treatment techniques: fraction-impurities, treatment of gasoline, treatment of kerosene, treatment of lubes.

UNIT –III **15 Hrs**

Thermal and catalytic processes: Cracking, catalytic cracking, catalytic reforming, Naphtha cracking, coking, Hydrogenation processes, Alkylations processes, Isomerization process.

Petrochemical Industry – Feedstocks-gases, liquids, solids; purification of gases, aromatics separation from Reformates-Udex process

UNIT –IV **15 Hrs**

Chemicals from methane: Introduction, production of Methanol, Formaldehyde, Ethylene glycol, and Methylamines

Chemicals from Ethane-Ethylene-Acetylene: Oxidation of ethane, production of Ethylene, Manufacture of Vinyl Chloride monomer, vinyl Acetate manufacture, Ethanol from Ethylene, Acetaldehyde from Acetylene.

TEXT BOOKS:

1. Modern Petroleum Refining Processes, B.K. Baskara Rao, Oxford & IBH Publishing, 4th ed., 2002.

REFERENCE BOOKS:

1. A text book on Petrochemicals, 4th ed., B.K. Bhaskara Rao, Khanna publishers, 2002.
2. Fuels Furnaces and Refractories by O P Gupta, Kanna Publishers, 1967.
3. George T Austin, Shreve's Chemical Process Industries - International Student Ed., 5th ed., McGraw Hill Inc., 1998.

Department of Chemical Engineering

B.Tech (CHEM) - 6th semester

SYLLABUS

(Elective-1)

(Applicable for 2012-13 admitted batch)

Course Title: **Clean Process Technologies** Subject code: **CHEM 3422**

L	T	P	C
3	1	0	4

COURSE OBJECTIVES:

The overall aim of the course is to provide

1. Knowledge and understanding of strategies and technologies for a cleaner industrial production.
2. Pollution prevention and waste minimization management strategies to industrial processes.
3. The understanding of advantages and disadvantages of applying cleaner production activities.
4. Knowledge on the implementation of cleaner technologies on selected industrial sectors.
5. Understanding of the concept and benefits of industrial ecology and eco-industrial parks.

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Understand the concept of environmental sustainability, and the difference between pollution prevention vs. pollution control.
2. Describe cleaner production activities and its benefit.
3. Describe the function of process internal solutions to minimize air pollution emissions (flue gas pollutants and VOC) and emissions through waste water discharges.
4. Explain the function of different process external methods to minimize pollutions to air or water.
5. Explain the concept of industrial ecology and its benefit.

UNIT I **15Hrs**

Industrial and commercial sector development and related energy and environmental issues, Global environmental issues including global energy issues, global warming, and ozone depletion, air and water quality issues, Overview of environmental sustainability, Introduction to life-cycle assessment.

UNIT II **15Hrs**

Pollution prevention vs. pollution control, Principles of pollution prevention and cleaner production, approaches and means of pollution prevention, Introduction to methods and tools for cleaner production, reuse, recycle, recovery, source reduction, raw material substitution, toxic use reduction and process modifications, Pollution prevention in material selection for unit operations, Pollution prevention for chemical reactors, Pollution prevention for separation devices, Pollution prevention in storage tanks, Pollution prevention assessment integrated with HAZOP analysis,

UNIT III **15Hrs**

Air pollution control and gas cleaning technology, Process internal solutions (process changes, raw material changes) and external solutions (gas treatment) in order to minimize air pollution (both gaseous compounds and particles)
Waste water treatment, Process internal solutions (process changes, raw material changes) and external solutions (different methods to treat waste water) in order to minimize water pollution.

UNIT IV **15Hrs**

Basic concept of industrial ecology and eco-industrial parks, Case studies on industrial applications of cleaner technologies in various industries including chemical, metallurgical, pulp and paper, textile, dairy, cement and other.

Text Books:

1. Paul. L. Bishop, *Pollution Prevention: Fundamentals and Practice*, McGraw Hill, 2000.
2. D.T. Allen and D.R. Shonnard, Green Engineering: Environmentally Conscious Design of Chemical Processes, Prentice-Hall, Inc., 2002.
3. N.L Nemerow, *Zero Pollution for Industry: Waste Minimization through Industrial Complexes*, John Wiley &Sons, 1995.

Reference Books:

1. Graedel, T.E., Allenby, B.R. *Industrial Ecology and Sustainable Engineering,* PHI Publishers, 2010.
2. Ayres, R.U., Ayres, L.W. *A Handbook of Industrial Ecology*, Edward Elgar Publishing, 2002.

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Elective-1)

(Applicable for 2012-13 admitted batch)

Course Title: **Fertilizer Technology** Subject code: **CHEM 3423**

L	T	P	C
3	1	0	4

Course Objectives: The course enables to:

1. Identify the sources available for Nitrogen and Hydrogen.
2. Know gas purification techniques.
3. Know different methods available for Production of ammonia and ammonia recovery.
4. Explain production of urea and nitric acid.
5. Understand the process available for production of various types of fertilizers.

Course outcomes:

Upon successful completion of the course, the students will be able to:

1. Define the characteristics of a good fertilizer
2. Explain types of fertilizer and raw materials available.
3. Discuss the production methods for various fertilizers.
4. Draw the production flow sheet and explain the equipments used in production process.
5. Explain about Controlled Released fertilizers.

UNIT –I **15 Hrs**

Source of Nitrogen and Hydrogen, Steam Reformation of hydrocarbons, Coal Gasification process, Partial oxidation of fuel oils, Gas purification, high and low temperature shift conversion, CO removal processes, Methanation.

UNIT –II **15 Hrs**

Manufacture of Ammonia, Ammonia synthesis by various processes, by product ammonia recovery by direct and indirect methods, Manufacture of nitric acid and production of urea, urea once through, total and partial recycle processes, Prilling.

UNIT –III **15 Hrs**

Manufacture of other nitrogenous fertilizer such as ammonium sulfate, calcium ammonium nitrate, ammonium chloride etc., granulation techniques. Phosphatic fertilizers, single and triple super phosphate, manufacture and production of ammonium phosphate and nitro phosphates, manufacture of phosphoric acid.

UNIT –IV **15 Hrs**

Potassium fertilizers, mixed and compound fertilizers, liquid fertilizers, Indian fertilizer industry, production economics and future plans, fertilizer application techniques for different soils, controlled release fertilizers.

TEXT BOOKS:

1. Chemistry and technology of fertilizers by V. Seucheli, Reinhold 1960/
2. Ammonia by Slack A.V. Marcel Dekker, 1973.

REFERENCE BOOKS:

1. Outlines of Chemical Technology by CE. Dryden

2. Manual of fertilizer processing by F.T.Nielsson, Dekker 1987

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Elective-1)

(Applicable for 2012-13 admitted batch)

Course Title: **Polymer Technology** Subject code: **CHEM 3424**

L	T	P	C
3	1	0	4

COURSE OBJECTIVES: The course content enables the students to:

1. Understand and be able to compute molecular weight averages from the molecular weight distribution.
2. Understand the major classes of step growth and chain growth polymerization and be able to specify reaction conditions to control molecular weight and, to the extent possible, its distribution.
3. Understand how polymers from the same monomer can have different chain architecture and how to control it during polymerization.
4. Understand the typical microstructure of glassy and semi-crystalline polymers, how this microstructure develops and how it may be characterized.
5. Articulate the physical basis of the elasticity of polymer networks, both cross-linked and entangled, and be able to specify what factors control their shear modulus.

COURSE OUTCOME(S): At the end of the course students will be able to:

1. Identify chemical formulas for common polymers and distinguish whether a polymer was likely synthesized via a condensation (step growth) or addition (chain) polymerization reaction.
2. Calculate the extent of reaction required to reach a particular degree of polymerization reaction and the time required to reach that extent of reaction given appropriate rate constants.
3. Determine the solubility of a polymer in a solvent given the Flory-Huggins interaction parameter.
4. Identify and analyze data from experimental methods of measuring the radius of gyration, different molecular weight averages, and second virial coefficient for polymer solutions.
5. Determine the volume fraction of crystallinity for a polymer sample and measure the glass transition temperature.

UNIT-I **15 Hrs**

Introduction; definitions: polymer& macro molecule, monomer, functionality, average functionality, co-polymer, polymer blend., plastic and resin.

Classification of polymers: based on source, structure, applications, thermal behavior, mode of polymerization.

Methods of polymerization: mass or Bulk polymerization process, solution polymerization process, suspension polymerization process and emulsion polymerization method comparison of merits and demerits of three methods.

Mechanism and kinetics of Addition or chain polymerization

a) Free radical addition polymerization

b) Ionic addition polymerizations

c) Coordination polymerization.

d) Coordination or step growth or condensation polymerization.

UNIT –II **15 Hrs**

Measurement of molecular weight and size:

End group analysis, Colligative property measurement, light scattering, ultra centrifugation, solution viscosity and molecular size and gel permeation chromatography, poly-electrolytes.

Polymer structure and physical properties: The crystalline melting point, the glass transition temperature, properties involving large deformations, properties involving small deformations, Property requirements and polymer utilization.

UNIT –III **15 Hrs**

Thermodynamics of polymer mixtures: Introduction, criteria for polymer solubility, the Flory Huggins theory, free volume theories, Free volume theory of diffusion in rubbery polymers, gas diffusion in glassy polymers, polymer-polymer diffusion.
Degradation of polymers, Role of the following additives in the polymers:

Fillers and reinforcing fillers ii) Plasticizers iii) Lubricants iv) Antioxidants and UV stabilizers v) Blowing agents vi)Coupling agents vii)Flame retardents viii) Inhibitors

UNIT –IV **15 Hrs**
Brief description of manufacture, properties and uses of:

i) Polyethylene (HDPE&LDPE), ii) Poly propylene iii) Polyvinylchloride iv) Polystyrene v) Polytetra floroethylene vi) Polymethyl mehacrylate vii) Polyvinylacetate & Polyvinylalcohol.

Polymer Processing: Molding, Extrusion, other processing methods (calandering, casting, coating, foaming, forming, laminating), multi-polymer systems and composites, additives and compounding.

TEXT BOOK:

1. Polymer Science and Technology, Joel R. Fried, Prentice Hall India.
2. Textbook of Polymer Science, Bill meyer, F.W.Jr. (3^{rd} ed.) John Wiley & sons 1984.

REFERENCE BOOKS:

1. Introduction to Plastics, J.H. Brison and C.C. Gosselin, Newnes, London, 1968.
2. Polymeric Materials, C.C.Winding and G.D.Hiatt Mc Graw Hill Book Co., 1961

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Open elective)

(Applicable for 2012-13 admitted batch)

Course Title: **Industrial Safety and Hazard Management**

Subject code: **CHEM3425**

L	T	P	C
3	1	0	4

Course Objectives:

The course content enables students to:

1. Work and develop safety and hazard management system.
2. Learn how to design inherently safer chemical plant.
3. Get knowledge of different hazardous chemicals and what are the hazards and how to work with them, inspection for safety, designing of flares, hazard analysis and risk assessment.
4. Know how to assist engineers and process safety personnel who are involved with chemical processes and operations where flammable gases, vapors, or mists are present.
5. Learn the techniques available for both preventing dust explosions and protecting people and facilities from their effects.

COURSE OUTCOME(S): At the end of the course students will be able to:

1. Understand the safety and ethical issues that may arise from industrial processes.
2. Understand and be able to communicate the importance of Safety in chemical engineering practice—both in ethical and economic terms.
3. Evaluate hazards both qualitatively, using techniques like "what if" and "HAZOP" analyses, and quantitatively, using techniques like fault tree and event tree analyses.
4. Understand and be able to communicate the difference between Hazard and Risk. Be able to express Safety in terms of Risk and to recognize unacceptable/inappropriate levels of Risk.
5. Understand hazards arising from runaway reactions, explosions and fires, and how to deal with them.

6. Understand the behavior of accidental releases of hazardous materials from industrial chemical processes, including consequences related to health and property.

UNIT-I **15Hrs**

Introduction: Safety Programs- Engineering Ethics- Accident and Loss Statistics- Acceptable Risk-Public Perceptions- The nature of the Accident Process-Inherent Safety.

Toxicology: how toxicants enter biological organisms – how toxicants are eliminated from biological organisms- effects of toxicants on biological organisms – toxicological studies .

UNIT-II **15Hrs**

Industrial Hygiene: Government of India regulations and OSHA – Industrial Hygiene
Identification – Evaluation - Control.

Fires and Explosions: The fire triangle, Distinction between fire and explosions; Definitions, Flammability characteristics of liquids and vapors, MOC and inerting, ignition energy, Auto ignition, Auto oxidation, Adiabatic compression, Explosions.

UNIT- III **15Hrs**

Designs to prevent fires and explosions: Inerting – static electricity – controlling static electricity – explosion – proof equipment and instruments – ventilation – sprinkler systems – miscellaneous designs for preventing fires and explosions.

Introduction to Reliefs: relief concepts – definitions – location of reliefs – relief types – relief scenarios – data for sizing reliefs – relief systems.

UNIT- IV **15Hrs**

Relief sizing: conventional spring – operated reliefs in liquid service – conventional spring –operated reliefs in vapor or gas service – rupture disc reliefs in liquid service- rupture disc reliefs in vapor or gas service – deflagration venting for dust and vapor explosions- venting for fires external to process vessels-reliefs for thermal expansion of process fluids.

Hazards identification: process hazards checklists – hazards surveys – hazards and operability studies – safety reviews – other methods.

Risk assessment: review of probability theory – event trees – fault trees – QRA and LOPA.

TEXT BOOKS:

1. Daniel A. Crowl, Joseph F. Louvar, Chemical Process Safety: Fundamentals with Applications, 3rd Ed., Prentice Hall, 2011.

REFERENCE BOOKS:

1. H.H.Fawcett and W.S.Wood, Safety and Accident Prevention in Chemical Operations, John Wiley and sons, 2nd edition, New York, 1982.
2. Coulson and Richardson's – Chemical engineering – R. K. Sinnot, Vol.6, Butterworth - Heinmann Ltd. 1996.

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Chemical Reaction Engineering Lab**

Subject code: **CHEM 3226**

L	T	P	C
0	0	3	2

Objectives:

- To familiarize students with main type of chemical reactors.
- To analyze the experimental data to obtain the reaction rate expression (reaction order and specific reaction rate constant).
- To compare the conversion of reactants for a specific reaction in various types of reactor.
- To understand the concept of residence time distribution in reactor systems.
- To determine mass transfer coefficient of systems with chemical reaction.

Outcomes:

At the end of the laboratory course, the students will be able to:

5. Develop rate law for use in reactor design based on reaction data from a reactor.
6. Make comparisons of ideal reactor types and be able to determine the best choice for simple objectives when using a single reactor or a set of reactors.
7. Characterize laboratory reactors through residence time distributions.
8. Determine mass transfer coefficient of Solid-Liquid and Liquid-Liquid systems.

Experiments:

1. Experiments using Batch reactor
- Determination of reaction order using a batch reactor and data analysis by (a) Differential method (b) Integral method.
- Determination of the activation energy of a reaction.
- Determination of rate constant of a reaction of known order.

2. Experiments using Tubular reactor
- Determination of the order of reaction and rate constant
- Determination of RTD and dispersion number using a tracer

3. Experiments using CSTR
- Determination of rate constant and the effect of residence time on conversion.

4. Experiments using CSTR in series
- Comparison of experimental and theoretical values of space times of reactors

5. Experiments using Packed bed reactor
- Determination of RTD and dispersion number for a packed-bed using a tracer.

6. Mass transfer with chemical reaction (Solid-Liquid System)
- Determination of mass transfer coefficient.

7. Mass transfer with & without chemical reaction (Liquid-Liquid System)
- Determination of mass transfer coefficient.

Department of Chemical Engineering

B.Tech (CHEM)- 6th semester

SYLLABUS

(Applicable for 2012-13 admitted batch)

Course Title: **Mass Transfer Operations Lab**

Subject code: **CHEM 3227**

L	T	P	C
0	0	3	2

COURSE OBJECTIVES:

This laboratory course will enable the students to:

1. Apply hand-on experiments relevant to the principles learned in the Mass Transfer Operations.
2. Estimate diffusivity coefficients and mass transfer coefficients.
3. Find out the equilibrium data for various systems.
4. Perform various experiments to understand the concept behind separation techniques.

COURSE OUTCOME(S): At the end of the course students are able to:

1. Perform experiments in relation to the Mass Transfer fundamentals.
2. Find out diffusivity and mass transfer coefficients.
3. Compare the equilibrium data developed with the theoretical data.
4. Evaluate the effectiveness of different separation techniques.

Experiments:

1. Estimation of diffusivity coefficients (any Two)

   (a) Vapors (b) solids (c) Liquids
2. Evaluation of Mass transfer coefficients

   (a) Surface Evaporation (b) Wetted wall column

3. Estimation of Equilibria (any Two)

   (a) Solid – Liquid (b) Liquid – Liquid (c) Vapor – Liquid

4. Distillation Experiments (any Two)

   (a) Steam distillation (b) Differential distillation

   (c) Packed bed distillation

5. Extraction Experiments

   (a) Ternary Liquid Equilibria (binodal curve)

   (b) Multi stage crosscurrent extraction

6. Batch Drying Experiment

7. Leaching Experiment