

SCHEME AND SYLLABUS

B.TECH.-III (CHEMICAL) 5th SEMESTER SCHEME FOR TEACHING AND EXAMINATION

Sr. No.	Course	Code	Credits	Teaching Scheme Hours per Week			Examination Scheme						Total Marks
				L	Tu	Pr	Theory			Practicals			
							Hr	Sess ional	Tu End Sem	Sess ional	End Sem		
1	Mass Transfer Operations – II (Core – 8)	CH301	5	3	1	2	2	50	25	50	25	25	175
2	Chemical Engineering Thermodynamics – II (Core – 9)	CH303	4	3	1	0	2	50	25	50	---	---	125
3	Chemical Reaction Engineering – II (Core – 10)	CH305	4	3	1	0	2	50	25	50	---	---	125
4	Institute Elective – I	--	3	3	0	0	2	50	0	50	---	---	100
5	Core Elective – I	CH3AA	3	3	0	0	2	50	0	50	---	---	100
6	Seminar	CH307	1	0	0	2	0	0	0	0	20	30	50
TOTAL			20	15	3	4		250	75	250	45	55	675
Total contact hours per week = 20				Total Credit = 20				Total marks = 675					

Institute Elective – I (CH3XX)			Core Elective – I (CH3AA)		
Sr. No	Code	Elective Course	Sr. No	Code	Elective Course
1.	CH361	Process Plant Safety	1.	CH321	Bioprocess Engineering
2.	CH363	Cleaner Technologies in Chemical Process Industries	2.	CH323	Computational Heat Transfer and Fluid Flow
3.	CH365	Fuels and Combustion	3.	CH325	Fundamentals of Biochemical Engineering
4.	CH367	Introduction to Engineering Statistics	4.	CH327	Introduction of Electrochemistry

B.TECH.-III (CHEMICAL) 6th SEMESTER SCHEME FOR TEACHING AND EXAMINATION

Sr. No.	Course	Code	Credits	Teaching Scheme			Examination Scheme						Total Marks
				Hours per Week			Theory			Practicals			
				L	Tu	Pr	Hr	Sess ional	Tu	End Sem	Sess ional	End Sem	
1	Professional Ethics, economics & management	HU302	4	4	0	0	2	50	---	50	---	---	100
2	Instrumentation and Process Control (Core-11)	CH302	5	3	1	2	2	50	25	50	25	25	175
3	Process Equipment Design and Drawing (Core-12)	CH304	5	3	1	2	2	50	25	50	25	25	175
4	Process Modelling and Simulations (Core-13)	CH306	4	3	1	0	2	50	25	50	---	---	100
5	Institute Elective – 2	--	3	3	0	0	2	50	---	50	---	---	100
6	Core Elective -2	CH3BB	3	3	0	0	2	50	---	50	---	---	100
TOTAL			24	19	3	4		300	75	300	50	50	750
Total contact hours per week = 26				Total Credit = 24				Total marks = 750					

Institute Elective – 2 (CH3YY)			Core Elective – 2 (CH3BB)		
Sr. No	Code	Elective Course	Sr. No	Code	Elective Course
1.	CH362	Environmental Health and Safety	1.	CH322	Polymer Engineering
2.	CH364	Petrochemical Technology	2.	CH324	Unit Processes
3.	CH366	Petroleum Refinery Engineering	3.	CH326	Chemical Product Design
4.	CH368	Waste to Energy Conversion	4.	CH328	Fundamentals of Colloid and Interface Science
5.	CH372	Industrial Waste Management Control	5.	CH332	Corrosion and Electrochemical Engineering

Mass Transfer Operations – II

L	T	P	Credit
3	1	2	05

Core – 8: CH301 Scheme

1. Course Outcomes (COs):

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

CO1	Explain the mass transfer principles with reference to solid-liquid, gas-liquid, liquid-liquid contact.
CO2	Evaluate the scope of absorption, adsorption, liquid-liquid extraction, crystallization, leaching and drying.
CO3	Design (process design) the equipments for absorption, adsorption and liquid-liquid extraction.
CO4	Recommend suitable mode of operation and equipment for absorption, adsorption, liquid-liquid extraction, crystallization, leaching and drying.
CO5	Determine the time of drying and rate of drying for removal of moisture.
CO6	Appraise the concept of novel separation like membrane separation, supercritical fluid extraction, microwave assisted extraction, ultrasound assisted extraction, etc.

2. Syllabus:

- **ABSORPTION** (8 Hours)
Equilibrium, Material balance for single component transfer, Multi-stage and packed tower operation (Equilibrium approach and rate approach), Graphical and analytical method for tray/ stage determination, Multi-component system, Non-isothermal operation, Absorption with chemical reaction
- **EQUIPMENT FOR GAS-LIQUID OPERATIONS** (3 Hours)
Sparged and agitated vessels, Venture scrubber, Wetted wall towers, Tray and packed towers, Mass transfer coefficients for packed towers, Hydrodynamic considerations
- **LIQUID-LIQUID EXTRACTION** (8 Hours)
Liquid equilibria, Stage-wise extraction, Graphical and analytical method for tray/ stage determination, Stage type extractor, Differential extractor
- **ADSORPTION AND ION-EXCHANGE** (6 Hours)
Adsorption equilibria, Stage-wise and continuous operations, Graphical and analytical method for tray/ stage determination, Principle of ion exchange, Equipments for adsorption and ion exchange
- **DRYING** (6 Hours)
Equilibrium, Batch and continuous drying, Mechanism and rate of drying, Equipments
- **LEACHING** (4 Hours)
Steady state and unsteady state operations, Methods of calculation, Equipments
- **CRYSTALLIZATION** (3 Hours)

Equilibrium, Operations and equipment

- **INTRODUCTION TO RECENT SEPARATION TECHNIQUE** (4 Hours)
Membrane separation, Supercritical fluid extraction, Microwave assisted extraction, Ultrasound assisted extraction, etc.

(Total Lecture Hours: 42 + Tutorial Hours: 14)

3. Practicals (At least 9 experiments to be performed):

1. To obtain ternary diagram for a given at a room temperature and select a suitable solvent
2. To evaluate the performance of solvent extraction for a single stage and multiple stage cross-current operation for a given system.
3. To study and verify the Freundlich isotherm by adsorbing a given solute from a solution on activated carbon.
4. To determine the efficiency for repetitive cycles of adsorption in a packed bed column.
5. To compare efficiency of the leaching operation for different solvents and select a suitable solvent.
6. To evaluate the performance of microwave assisted extraction (MAE) and ultrasound assisted extraction (UAE) in leaching.
7. To assess the performance of fluidized bed drying.
8. To assess the performance of cooling tower.
9. To analyze the sample of unknown concentration using Gas Chromatography.
10. To analyze the sample of unknown concentration using UV visible spectroscopy.
11. To explain the mechanism of Pervaporation and demonstrate its working.
12. To demonstrate the working of Adsorption.
13. Experiments through virtual lab

4. Books Recommended:

1. Treybal R.E., "Mass-Transfer Operations", 3rd Ed., McGraw-Hill, Singapore, 1981.
2. McCabe W.L, Smith J.C., Harriott P., "Unit Operations in Chemical Engineering", 6th & 7th Eds., McGraw-Hill, New York, 2001 & 2005.
3. Coulson J.M., Richardson J.F., Backhurst J. R., Harker J.H. "Coulson & Richardson's Chemical Engineering", Vol. 1, 6th Ed., Elsevier, New Delhi, 2004.
4. Foust, A. S., Wenzel, A. L., Clump, C. W., Maus, L., Andersen, L. B. "Principles of Unit Operations", 2nd Ed., John Wiley & Sons, Singapore, 2004.
5. Dutta, B. K., "Principles of Mass Transfer and Separation Process" PHI Learning Pvt Ltd., New Delhi, 2007.

Chemical Engineering Thermodynamics - II

L	T	P	Credit
3	1	0	04

Core – 9: CH303

Scheme

1. Course Outcomes (COs):

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

CO1	Develop a fundamental understanding of the basic principles of chemical engineering thermodynamics for phase equilibrium
CO2	Compare ideal gas/solution models to reflect behavior of real mixtures based on the concepts of chemical potential, fugacity, and excess free energy
CO3	Explain the Vapour-Liquid Equilibrium relations to solve the process separation
CO4	Evaluate the different methods/assumptions for performing phase equilibrium calculations
CO5	Apply the appropriate models to calculate phase equilibrium problems
CO6	Determine the equilibrium products and their concentration in equilibrium when dealing with systems involving chemical reactions.

2. Syllabus:

- **THERMODYNAMIC PROPERTIES OF FLUIDS** (16 Hours)
Single Phase Mixtures and Solutions; Partial molar properties, Gibbs-Duhem equation, chemical potential, Ideal and non-ideal mixtures/Solutions, fugacity and fugacity coefficient for pure components and for mixture of gases and liquids. Lewis Randall rule, Henry's law, Excess properties of mixtures, activity co-efficient.
- **PHASE EQUILIBRIUM** (17 Hours)
Phase rule, Phase Equilibrium Criteria, vapor-liquid equilibrium of ideal and non-ideal solution at low to moderate pressures, Raoult's Law and Modified Raoult's Law; testing of vapor-liquid equilibrium data, activity co-efficient models, LLE, Triangular diagrams.
- **CHEMICAL EQUILIBRIUM** (9 Hours)
Criteria, equilibrium conversion (X), constant (K), effect of Temp. & Pressure on K, evaluation of K, evaluation of equilibrium conversion for gas phase reaction.

(Total theory hours 42 + Tutorial hours 14)

3. Books Recommended:

1. Smith J. M. Van Ness H. C., Abbott M.M., "Introduction to Chemical Engineering Thermodynamics", 6th & 7th Eds., McGraw-Hill, New York, 2001 & 2005.
2. Sandler, S.I., "Chemical and Engineering Thermodynamics", 2nd Ed., Wiley, New York, 1989.
3. Rao Y. V. C., "Chemical Engineering Thermodynamics", Universities Press Limited, Heydrabad, 1997.
4. Kyle, B.G., "Chemical and Process Thermodynamics", 2nd Ed., Prentice-Hall of India, New Delhi, 1990.
5. Koretsky, Milo D., Engineering and chemical Thermodynamics, John Wiley & Sons(Asia) Pte ltd., Singapore

Chemical Reaction Engineering - II

L	T	P	Credit
3	1	0	04

Core – 10: CH305

Scheme

1. Course Outcomes (COs):

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

CO1	Demonstrate concepts of chemical reaction & reactor engineering, and kinetics of heterogeneously catalysed reactions.
CO2	Interpret catalyst characterisation results and suggest improvement in catalysts
CO3	Analyse flow behaviour and Evaluate performance of a chemical process equipment in light of RTD
CO4	Analyse and compare catalysis in different industries (e.g., Petrochemicals, Refining Processes)
CO5	Illustrate advance concepts in heterogeneous catalysis
CO6	Correlate safe operations with process catalyst systems

2. Syllabus:

- **RESIDENCE TIME DISTRIBUTION** (7 Hours)
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
- **FLUID- FLUID REACTIONS** (6 Hours)
The rate equation, Kinetic regimes for mass transfer and reaction, fast reaction, intermediate reaction, slow reaction, Slurry reaction kinetics, Application to design
- **FLUID SOLID NON-CATALYTIC REACTIONS** (8 Hours)
Particles of single size, plug flow of solids, Mixture of particles of different and unchanging sizes, mixed flow of particles of a single unchanging size, Selection of a model, Determination of rate controlling step, Application to design, Application to fluidized bed
- **CATALYTIC REACTORS** (8 Hours)
Kinetics, External and Internal Diffusional Resistances, Effects of Heat Generation/Absorption, Effectiveness Factors, Fixed Bed, Fluid Bed, Trickle bed, Slurry Reactors, LHHW Models, Method of Initial Rates
- **CATALYSIS** (6 Hours)
Typical Catalysts used in chemical processes, Catalyst Characterizations, Catalyst Deactivation and Regeneration, Temperature Progression, Moving Bed Reactors, Metal recovery from the Spent Catalysts, nanocatalysis

- **ZEOLITE CATALYSIS** **(3 Hours)**
Synthesis, Applications in Refining and Petrochemical Processes, Rise of Acidity, Modifications, Shape Selectivity
- **ENVIRONMENTAL CATALYSIS** **(2 Hours)**
Importance, Applications, Reactions involved
- **STRUCTURED REACTORS** **(2 Hours)**
Configurations, Preparation, Hydrodynamics and Applications, Accelerated Deactivation of catalysts, Laboratory reactors, Oscillatory motion of reactants in catalyst pores, Microreactors.

(Total Lecture Hours: 42 + Tutorial Hours: 14)

3. Books Recommended:

1. Fogler H.S., "Elements of Chemical Reaction Engineering", 4th Ed., Prentice Hall, NJ, 2006.
2. Levenspiel O., "Chemical Reaction Engineering", 3rd Ed., John Wiley & Sons, Singapore, 1998.
3. Smith J. M., "Chemical Engineering Kinetics", 3rd Edition, McGraw Hill, N Y, 1981.
4. Davis M.E., Davis R.J., "Fundamentals of Chemical Reaction Engineering", McGraw-Hill, New York, 2003.
5. Froment G.F., Bischoff K.B., "Chemical Reactor Analysis and Design", 2nd Ed., John Wiley & Sons, Singapore, 1990.

Elective: Cleaner Technologies in Chemical Process Industries

L	T	P	Credit
3	0	0	03

CH363**Scheme****1. Course Outcomes (COs):**

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

CO1	Recognize the role of cleaner/greener technologies in the survival and sustainable development of chemical processing industries.
CO2	Interpret the concept and principles of cleaner production in industries.
CO3	Apply the basic principles of green chemistry/green engineering to develop environmentally sound technologies.
CO4	Identify reagents, reactions and technologies that should be and realistically could be targeted for replacement by green alternatives.
CO5	Explain the role of life cycle assessment in sustainable production.
CO6	Appraise the social and environmental responsibility of engineers in the global community.

2. Syllabus:

- **INTRODUCTION TO CLEANER TECHNOLOGY** (3 Hours)
Industrial impacts on the environment, Concept of sustainable development, Cleaner technology and cleaner production, Basis, necessity and scope of cleaner production/cleaner technologies in survival of chemical process industries.
- **CLEANER PRODUCTION TOOLS** (5 Hours)
C.P. tools, techniques, methodology, Assessment of cleaner production.
- **GREEN CHEMISTRY AND GREEN ENGINEERING** (8 Hours)
Principles and concepts of green chemistry and green engineering, green chemistry metrics, Environmentally benign solvents, design of cleaner production/green processes.
- **INHERENTLY SAFER DESIGN** (6 Hours)
Industrial process safety strategies, Hazard Prevention by CT Alternatives, HAZOP, HAZAN, Inherent safety concepts and strategies.
- **LIFE CYCLE ASSESSMENT** (6 Hours)
ISO 14000, Life cycle analysis of products and processes, LCA methodologies
- **ENERGY AND ENVIRONMENTAL AUDIT** (5 Hours)
Energy conservation, Energy audit and its methodology, Environmental auditing
- **WASTE MINIMIZATION CIRCLES** (4 Hours)
Concept, Need and benefits, Methodology, Techniques and barriers

- **INDUSTRIAL CASE STUDIES** (5 Hours)
Typical case studies from industrial sectors viz. Petrochemicals, Polymers, Chloralkali, Dyes, Pharmaceuticals, Pesticides, Food processing, Textile and Specialty Chemicals.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Gujarat Cleaner Production Centre, “Cleaner Production and its Application to Industries”, GCPC, Gandhinagar, Gujarat, 2010.
2. Lennart Nilsson, Per Olof Persson, Lars Ryden, Siarhei Darozhka, Audrone Zaliauskiene “Cleaner Production: Technologies and Tools for Resource Efficient Production”, Baltic University Press, 2007.
3. United Nations Environment Programme “Cleaner Production - A Training Resource Package”, 1st Edition, UNEP/Earthprint, 1996.
4. David T. Allen, David R. Shonnard, “Green Engineering: Environmentally Conscious Design of Chemical Processes”, Prentice Hall, 2001.
5. Concepción Jiménez-González, David J.C. Constable, “Green Chemistry and Engineering: A Practical Design Approach”, John Wiley & Sons, 2011.

4. Additional Reading:

1. Kenneth L. Mulholland “Identification of Cleaner Production Improvement Opportunities”, John Wiley & Sons, 2006.
2. Center for Chemical Process Safety (CCPS) “Inherently Safer Chemical Processes: A Life Cycle Approach”, John Wiley & Sons, 2010.
3. Asian Productivity Organization, “Working Manual on Energy Auditing in Industries”, APO, Japan, 2008.

Elective: PROCESS PLANT SAFETY

L	T	P	Credit
3	0	0	03

CH361**Scheme****1. Course Outcomes (COs):**

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

CO1	Recognize the importance of safety in any chemical process industries.
CO2	Adapt the basic fundamentals of chemical process safety, laws of safety.
CO3	Apply various the methods of hazard identification for any chemical process.
CO4	Perform the risk analysis and risk assessment for any system to minimize the hazards.
CO5	Recognize different relief systems which are used in plant.
CO6	Evaluate the characteristics of various causes of incidents like toxic release, fire and explosion etc.

2. Syllabus:

- **INTRODUCTION** (04 Hours)
Safety Programs, Accident Loss Statistics- FAR, OSHA, Fatality rate, Acceptable risk, Inherent safety, Nature of the accident process and their steps.
- **TOXICOLOGY** (04 Hours)
Entry of toxicants in Biological organism (BO), Elimination of Toxicant from BO, Effect of Toxicants in BO, Dose Versus Response, TLVs.
- **INTRODUCTION TO RELIEFS** (05 Hours)
Relief Concepts, Definitions, Location of Reliefs, Relief Types, Relief Systems.
- **FIRE AND EXPLOSION** (07 Hours)
The fire triangle, Distinction between Fire and explosion, estimation of flammability characteristics of vapor and liquids, Limiting oxygen characteristics and inerting, Detonation and deflagration, BLEVE, Vapor-cloud explosion, Fire extinguisher.
- **HAZARD IDENTIFICATION** (07 Hours)
Process hazard checklists, HAZOP study, Safety Reviews, Other methods, Problem solving.
- **RISK ASSESSMENT** (10 Hours)
Review of Probability theory, Probability of Coincidence, Revealed & Unrevealed failures, Fault tree analysis, Cut Sets, Path sets, Reliability diagram, Event tree analysis, Quantitative risk analysis, Layer of Protection analysis, Consequence, Frequency, Problems solving.
- **CASE HISTORIES** (05 Hours)
Flixborough, England, Bhopal Gas Tragedy, A massive explosion in Pasadena, Leakage

of 2,3,7,8-tetrachlorodibenzoparadioxin in Seveso, Related to Static Electricity, Chemical Reactivity, System Designs, Procedures.

(Total Lecture Hours: 42 Hours)

3. Books Recommended:

1. Crowl D. A., Louvar J. F., "Chemical Process Safety", Prentice-Hall, 2nd Ed., New York, 2002.
2. Sanders R E., "Chemical Process Safety", Butterworth-Heinemann, 3rd Ed., New Delhi, 2005.
3. Green D.W., Perry R.H., "Perry's Chemical Engineers' Handbook", McGraw-Hill, 8th Ed., 2007.
4. "Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control", Butterworth-Heinemann, 4th Ed., 2012.
5. Raju, K.S.N., "Chemical Process Industry Safety", McGraw Hill Education Pvt Ltd., India, 2014.

4. Additional Reading:

(If there are more than five references, put it here and number them from 1)

Process Plant Safety

This subject can be considered as global elective as it is related to safety in chemical industries.

This subject gives the detailed information about the following:

1. importance of safety in any chemical process industries.
2. basic fundamentals of chemical process safety, laws of safety.
3. various the methods of hazard identification for any chemical process.
4. risk analysis and risk assessment for any system to minimize the hazards.
5. different relief systems which are used in plant.
6. the characteristics of various causes of incidents like toxic release, fire and explosion etc.

Bioprocess Engineering

This subject can be considered as departmental elective as the knowledge of this subject can be clubbed with chemical engineering subjects and useful in biochemical industries.

This subject gives the detailed information about the following:

1. basic of microbiology and bioprocess engineering.
2. fundamentals of metabolic reaction occurred in micro-organism and their role in various industrial applications.
3. microbial growth kinetics and its importance in various industrial applications.
4. design of different types of bioreactors and understand their working.
5. various techniques involved in downstream processes for the recovery of bio-compounds.

Enzyme Science and Technology

This subject can be considered as departmental elective as the knowledge of this subject can be clubbed with chemical engineering subjects and useful in chemical and biochemical industries.

This subject gives the detailed information about the following:

1. definition of enzymes in terms of classifications, characterization, purification methods etc.
2. various mechanisms and kinetics of enzyme action as catalyst in biochemical reactions.
3. various types of enzyme inhibition and its effect on enzymatic reactions.
4. various methods of enzyme immobilization and their significance.
5. different types of enzymatic reactors for enzymatic reactions.
6. various applications of enzyme in chemical and biochemical industries.

Unit Processes

This subject can be considered as departmental elective as it is related to various types chemical and physical processes which are occurred in chemical process industries.

Elective: Fuels and Combustion

L	T	P	Credit
3	0	0	03

CH365

Scheme

1. Course Outcomes (COs):

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

CO1	Discuss energy resources, global energy consumption, fundamentals of combustion
CO2	Describe origin, classification, analysis, properties of solid, liquid, gaseous fuels and their applications
CO3	Solve combustion stoichiometry and thermodynamics problems
CO4	Analyze the performance of combustion appliances
CO5	Discuss production processes and technologies of Agro and Bio fuels and their applications
CO6	Explain the social and environmental responsibility of engineers in the global community

2. Syllabus:

- **INTRODUCTION (3 Hours)**
Global energy consumption, properties of fuels, coal, liquid fuels, gaseous fuels and agro-residues.
- **SOLID FUELS (12 Hours)**
Solid Fuels, Coal, origin, coal mining, classification of coal, analysis and properties, action of heat on coal, gasification, oxidation, hydrogenation and liquefaction of coal, efficient use of solid fuels.
- **LIQUID FUELS (10 Hours)**
Origin and classification of petroleum, crude exploration, petroleum refining processes, transportation, storage and handling of liquid fuels, properties & testing of petroleum products, internal combustion engine.
- **GASEOUS FUELS (5 Hours)**
Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG, cleaning and purification of gaseous fuels.
- **MANUFACTURED FUELS (2 Hours)**
Agro fuels, Bio-Fuels: types of bio-fuels, production processes and technologies, bio fuel applications
- **COMBUSTION (10 Hours)**
Combustion stoichiometry and thermodynamics, calculation of heat of combustion, theoretical & actual combustion processes - air fuel ratio, estimation of dry and wet flue gases for known fuel composition, calculation of the composition of fuel & excess air supplied, flue gas analysis.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Sarkar, S., "Fuels and Combustion", 3rd. ed., Universities Press,2009
2. Dave, R.A. (Ed.), "Modern Petroleum Technology", Vol. 1, Upstream, 6th ed., John Wiley & Sons Ltd,2001.
3. Lucas, A.G. (Ed.) "Modern Petroleum Technology", Vol. 2, Downstream, 6th ed., John Wiley & Sons Ltd,2002.
4. Glassman, I. "Combustion", 2nd ed., Academic Press,2014.
5. Rao, B.K.B., "Modern Petroleum Refining Processes", 4th ed., Oxford & IBH Publishing Co. Pvt. Ltd,2018

Elective: Introduction to Engineering Statistics

L	T	P	Credit
3	0	0	03

CH367

Scheme

1. Course Outcomes (COs):

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

CO1	Understanding of descriptive statistics by quantitative reasoning and data visualization
CO2	Knowledge of the basics of inferential statistics from sample data analysis
CO3	Understanding the concept of the probability and regression analysis
CO4	Apply statistical reasoning and procedures in the analysis of real data
CO5	Employ the concept of parametric and non-parametric test for statistical analysis
CO6	Solve statistical problem using software package

2. Syllabus:

- **INTRODUCTION** (4 Hours)
Definition and scope of statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, scales of measurement nominal, ordinal, interval and ratio.
- **MEASURES OF CENTRAL TENDENCY** (5 Hours)
Mean, Median, Mode. Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation.
- **DATA ANALYSIS** (5 Hours)
Types of variables, data collection principles, types of studies, examining numerical data
Graphical methods: histograms and other graphs, Examining categorical data, Tabular methods: contingency tables, Graphical methods: bar plots and other graphs, Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays
- **PROBABILITY** (6 Hours)
Elementary probability rules, conditional probability, normal distribution, binomial distribution, probability distribution function
- **HYPOTHESIS TESTING** (4 Hours)
Null hypothesis, alternative hypothesis, p-value, Type-I and Type-II error, confidence interval, central limit theorem
- **REGRESSION** (5 Hours)
Lines of regression, properties of regression coefficients, Multiple and Partial correlation coefficients in three variables and their properties.

- **PARAMETRIC AND NON-PARAMETRIC TESTS** (5 Hours)
One Sample t-test, paired t-test, ANOVA, two-way ANOVA, sign test, Wilcoxon's signed rank test.
- **APPLICATION OF STATISTICAL ANALYSIS IN ENGINEERING** (8 Hours)
Case Studies, Elementary statistics using software package like MINITAB, Excel.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Goon,A.M., Gupta,M.K. and Dasgupta,B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn. The World Press, Kolkata.
2. Mood, A.M., Graybill, F.A. andBoes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
3. Bhat B.R, Srivenkataramana T and Rao Madhava K.S.(1996): Statistics: A Beginners Text, Vol. I, New Age International (P) Ltd.
4. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia
5. Tamhane, A. C. and Dunlop, D. D. (2000) Statistics and Data Analysis: From Elementary to Intermediate. Prentice Hall: Upper Saddle River, NJ.

Elective: Bioprocess Engineering

L	T	P	Credit
3	0	0	03

CH321**Scheme****1. Course Outcomes (COs):**

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

CO1	Recognize the basic of microbiology and bioprocess engineering.
CO2	Apply the fundamentals of metabolic reaction occurred in micro-organism and their role in various industrial applications.
CO3	Analyze the microbial growth kinetics and its importance in various industrial applications.
CO4	Compare chemical engineering with bioprocess engineering.
CO5	Design different types of bioreactors and understand their working.
CO6	Summarize various techniques involved in downstream processes for the recovery of bio-compounds.

2. Syllabus:

- **AN OVERVIEW OF BIOLOGICAL BASICS** (4 Hours)
Classification of cells; Cell Construction; Cell Nutrients.
- **MAJOR METABOLIC PATHWAYS** (8 Hours)
Bioenergetics; Glycolysis; TCA Cycle; Respiration; Control Sites in Aerobic Glucose Metabolism; Overview of Biosynthesis; Overview of Anaerobic Metabolism; Overview of Autotrophic Metabolism; Metabolic Regulations.
- **MICROBIAL GROWTH** (8 Hours)
Batch Growth; Quantifying growth kinetics; Continuous growth.
- **BIOREACTORS** (8 Hours)
Introduction to bioreactors; Batch and fed-batch bioreactors; Continuous bioreactors; Bioreactor operation; Immobilized Cell Systems; Sterilization; Aeration.
- **BIOSEPARATIONS** (8 Hours)
Biomass removal; Biomass disruption; Membrane based techniques; Extraction; Adsorption and Chromatography.
- **INDUSTRIAL PROCESSES** (6 Hours)
Description of industrial processes; Process flow-sheeting; Process economics.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Shuler, M.L., and Kargi, F., "Bioprocess Engineering: Basic Concepts", Prentice Hall, 2001.
2. Aiba, S., Humphrey, A.E., and Mills, N.F., "Biochemical Engineering", 2nd edition, Academic Press, New York, 1973.
3. Bailey, J.E., Ollis, D.F., "Biochemical Engineering Fundamentals", 2nd ed., McGraw Hill, 1986.
4. Atkinson, B., "Biochemical Reactors", Pion Ltd., London, 1974.
5. Pyle, D.L., "Separation for Biotechnology", Royal Society of Chemistry, Cambridge, 1994.

Elective: Computational Heat Transfer and Fluid Flow

L	T	P	Credit
3	0	0	03

CH323

Scheme

1. Course Outcomes (COs):

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

CO1	Formulate and analyze the heat transfer and fluid flow problems.
CO2	Adapt appropriate solution methodology for accurate solutions.
CO3	Analyze and adopt the appropriate numerical discretization technique to solve the heat transfer problems.
CO4	Adapt the appropriate computational requirements for accurate solution of the given problem.
CO5	Adapt the appropriate algorithm to solve the given problem.
CO6	Select the appropriate software tool/package to solve heat transfer and fluid flow problems and analyzing the results.

2. Syllabus:

- **INTRODUCTION (5 Hours)**
Mathematical description of fluid flow and heat transfer, conservation equations for mass, momentum, energy and chemical species, classification of partial differential equations, coordinate systems, CFD software packages and tools.
- **DISCRETIZATION TECHNIQUES (7 Hours)**
One dimensional steady state diffusion problem's: Solution methodology for linear and non-linear problems (Point-by-point iteration, TDMA). Two- and three-dimensional discretization: Discretization of unsteady diffusion problems (Explicit/Implicit and Crank-Nicolson's algorithm; stability of solutions).
- **MODELLING OF DIFFUSION PROBLEMS (8 Hours)**
Finite difference method (FDM), Convergence, Consistency, Error and Stability, Accuracy, Boundary conditions, CFD model formulation. Taylor Series and control volume formulations; modelling of heat conduction, convection-diffusion, and flow field using finite volume method (FVM); introduction to FVM with unstructured grids; modelling of phase change problems; introduction to turbulence modelling; application to practical problems.
- **MESH GENERATION AND SOLUTION ALGORITHMS (7 Hours)**
Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation. Discretization schemes for pressure, momentum, and energy equations-Explicit and implicit Schemes, First order upwind scheme, second order upwind scheme, QUICK scheme, SIMPLE, SIMPLER and MAC algorithm, pressure-velocity coupling algorithms, velocity-stream function approach, solution of Navier-Stokes equations.

- **TURBULENCE AND MULTIPHASE PROBLEMS** (5 Hours)
Large Eddy Simulation (LES). Direct Numerical Simulation (DNS). Modelling of multiphase problems: volume of fluid (VOF) and Level Set Methods.
- **CASE STUDIES-PROJECTS/EXERCISES** (10 Hours)
Solving simplified problems: formulation, discretization with coarse/fine grids, applying appropriate boundary and initial conditions and solving by hand calculations. Solving practical problems using software: writing user sub-routines; post-processing and interpretation of results.

(Total Lecture Hours: 42)

3. Books Recommended:

1. S. V. Patankar, "Numerical Heat Transfer and Fluid Flow," Special Indian Edition, Hemisphere Publishing Corporation, CRC Press, reprinted in 2017.
2. D. A. Anderson, J. C. Tannehill, and R. H. Pletcher, "Computational Fluid Mechanics and Heat Transfer," Second Edition, Hemisphere Publishing Corporation, 1997.
3. J. H. Ferziger and M. Peric, "Computational Methods for Fluid Dynamics", Second Edition, Springer, Berlin, 1999.
4. H. K. Versteeg and W. Malalasekera "An Introduction to Computational Fluid Dynamics: The Finite Volume Method" Second Edition, Pearson, Prentice Hall, 2007.
5. Atul Sharma "Introduction to Computational Fluid Dynamics: Development, Application and Analysis" First Edition, John Wiley & Sons Ltd. 2017.

Elective: Fundamentals of Biochemical Engineering

L	T	P	Credit
3	0	0	03

CH325**Scheme****1. Course Outcomes (COs):**

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

CO1	Determine the scope of biochemical engineering chemical and biochemical industries.
CO2	Relate the Basics of microbial growth.
CO3	Describe the significance of genetically modified organism in industrial applications.
CO4	Summarize the overview of bioseparation methods.
CO5	Explain various separation methods used in biochemical industries for downstream processes.
CO6	Give examples on various industrial applications.

2. Syllabus:

- **INTRODUCTION** (6 Hours)
Scope and possibilities; Characteristics and classification of biological matter; Basics of microbial growth.
- **OVERVIEW OF BIOSEPARATIONS** (4 Hours)
An Overview of bioseparations; Cell disruptions; Genetically modified organism.
- **SEPARATION METHODS** (20 Hours)
Filtration; Centrifugation; Adsorption; Extraction; Membrane separation processes; Concepts of precipitation, Chromatography – Basic concepts; Gel filtration; Ion exchange chromatography; Hydrophobic chromatography; Affinity chromatography; Suitable examples; Electrokinetic methods of separations; Finishing operations and formulations
- **INDUSTRIAL APPLICATIONS** (12 Hours)
Biomass to Biofuels; Bioremediation; Biocatalysts; Biofouling; Microbial Polymer and plastics; Natural resources recovery.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Bailey, J.E., Ollis, D.F., "Biochemical Engineering Fundamentals", 2nd ed., McGraw Hill, 2010.
2. Weatherley, L. "Engineering Processes for Bioseparations", Butterworth-Heinemann Ltd., Oxford, 1995. (reprint)
3. Pyle, D.L. "Separation for biotechnology", Royal Society of Chemistry, Cambridge, 1994. (reprint)
4. Scragg, A. "Environmental Biotechnology", 2nd Ed., Oxford University Press, 2011.
5. Sivasankar, B "Bioseparations Principles and Techniques", PHI Learning private limited, New Delhi, 2010.

Elective: Introduction to Electrochemistry

L	T	P	Credit
3	0	0	03

CH327 Scheme

1. Course Outcomes (COs):

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

CO1	Describe the fundamentals of electrochemical reactions
CO2	Apply knowledge of the principles of electrochemical reactions and electrochemical techniques
CO3	Evaluate the information that can be obtained from the electrochemical techniques studied during analysis
CO4	Review the application in various fuel cell technologies and in storage devices
CO5	Discuss the utilization of various advanced techniques

2. Syllabus:

- **INTRODUCTION TO ELECTROCHEMISTRY** (5 Hours)
Basic electrochemical concepts, Electrochemical concepts of oxidation and reduction; Electrode Reaction; Simple Electron Transfer Reactions; Equilibrium Potentials; Potential differences at interfaces.
- **ELECTROCHEMICAL CELLS** (5 Hours)
Electrolytic and Galvanic cells; different types of electrodes; Electrodes and electrode reactions; Reference electrodes; electrode potentials including standard electrode potential, half - cell and cell reactions; emf of a Galvanic cell and its measurement.
- **EXPERIMENTAL ELECTROCHEMISTRY** (5 Hours)
Two-Electrode vs. Three-Electrode Cells, Working, Counter and Reference Electrodes; Electrolytes; Separators and Membranes; Nernst equation and its applications; Relationship between cell potential and Gibbs' energy change.
- **FUEL CELL ELECTROCHEMISTRY** (15Hours)
Introduction, structure, principles, workings, potentials, limitations, scale up of various fuel cells like Hydrogen fuel cell, Microbial fuel cell, Microbial desalination cell, Microbial electrolysis cell, Benthic microbial fuel cell, Osmotic microbial fuel cell, etc. Principle of battery, advanced rechargeable battery, Li-ion batteries, nano-structured materials for Li-ion batteries, Power management system, capacitors, and supercapacitors.
- **VARIOUS ADVANCED TECHNIQUES FOR PERFORMANCE** (12Hours)
Electrochemical techniques, Electrochemical impedance spectroscopy (EIS) and its application, cycling voltammetry and linear polarization, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents, columbic efficiency, Role and significance of bioelectrochemistry, Glycolysis; TCA (TriCarboxylicacid) Cycle, Respiration, Electron transport mechanism.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Bockris, J.O.M. and Reddy, A.K.N., "Modern Electrochemistry –Vol. I & II", Second Edition, Plenum Press, New York, 2000.
2. Logan, B.E., "Microbial Fuel Cells", First Edition, Wiley, New Jersey, 2007.
3. Hoogers, G, "Fuel Cell Technology Hand Book", CRC Press, New York, 2003.
4. Bard, A.J. and Faulkner, L.R. "Electrochemical Methods – Fundamentals and applications" 2nd Edition John Wiley & Sons, New York, 2001.
5. Bailey, J.E., Ollis, D.F., "Biochemical Engineering Fundamentals", 2nd Edition, McGraw Hill, New York 1986.

B. Tech. III (Chemical Engineering), Semester - VI

L	T	P	Credit
4	0	0	05

Professional Ethics, Economics and Business Management**HU 302****Scheme****1. Course Outcomes (COs):**

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

CO1	Identify application of ethics in society and development of understanding regarding Professional ethical issues related to Chemical engineering
CO2	Develop managerial skills to become future engineering managers
CO3	Develop skills related to various functional areas of management (Marketing Management, Financial Management, Operations Management, Personnel Management etc.)
CO4	Build knowledge about modern management concepts (ERP, SCM, e-CRM, etc.)
CO5	Develop experiential learning through Management games, Case study discussion, Group discussion etc.
CO6	Apply knowledge of Economics and Business management aspects in Chemical engineering

2. Syllabus:

- PROFESSIONAL ETHICS (14 Hours)**

Introduction, Approaches to Ethics, Meaning of Ethics, Major attributes of Ethics, Business Ethics, Factors influencing Ethics, Importance of Ethics, Ethics in Management, Organizational Ethics, Ethical aspects in Marketing, Mass communication and Ethics - Television, Whistle blowing, Education – Ethics and New Professional, Intellectual Properties and Ethics, Introduction to Professional Ethics, Engineering Ethics, Ethical issues related to Chemical Engineering

- ECONOMICS (8 Hours)**

Introduction To Economics, Micro & Macro Economics, Applications & Scopes Of Economics, Demand Analysis, Demand Forecasting, Factors Of Production, Types Of Cost, Market Structures, Break Even Analysis

- MANAGEMENT (12 Hours)**

Introduction to Management, Features Of Management, Nature Of Management, Development of Management Thoughts – Scientific Management By Taylor & Contribution of Henry Fayol, Coordination & Functions Of Management, Centralization & Decentralization, Decision Making; Fundamentals of Planning; Objectives & MBO; Types of Business Organizations: Private Sector, Public Sector & Joint Sector; Organizational Behavior: Theories of Motivation, Individual & Group Behavior, Perception, Value, Attitude, Leadership

• **FUNCTIONAL MANAGEMENT** **(18 Hours)**

Marketing Management: Core Concepts Of Marketing, Marketing Mix (4p), Segmentation – Targeting – Positioning, Marketing Research, Marketing Information System, Concept of International Marketing, Difference Between Domestic Marketing & International Marketing; Operations Management: Introduction to Operations Management, Types of Operation Systems, Types of Layouts, Material Handling, Purchasing & Store System, Inventory Management; Personnel Management: Roles & Functions of Personnel Manager, Recruitment, Selection, Training, Industrial Dispute, Collective Bargaining; Financial Management: Goal of Financial Management, Key Activities In Financial Management, Organization of Financial Management, Financial Institutions, Financial Instruments, Sources of Finance

• **MODERN MANAGEMENT ASPECTS** **(4 Hours)**

Introduction To ERP, e – CRM, SCM, RE – Engineering, WTO, IPR Etc.

Tutorial: Case Study Discussion, Group Discussion, Management games and Assignments / Mini projects & presentation on related Topics

(Total Lecture Hours: 56 + Tutorial Hours:14)

3. Books Recommended:

1. Balachandran V.and Chandrasekaran, Corporate Governance, Ethics and Social Responsibility, PHI, 2nd Edition, 2011
2. Prasad L.M., Principles & Practice Of Management, Sultan Chand & Sons, 8th Edition,2015
3. Banga T. R. & Shrama S.C., Industrial Organisation & Engineering Economics, Khanna Publishers, 25th Edition, 2015
4. Everett E. Adam, Ronald J. Ebert, Production and Operations Management , Prentice Hall of India, 5th edition, 2012
5. Kotler P., Keller K. L, Koshi A.& Jha M., Marketing Management – A South Asian Perspective, Pearson, 14th Edition, 2014
6. Tripathi P.C.,Personnel Management & Industrial Relations, Sultan Chand & sons, 21st Edition, 2013
7. Chandra P., Financial Management, Tata McGraw Hill, 9th Edition, 2015

Instrumentation and Process Control

L	T	P	Credit
3	1	2	05

Core – 11: CH302

Scheme

1. Course Outcomes (COs):

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

CO1	Develop and analyse the differential equation models of first order system and Analyse dynamic behaviour of first order system to various disturbances like step, impulse, sinusoidal, ramp etc, as well as linearization problems
CO2	Analyse second order system and higher order system for dynamic behaviour to various disturbances
CO3	Develop closed loop transfer functions and Evaluate stability of control system with various tools like Routh test criterion etc
CO4	Evaluate frequency response and Create bode diagrams and evaluate stability by bode stability criteria
CO5	Design control system by controller tuning methods to industrial control systems, Analyse Control valves,
CO6	Recognize advanced controllers and their requirement, Apply measurement concepts of process parameters in process industries for control, create root locus, recognize control valve characteristics

2. Syllabus:

- **INTRODUCTION** (1 Hour)
Steady and unsteady state design equation for an agitated heated tank. Introduction to P, PI, and PID controls.
- **DYNAMICS OF FIRST ORDER SYSTEMS** (4 Hours)
Dynamics of first order systems subjected to various disturbances like step, ramp, impulse & sinusoidal e.g. liquid level tanks, mixing process, thermometer etc. response of first order system in series.
- **DYNAMICS OF SECOND ORDER SYSTEMS** (5 Hours)
Dynamics of second order systems subjected to various disturbances like step, impulse, sinusoidal.
- **LINEAR CLOSE LOOP SYSTEM** (3 Hours)
Linear close loop system, Servo and Regulator problem.
- **CLOSED LOOP TRANSFER FUNCTION** (4 Hours)
Closed loop transfer function, block diagrams for various simple systems, Transient response of the control system.
- **STABILITY OF CONTROL SYSTEM** (4 Hours)
Stability of control system, Routh test criterion, Concept of Root Locus, frequency analysis, Bode diagrams for simple order system (first order system, second order system, P, PI, PD controllers)

- **USE OF MATLAB IN PROCESS CONTROL** (2 Hours)
- **ADVANCED CONTROL** (5 Hours)
Cascade Control, Feed forward Control, Ratio control, Split Range Control, Auctioneering Control and Multivariable Control.
- **CONTROLLER TUNING AND PROCESS IDENTIFICATION** (4 Hours)
- **CONTROLLERS AND CONTROL ELEMENTS** (2 Hours)
Controller, control elements, control valves.
- **DISTRIBUTED CONTROL SYSTEM (DCS)** (2 Hours)
Distributed control system (DCS), Programmable Logical Control System (PLC).
- **FLOW, LEVEL, PRESSURE AND TEMPERATURE MESUREMENT** (4 Hours)
Construction, working principle, selection criteria and application of the measurement devices
- **SENSOR AND TRANSDUCER, INSTRUCTION PANELS, INTERFACE** (2Hours)

(Total Lecture Hours: 42 + Tutorial Hours: 14)

3. Practicals:

1. Dynamics of First Order Liquid Level System.
2. Study of Linearization
3. Dynamics of Non Interacting Tanks.
4. Dynamics of Interacting Tanks
5. Response of Manometer system
6. On-Off Controller
7. P-PI Controller
8. Cascade and Split Range Controller
9. Ratio and Feed Back - Feed Forward Controller
10. Dynamic Simulation of Distillation Operation
11. Control of CSTR in Series
12. Control of PFR
13. Control of EVAPORATOR
14. Study of Temperature Control Trainer, Pressure Control Trainer, Flow Control Trainer, Level Control Trainer
15. Dissolved Oxygen Meter
16. Thermocouple Calibration

4. Books Recommended:

1. Coughnowr D.R., LeBlanc S. E. "Process Systems Analysis and Control", 3rd Edition, McGraw Hill Inc., New York, 2009.
2. Stephanopoulos G., "Chemical Process Control", Prentice Hall of India Pvt. Ltd., New Delhi, 2001.
3. Luben W.L., Luben M.L., "Essentials of Process Control", McGraw Hill Inc., New York, 1997.
4. Coughnowr D. R. , Koppel L. B. , "Process system Analysis and control " McGraw Hill Inc., New York, 1st Edition, 1986.
5. Eckman D.P., "Industrial Instrumentation", Wiley Eastern Limited, 2004.

Process Equipment Design and Drawing

L	T	P	Credit
3	1	2	05

Core – 12: CH304

Scheme

1. Course Outcomes (COs):

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

CO1	Select appropriate material of construction for various types of process equipments
CO2	Choose appropriate design methodology for designing various parts of process equipments as well as entire vessels
CO3	Classify various process equipments according to various design codes and standards
CO4	Design and evaluate process equipments including pressure vessels, heat exchangers, distillation columns, extraction columns, absorbers, strippers, storage tanks, etc.
CO5	Design process equipments subjected to internal pressure and external pressure
CO6	Analyze the environmental, plant, and personnel safety criteria and implement them in designing process vessels.

2. Syllabus:

- **INTRODUCTION** (2 Hours)
Introduction to Chemical Engineering Design, Process design, Mechanical aspects of process equipment design, General design procedure, Equipment classifications, Design codes and standards (IS, ASTM and BS)
- **CRITERIA IN VESSEL DESIGN** (3 Hours)
Properties of materials, Material of construction for various equipments and services, Material specifications, Fabrication techniques
- **DESIGN OF PRESSURE VESSELS** (11 Hours)
Design of pressure vessels under internal pressure, Construction features, Pressure vessel code, Design of shell, various types of heads, nozzles, flanges for pressure vessel, Design and construction features of thick-walled pressure vessels, Various types of jackets and coils for reactors, Auxiliary process vessels
- **SUPPORTS FOR VESSELS** (4 Hours)
Design consideration for supports for process equipments, Design of brackets support, leg support skirt, support, saddle support.
- **DESIGN OF STORAGE VESSEL** (3 Hours)
Storage of nonvolatile and volatile liquids and gases, Codes for storage vessel design, Bottom, Roof and Shell designs.
- **DESIGN OF VESSELS UNDER EXTERNAL PRESSURE** (3 Hours)
Design criteria for external design pressure, vessels operated under vacuum, Use of stiffeners, Design of covers, pipes and tubes
- **DESIGN OF HEAT EXCHANGERS** (8 Hours)

Types of heat exchangers, Selection criteria, Design of heat exchangers- shell, tube, baffles, closures, channels, tube sheets etc.

- **DESIGN OF DISTILLATION AND ABSORPTION COLUMNS (6 Hours)**
Basic features of tall vertical equipments/ towers, Towers/Column Internal, Design of tower shell and internals, supports etc.
- **PROCESS HAZARDS & SAFETY, MEASURES IN EQUIPMENT DESIGN (2 Hours)**
Equipment testing, Analysis of hazards, Pressure relief devices, Safety measures in process equipment design

(Total Lecture Hours: 42 + Tutorial Hours: 14)

3. Practicals:

Selected Design and Drawing

1. Design & drawing of Pressure Vessels
2. Design & drawing of Heat Exchangers
3. Design & drawing of Distillation Columns
4. Design & drawing of Reactors
5. Design & drawing of Storage Vessels
6. Design & drawing of Evaporators
7. Design & drawing of Crystallizers
8. Design & drawing of Dryers, etc.
9. Sketches of equipment accessories such as covers for pressure vessels, flanges, flange facing, supports, roofs for storage vessel, jackets, coils, tube sheet for heat exchangers, baffles in head exchangers, trays for distillation columns, packing for distillation towers, liquid distributors etc.
10. AutoCAD drawing: Flange, Hub, 3-D Pressure vessel, 3-D Flange

4. Books Recommended:

1. Joshi M.V., Mahajani V.V., Umarji S.B., "Joshi's Process Equipment Design", 5rd Ed., MacMillan, Delhi, 2014.
2. Indian Standard 2825 (1969).
3. Bhattacharyya B.C., "Introduction to Chemical Equipment Design: Mechanical Aspects", 5th Ed., CBS Publishers, New Delhi, 2008.
4. Soares C., "Process Engineering Equipment Handbook", McGraw-Hill, New York, 2002.
5. Cheremisinoff N.P., "Handbook of Chemical Processing Equipment", Butterworth Heinemann, Oxford, 2000.

Process Modeling and Simulation

L	T	P	Credit
3	1	0	04

Core-13: CH306

Scheme

1. Course Outcomes (COs):

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

CO1	Formulate and develop mathematical models of chemical engineering systems
CO2	Solve and validate the developed model
CO3	Analyze various phenomena in chemical processes
CO4	Find errors while analyzing experimental data
CO5	Develop simulation skills to solve mathematical problems with the help of various simulation software.
CO6	Develop prediction and decision-making skills based on mathematical models.

2. Syllabus:

- **INTRODUCTION** (4 Hours)
Physical and mathematical modelling, Principles of similarity, Independent variables, Dependent variables, Parameters and boundary conditions
- **MODELS** (10 Hours)
Principle of formulations, Mathematical consistency of model, Continuity equations, Component continuity equations, Energy equations, Equations of motion, Transport equations, Equilibrium, Chemical Kinetics with examples.
- **APPLICATIONS IN CHEMICAL ENGINEERING SYSTEMS** (16 Hours)
Heater, Boiler, Heat Exchanger, Condenser; Evaporation, Distillation Column, Adsorption column, Absorption Column, Stripping Column, Extraction, Leaching, Drying, Crystallization, CSTR, Plug flow reactor, Ammonia reactor.
- **SIMULATION** (8 Hours)
Simulation and Information Flow diagram; Parameter estimation; Tools of Simulation
- **INDUSTRIAL SIMULATORS** (4 Hours)
Introduction and applications

(Total Lecture Hours: 42 + Tutorial Hours: 14)

3. Books Recommended:

1. Mickley H. S., Sherwood T. S., Reed C. E., "Applied Mathematics in Chemical Engineering", Tata-McGraw-Hill, New Delhi, 2nd Edition, 2002.
2. Jensen V.G., Jeffreys G.V., "Mathematical Methods in Chemical Engineering", 2nd Ed., Academic Press, London, 1978.
3. Salariya R. S., "Computer Oriented Numerical Methods", Khanna Publisher, India, 2015.

4. Lubyen W. L., "Process Modeling, Simulation and Control for Chemical Engineers", 2nd Ed., McGraw-Hill, New York, 1989.
5. Pushpavanam S., "Mathematical Methods in Chemical Engineering", Prentice-Hall of India, New Delhi, 1st Edition, 2001.

Elective: Environment Health and Safety

L	T	P	Credit
3	0	0	03

CH362

Scheme

1. Course Outcomes (COs):

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

CO1	To describe the environmental ecosystem and its significance.
CO2	To analyze the effects of pollutants on the environment and health.
CO3	To decide the treatment technologies for waste effluents.
CO4	To justify the significance of safety for industries and available laws.
CO5	To estimate the hygiene and occupational health in industrial environment.
CO6	To propose the treatment methodologies for resource generation.

2. Syllabus:

- **INTRODUCTION (5 Hours)**
Importance of Environment, its components, ecology, biosphere, interaction, impact of development, pollution and its effects, reversibility of environment. Safety, Health and safe practices in industries and its importance, sources of pollution from Chemical Industries, public awareness, and sustainability.
- **IMPACT ON BIOLOGICAL ENVIRONMENT (8 Hours)**
Discharge of various effluents (water, air, and solid) and their impacts on environmental and human health, characterization, identification, different treatment processes (chemical, biological, and advanced), Mix first and separate later (MFSL) approach and its disadvantages, decentralization, tertiary treatment, and disinfection.
- **SOLID WASTE TREATMENT AND DISPOSAL (9 Hours)**
Definition, Types of solid waste, generation, onsite handling, storage & processing, Different types of disposal techniques, recovery of resources, reuse of solid waste, electronic waste, policies, and current practices.
- **SAFETY PRACTICES IN INDUSTRIES (5 Hours)**
Safety, loss prevention, safe practice, codes of safety, and integrity for various types of processes, safety and morals, accidents, accident reporting and investigation, personal protective equipments', releases mitigation procedures, financial aspects of safety, case histories, release of toxic effluents
- **INDUSTRIAL HYGIENE AND OCCUPATIONAL HEALTH (5 Hours)**
Industrial hygiene, health and environmental effects, safety and health training, stress safety, radiations and industrial hazards, industrial noise, vibration, electric hazards, Disposal of scrap and other trade wastes, spillage prevention, housekeeping and its advantages, First aid, causalities and injuries.

- **LEGISLATIVE MEASURES** (5 Hours)
Different laws related to liquid, solid, and gases effluents, Different standards and legislations, Factories Act, Workman's Compensation Act, Air Water Pollution Act, Bureau of Indian Standards on safety and health, OSHA, etc.
- **RESOURCE GENERATION** (5 Hours)
Minimizing waste generation, reduce, reuse and recycling of by-products, Waste utilization, waste to energy concept, Sustainability, various advanced techniques like UASB, MFC, OMFC etc.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Masters G.M., "Introduction to Environmental Engineering and Science", Prentice-Hall, New Delhi, 3rd Edition, 2008.
2. MaCarty S., "Chemistry for Environmental Engineering", Tata-McGraw-Hill, New Delhi, 5th Edition
3. Metcalf & Eddy, "Waste Water Engineering: Treatment, Disposal and Reuse", Tata-McGraw-Hill, New Delhi, 4th Edition, 2002.
4. Crowl D. A., Louvar J. F., "Chemical Process Safety", Prantice-Hall, 2nd Ed., New York, 2002.
5. Grady, C.P.L, Daigger, G, and Lim, H, C, "Biological Waste Water Treatment", 2nd Edition, Marcel Dekker, 1999.

4. Further Reading:

1. Lees, F.P., "Loss Prevention in Process Industries", Butterworths, NewDelhi, 4thEdn., Aug 2012
2. Rao, C. S., "Environmental Engineering", Wiley Eastern Limited, New Delhi, 1995.
3. Droste R. L., "Theory and Practice of Water and Wastewater Treatment", Wiley India, 1996.

Elective: Petrochemical Technology

L	T	P	Credit
3	0	0	03

CH364

Scheme

1. Course Outcomes (COs):

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

CO1	Identify the origin, accumulation and types of petroleum.
CO2	Explain the process of fractionation of crude oil and identify the specifications required for good quality petroleum product.
CO3	Discuss the production process of various types of petrochemical products.
CO4	Describe the operation of various petrochemical industries and process parameters for petrochemical production.
CO5	Describe safety and environmental aspects in petrochemical industries.
CO6	Apply subject knowledge to solve problems arising in various petrochemical industries.

2. Syllabus:

- **ORIGIN OF PETROLEUM AND INTRODUCTION TO PETROCHEMICALS** (4 Hours)
Origin of petroleum, Classification of crude, Composition of crude, Types of refineries and refinery products, Raw material for organic chemical industries, Profile of petrochemical industry and its structure.
- **UNIT PROCESSES AND PETROCHEMICAL PROCESSING** (6 Hours)
Unit processes in petrochemical industries and applications, Nitration and derived chemicals like nitrobenzene, nitrotoluenes, Halogenation and derived chemicals like DCM, MCA, VCM, chlorobenzene, Esterification and production of C1 to C4 alcohols.
- **PRODUCTION OF OLEFINS AND DERIVATIVES** (10 Hours)
Naphtha and gas cracking for production of olefins, Recovery of chemicals from FCC and steam cracking, Ethylene derivatives: Ethylene Oxide, Ethylene glycol, Vinyl chloride, Propylene and Propylene oxide.
- **PRODUCTION OF AROMATICS AND SPECIALTY PRODUCTS** (10 Hours)
Aromatics separation train, Aromatics product profile - Benzene, Toluene, Xylene, Ethyl benzene & Styrene, Cumene and phenol, Bisphenol, Aniline, Specialty products like industrial grease- Manufacture of calcium grease, Liquid paraffin and petroleum jelly. Polymer gasoline: Feed stock and reactions of polymer gasoline.
- **PRODUCTION OF POLYMERS, ELASTOMERS AND FIBERS** (12 Hours)
Polymers: Polyethylene, Polypropylene, Polystyrene, Polyvinylchloride, polycarbonate, Thermoset resin: phenol formaldehyde, urea formaldehyde and melamine formaldehyde
Elastomers: Styrene Butadiene Rubber (SBR), Poly butadiene, Nitrile rubber, Polyimides or Nylons (PA), DMT and Terephthalic acid, Polyester, Acrylic fibre, Modified acrylic fibre, Acrylonitrile, Acrolein, Viscose rayon and Acetate rayon.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Groggins P.H., 'Unit Processes in Organic Synthesis', Tata McGraw Hill, 5th Edition, 1995.
2. Chauvel A. and Lefebvre G., 'Petrochemical Processes - I' Gulf Publication; 1st Edition, 1989.
3. Mall I.D., 'Petrochemical Process Technology', Macmillan India Ltd., 2007.
4. Rao M. Gopala, Marshall Sittig, 'Dryden's Outlines of Chemical Technology', East West Press, 3rd Edition, 1997.
5. Wiseman P., 'Petrochemicals,' Ellis Horwood Ltd., 1986.

Elective: Petroleum Refinery Engineering

L	T	P	Credit
3	0	0	03

CH366

Scheme

1. Course Outcomes (COs):

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

CO1	Demonstrate characteristics of crude oil
CO2	Categorize crude before refining
CO3	Explain characteristics of refinery products
CO4	Demonstrate primary and secondary processing required for crude
CO5	Identify different products from primary and secondary processes
CO6	Summarize all the refining processes and effect of the process variables on conversion

2. Syllabus:

- **INTRODUCTION** (2 Hours)
Overall Refinery Flow
- **PRODUCTS** (3 Hours)
Low-Boiling Products, Distillate Fuels, Heating Oils, Residual Fuel Oils and their specification and applications.
- **REFINERY FEEDSTOCKS** (3 Hours)
Crude Oil Properties, Composition of Petroleum, Crudes Suitable for Asphalt Manufacture, Crude Distillation Curves like ASTM, TBP, EFV
- **CRUDE DISTILLATION** (4 Hours)
Desalting Crude Oils, Atmospheric Topping Unit, Vacuum Distillation, Auxiliary Equipment
- **COKING AND THERMAL PROCESSES** (4 Hours)
Types, Properties, and Uses of Petroleum Coke, Process Description—Delayed Coking, Flexicoking, Fluid Coking, Yields from Flexicoking and Fluid Coking, Visbreaking.
- **CATALYTIC CRACKING** (4 Hours)
Fluidized-Bed Catalytic Cracking, Cracking Reactions, Cracking Catalysts, FCC Feed Pretreatment, Process Variables, Heat Recovery
- **CATALYTIC HYDROCRACKING** (4 Hours)
Hydrocracking Reactions, Feed Preparation, Hydrocracking Process, Hydrocracking Catalyst, Process Variables, Hydrocracking Yields.
- **HYDROPROCESSING AND RESIN PROCESSING** (4 Hours)
Composition of Vacuum Tower Bottoms, Processing Options, Hydroprocessing, Expanded-Bed Hydrocracking Processes, Moving-Bed Hydroprocessors, Solvent Extraction.

- **HYDROTREATING** (3 Hours)
Hydrotreating Catalysts, Aromatics Reduction, Reactions, Process Variables, Construction and Operating Costs
- **CATALYTIC REFORMING AND ISOMERIZATION** (4 Hours)
Reactions, Feed Preparation, Catalytic Reforming Processes, Reforming Catalyst, Reactor Design, Yields and Costs, Isomerization
- **ALKYLATION AND POLYMERIZATION** (4 Hours)
Alkylation Reactions, Process Variables, Alkylation Feedstocks, Alkylation Products, Catalysts, Hydrofluoric Acid Processes, Sulfuric Acid Alkylation Processes, Comparison of Processes, Alkylation Yields and Costs, Polymerization.
- **PRODUCT BLENDING** (3 Hours)
Reid Vapor Pressure, Octane Blending, Blending for Other Properties.

(Total Lecture Hours: 42)

3. Books Recommended:

1. James H. Gary, Glenn E. Handwerk, Mark J. Kaiser, "Petroleum Refining Technology and Economics", 5th Ed., CRC Press 2007
2. W. L. Nelson, *Petroleum Refinery Engineering*, 4th Ed, McGraw-Hill Book Company, New York, 1958.
3. David S.J. Jones, Peter R. Pujado, "Handbook of Petroleum Processing", 1st Ed., Springer Publication, 2008.
4. Rao B.K.B., "Modern Petroleum Refining Processes", 4th Ed., Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, 2002, (4th Ed).
5. Mohamed A. Fah Im, Taher A. Alsahhaf, and Amal Elkilani, *Fundamentals of Petroleum Refining*, 1st Ed., Elsevier, 2009.

Elective: Waste to Energy Conversion

L	T	P	Credit
3	0	0	03

CH368

Scheme

1. Course Outcomes (COs):

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

CO1	To explain the potential of energy from waste.
CO2	To classify the biological routes for energy production from waste.
CO3	To explain the basic principles of electrochemistry for the conversion of waste in to electricity.
CO4	To decide the various types of fuel cells/ reactors for the conversion of waste to Energy.
CO5	To estimate the performance of fuel cell by various advanced techniques.
CO6	To propose the advanced techniques/systems for full scale operations.

2. Syllabus:

- **INTRODUCTION (3 Hours)**
Characterization and classification of waste as fuel, potential, conventional practices for waste management, need of nonconventional techniques, segregation of waste, thermodynamic aspects, types of various techniques, environmental aspects, future, and limitations.
- **POTENTIAL OF ENERGY FROM WASTE (5 Hours)**
Quantum of various types of waste (solid and liquid: E-waste, agro based, forest residue, industrial waste, municipal solid and liquid waste), basic calculations for energy potentials, demand and supply of energy, **case** study from incineration, gasification, anaerobic digestion, pyrolysis, syngas utilization etc.
- **BIOLOGICAL ASPECTS (8 Hours)**
Fermentation, anaerobic digestion, algal biomass cultivation, examples like slow rate and high rate reactors, UASB reactors, biochemical aspects for efficient conversion, methane to electricity conversion.
- **ELECTROCHEMICAL ASPECTS (6 Hours)**
Basics of electrochemistry involved in fuel cell, bio-electrochemistry fundamentals, types of cells (galvanic and electrolytic) and lithium ion batteries etc.
- **VARIOUS TYPES OF FUEL CELLS (8 Hours)**
Introduction, structure, principles, workings, potentials, limitations, scale up of various fuel cells like Hydrogen fuel cell, Microbial fuel cell, Microbial desalination cell, Microbial electrolysis cell, Benthic microbial fuel cell, Osmotic microbial fuel cell, etc.
- **VARIOUS ADVANCED TECHNIQUES FOR PERFORMANCE (7 Hours)**
Polarization, Electrochemical Impedances spectroscopy, Cyclic voltammetry, columbic efficiency, Tafel plots, etc.
- **HYBRID SYSTEMS AND CASE STUDY (5 Hours)**
Potential of single units and stacking of multiple units, integration potentials of various hybrid technologies, integration of solar energy, pilot scale demonstration of units, limitations, Power management system for DC/DC or DC/AC conversion

(Total Lecture Hours: 42)

3. Books Recommended:

1. Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store, 2nd Edition, Kindle Edition, 2011
2. Bard A. J., Faulkner L. R., "Electrochemical Methods: Fundamentals and Applications", 2nd Edition, Wiley, 2010.
3. Bagotsky V.S., Skundin A. M., "Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors" 1st Edition, 2014.
4. Young G.C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons, 1st Edition, 2010
5. Logan B. E., "Microbial Fuel Cells", First Edition, Wiley (2007).

4. Further Reading:

1. Davis M. L. and Cornwell, D. A., "Introduction to environmental engineering", Mc Graw Hill International Edition, Singapore, 2008.
2. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), "Biomass Conversion Processes for Energy and Fuels", New York, Plenum Press, 1981.

Elective: Industrial Waste Management Control

L	T	P	Credit
3	0	0	03

CH372

Scheme

1. Course Outcomes (COs):

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

CO1	Recognize different types of industrial waste and their characteristics.
CO2	Analyze the role of microorganisms and its importance in Biological treatment of wastewater.
CO3	Compare different secondary wastewater treatment methods.
CO4	Design different types of wastewater treatment reactors.
CO5	Adapt various waste treatment methods.
CO6	Solve the problems related to wastewater treatment methods.

2. Syllabus:

- **INTRODUCTION (3 Hours)**
Industrial waste, types of industrial waste, sources of industrial waste, characteristics of industrial waste, effects of waste on sewage treatment plants, waste reduction alternatives.
- **WASTEWATER CHARACTERISTICS (2 Hours)**
Types of wastewater, Significance of wastewater contaminants, Discharge limit of wastewater, handling and storage of wastewater.
- **TREATMENT OF WASTEWATER (20 Hours)**
Preliminary or primary treatment of wastewater: Different physical and chemical treatments, Secondary treatment: Aerobic and anaerobic treatment, BOD, COD, MLSS, MLVSS, Attached growth, Suspended growth, Activated sludge growth process, Upflow anaerobic sludge blanket reactor, trickling filter, Rotating biological contactor etc. Various post treatment methods such as lagoon, stabilizing pond, facultative pond etc. Tertiary treatment or advanced treatment: Membrane separation process, membrane bioreactor, nitrogen removal process, phosphorus removal process, Disinfection.
- **SLUDGE TREATMENT AND DISPOSAL (5 Hours)**
Sequence of operations for sludge treatment: Concentration, Digestion, Conditioning, Dewatering, Oxidation.
- **SOLID WASTE TREATMENT (12 Hours)**
Definition, Types of solid waste, storage and handling of solid waste, Different treatment of solid waste, E-waste treatment, Hazardous waste management.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Board, NIIR “Modern Technology of Waste Management: Pollution Control, Recycling, Treatment and Utilization”, Asia Pacific Business Press Inc., 2003.
2. Hammer, M.J. and Hammer M.J. Jr.” Water and Wastewater Technology”, 6th Ed. Prentice Hall Inc., 2008.
3. Bhatia, S.C., “Managing Industrial Pollution”, Macmillan India Ltd., 2003.
4. Rao, C.S. “Environmental pollution control engineering”, New Age International, 2nd Ed., 2011.
5. Nag, A. and Vizayakumar, A. “Environmental education and solid waste management”, New Age International, 2005.

Elective: Polymer Engineering

L	T	P	Credit
3	0	0	03

CH322

Scheme

1. Course Outcomes (COs):

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

CO1	Estimate the basic concept of monomer, polymer and repeating units with properties.
CO2	Classify different polymerization reactions and their mechanisms/kinetics
CO3	Analyse and improve skills in thermal and mechanical properties of polymers
CO4	Describe the viscoelastic behaviour of polymers with respect to their chemical structures and molecular weights
CO5	Demonstrate an ability to predict how the molecular weight will affect properties.
CO6	Analyze polymerization data and predict the conversion and molecular weight,

2. Syllabus:

- **INTRODUCTION** (2 Hours)
Monomers, polymers, classification of polymers
- **POLYMER CHEMISTRY** (9 Hours)
Polymerization methods: addition and condensation; their kinetics, copolymerization, monomer reactivity ratios and its significance, kinetics, different copolymers, random, alternating, azeotropic copolymerization, block and graft copolymers, techniques for copolymerization-bulk, solution, suspension, emulsion
- **POLYMER CHARACTERIZATION** (10 Hours)
Concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, Fractional precipitation, Fractional Elution, Gel Permeation Chromatography (GPC), membrane osmometry, dilute solution viscosity method, ultracentrifugation, analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques.
- **POLYMER BLENDS AND COMPOSITES** (4 Hours)
Difference between blends and composites, their significance, choice of polymers for blending, FRP, particulate, long and short fibre reinforced composites, Nanocomposites.
- **POLYMER TECHNOLOGY** (3 Hours)
Polymer compounding, need and significance of polymer compounding, different compounding ingredients for polymer, crosslinking and vulcanization.
- **POLYMER PROCESSING** (6 Hours)
Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, extrusion, pultrusion, calendaring, rotational molding, thermoforming, rubber processing in two-roll mill, internal mixer.

- **POLYMER DEGRADATION** (3 Hours)
Definition, Types of degradation, some new research on polymer degradation.
- **POLYMER SYNTHESIS AND PROPERTIES** (5 Hours)
Commodity and general-purpose thermoplastics and thermosetting polymers: PE, PP, PS, PVC, PF, MF, UF, Epoxy, Unsaturated polyester etc.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Gowariker, V.R., Viswanathan, N.V., and Sreedhar, J., "Polymer Science" 1st Edition, Halsted Press (John Wiley & Sons), New York, 1986.
2. Billmeyer, F.W., "Text Book of Polymer Science, 3rd edition, John Wiley & Sons, New York, 1984.
3. Ghosh, P. "Polymer Science & Technology of Plastic, Rubber, Blends and Composites" 2nd Edition, Tata McGraw-Hill, New delhi, 2008.
4. Morton-jones, D.H., Chapman and Hall, "Polymer Processing", Springer, London, 1989, 1st Edition.
5. McCrum, N.G., Buckley, C.P. and Bucknall, C.B., "Principles of Polymer Engineering", 2nd Edition, Oxford Science Publication, 1997.

Elective: UNIT PROCESSES

L	T	P	Credit
3	0	0	03

CH324**Scheme****1. Course Outcomes (COs):**

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

CO1	Recognize the significance of unit processes in the field of chemical engineering.
CO2	Apply the basic chemical process kinetics, types of reactor for different types of reaction.
CO3	Determine the selection of appropriate equipment for different process.
CO4	Summarize all the unit processes.
CO5	Analyze the chemistry behind the manufacturing of different chemical products.
CO6	Evaluate the effect of various physical and chemical factors on unit processes.

2. Syllabus:

- **INTRODUCTION** (4 Hours)
Definition and importance of Unit processes in Chemical Engg., Outlines of unit processes, and operations, Chemical process kinetics and Factors affecting it, types of reactors, Symbols used in Chem. Engg. Process flow diagram.
- **NITRATION** (4 Hours)
Definition & scope of nitration reactions, Nitrating agents, Aromatic Nitration (Schimid and Biazzi; nitrators) mixed acid for nitration, D.V.S. value and nitric reaction, Comparison of batch Vs. Continuous nitration, manufacture of Nitrobenzene, Dinitrobenzene.
- **AMINATION BY REDUCTION** (6 Hours)
Definition & scope of Amination reactions, various methods of reductions and factors affecting it, Batch and Continuous process for manufacture of Aniline from Nitrobenzene, Continuous process for manufacture of Aniline from nitrobenzene using catalytic fluidized bed reactor, material of construction in such processes.
- **HALOGENATION** (5 Hours)
Definition and scope of various halogenation reactions, Halogenating agents, thermodynamics and kinetics of halogenations reactions. Benzene hexa-chloride and vinyl chloride from Ethylene and Acetylene.
- **SULFONATION AND SULFATION** (3 Hours)
Definition and scope of such reactions, sulfonating and sulfating agents and their applications, Chemical and physical factors affecting it. manufacture of Benzene sulfonates, Sulfation of Dimethyl Ether and Lauryl Alcohol.
- **AMINATION BY AMMONOLYSIS** (3 Hours)
Definition & types of reactions, Aminating agents, Physical and Chemical factors affecting it. Catalyst used in Ammonolysis, manufacture of Aniline from chlorobenzene and Nitroaniline from Dichloro Nitro Aniline.

- **OXIDATION** **(5 Hours)**
Definition and Types, Oxidizing agents, Liquid phase oxidation. Thermochemistry and kinetics. manufacture of Acetaldehyde from Acetic acid and manufacture of Acetic acid from Ethanol. Vapor phase oxidation of Benzene and Naphthalene, Apparatus and its material of construction for oxidation reactions.
- **HYDROGENATION** **(5 Hours)**
Definition and its scope, properties of hydrogen and sources of hydrogen, gas catalytic hydrogenation and hydrogenolysis, Kinetics and thermodynamics of hydrogenation reactions, Apparatus and material of construction, Industrial hydrogenation of fat & oil, manufacture of Methanol from CO₂ & H₂.
- **HYDROLYSIS** **(4 Hours)**
Definition and types of hydrolysis, Hydrolyzing agents, thermodynamics and kinetics of Hydrolysis, Industrial Hydrolysis of fat, manufacture of ethanol from ethylene (shell process).
- **POLYMERIZATION** **(3 Hours)**
Introduction & chemistry of polymerization reactions, classifications of polymers methods of polymerization.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Groggins P. H., "Unit Processes in Organic Synthesis", 5th edition, Tata-McGraw Hill, New Delhi, 2001.
2. Gopalarao. M. , Sitting M., "Dryden's Outlines of Chemical Tech.", 2nd Ed., East-West Pub., New Delhi, 1997.
3. Austin G. T., "Shreve's Chemical Process Industries", 5th Ed. McGraw-Hill Pub., 1994.
4. Kent J.A., "Riggel's Handbook of Industrial Chemistry", 11th Ed., Van Nostrand Reinhold, 1974.
5. Robert Thronton Morrison, et al., "Organic Chemistry". 7th Edition, Pearson Publications, 2014.

Elective: Chemical Product Design

L	T	P	Credit
3	0	0	03

CH326

Scheme

1. Course Outcomes (COs):

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

CO1	Recognize the importance of Chemical Product Design.
CO2	Analyze the complex issues involved in chemical product.
CO3	Determine relevant product attributes based on property function
CO4	Select and apply tools to design product and devices
CO5	Design novel engineering device based on requirements.
CO6	Design new product structures and evaluate the performance by advanced computing tools (e.g. Molecular Simulation)

2. Syllabus:

- **INTRODUCTION (4 Hours)**
Importance of Chemical product design, Classification of chemical products: Specialty products, formulated products, assembled products; Framework for Chemical product design and development, product introduction and design procedure
- **DESIGN CRITERIA (4 Hours)**
Needs: identifying products, converting needs to specifications; Ideas: Ideas sources, sorting and screening of ideas; Selection: selection criteria based on thermodynamics and kinetics, other criteria; Manufacture
- **PRODUCT DESIGN APPROACHES (4 Hours)**
Experiments, database, Heuristics, Model based approach; Heuristics: hierarchical decomposition method, heuristics to design engineering parameters of a chemical product
- **MODEL-BASED PRODUCT DESIGN APPROACH (9 Hours)**
Molecular dynamics, Mathematical Programming
- **CHEMICAL PRODUCT DESIGN AND PROCESS DESIGN (10 Hours)**
- **UNCONVENTIONAL PROCESSING TECHNIQUE**
Addition/formation techniques: coating, agglomeration such as sintering, and particle agglomeration, and synthesis such as Solvothermal synthesis, coprecipitation, electrolysis process, and emulsion techniques are commonly used for synthesis.
Removal/ destruction techniques: Etching, Breakage and coalescence, challenges, Introduction to Heuristics and Mathematical Programming for process design
- **DESIGNING PRODUCTS (8 Hours)**
Molecular Products, formulated products, and Microstructure

- **ECONOMIC ANALYSIS:** (3 Hours)
Economic metrics for product development, economics of product development, Sensitivity analysis, challenges

(Total Lecture Hours: 42)

3. Books Recommended:

1. Cussler, E.L., and G. D. Moggridge, "Chemical Product Design", Cambridge University press, 2nd Ed., 2011.
2. Seider, W.D., Seader, J.D., Lewin, D.R., "Product and Process Design Principles", 4th Ed., Wiley, New York, 2004.
3. Wei, J., "Product Engineering: Molecular structure and properties", 2nd Ed., Oxford University Press, 2007.
4. Selected topics from "Tools for chemical product design", Eds: M. Martin, M. R. Eden, N. G. Chemmangattuvalappil, Chemical aided chemical engineering book, 39. Elsevier
5. Moggridge G. D., Cussler, E.L., and, An Introduction to Chemical Product Design, Chemical Engineering Research and Design, 78 (1) 2000, 5-11

Elective: Fundamentals of Colloid and Interface Science

L	T	P	Credit
3	0	0	03

CH328**Scheme****1. Course Outcomes (COs):**

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

CO1	State and recognize the fundamental principles of colloids and interfacial science
CO2	Identify various types of colloidal dispersions and classify them based on their characteristics
CO3	Calculate surface tension and/or interfacial tension for various systems based on the data given related to various methods
CO4	Classify various types of surfactants based on their characteristics, structure, and applications
CO5	Describe the important concepts of interfacial science,
CO6	Evaluate the stability of interfaces, stability of colloidal dispersions, wetting and spreading of droplets on various substrates, and their applications in chemical engineering

2. Syllabus:

- **INTRODUCTION** (3 Hours)
Introduction to Colloids, Colloidal systems, Thin Films, Surfaces and Interfaces, Characteristics of colloidal systems, Industrial applications.
- **PHENOMENOLOGY OF COLLOIDAL MATERIALS** (5 Hours)
Forces in colloidal systems, Hydrophobic interaction, Stability, Association colloids, DLVO theory, Non-DLVO forces, Brownian motion and Brownian flocculation.
- **INTER-MOLECULAR AND INTER-PARTICLE FORCES** (8 Hours)
Charge-charge interaction, Dipole-dipole interaction, Ion-dipole interaction, van der Waals interaction, Hamaker's approach, Deryaguin's approximation, Lifshitz continuum theory of forces between macroscopic bodies.
- **SURFACTANTS, MICELLES AND SELF ASSEMBLY SYSTEMS** (8 Hours)
Classification of surfactants, Factors affecting behavior of surfactants, Vesicles, Micelles, Reverse micelles, Mixed surfactant systems, Monolayers, Bilayers, Applications.
- **EMULSIONS, FOAMS AND GELS** (4 Hours)
Characteristics and applications of Emulsions, Gels, Microemulsions, Stability of Emulsions, Applications of foams, Hydrotropy: theory and applications, Foam stability and foamability, applications
- **ELECTROKINETIC PHENOMENA** (3 Hours)
Electroosmosis, Electrophoresis, etc.

- **INTERFACES AND THIN FILMS** (3 Hours)
Interfaces, Curved interfaces, Interfacial tension and its measurement, Thermodynamics of interfaces, Interfacial rheology, Friction, Lubrication, Adhesion, Macromolecular Surface Films, Charged Films, and Langmuir-Blodgett Layers
- **WETTING AND SPREADING** (3 Hours)
Contact angle, Surface characteristics, Modification of wetting, Capillarity, Thermodynamics of wetting and spreading.
- **SELECTED TOPICS FROM CURRENT LITERATURE** (5 Hours)

(Total Lecture Hours: 42)

3. Books Recommended:

1. Ghosh, P., "Colloid and Interface Science", PHI Learning, New Delhi, 2009.
2. Miller, C. A. and P. Neogi, "Interfacial Phenomena : Equilibrium and Dynamic Effects", 2nd Edn., CRC Press, NY, 2019.
3. Hiemenz, P. C., and R. Rajgopalan, "Principles of Colloid and Surface Chemistry", 3rd Edn., Marcel Dekker, NY, 1997.
4. Adamson, A. W. and Gast, A., "Physical Chemistry of Surfaces", 6th edition, John Wiley and Sons, 1997.
5. Stokes, R. J. and Evans, D.F., "Fundamentals of Interfacial Engineering", Wiley-VCH, N.Y., 1996.

Elective: Corrosion and Electrochemical Engineering

L	T	P	Credit
3	0	0	03

CH332

Scheme

1. Course Outcomes (COs):

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

CO1	Apply laws of electrochemistry to understand mechanism of corrosion
CO2	Estimate the rate of corrosion.
CO3	Differentiate between different types of corrosion.
CO4	Identify the factors causing corrosion and solve problems involving various types of corrosion.
CO5	Assessment of damage caused by corrosion.
CO6	Select suitable technique for corrosion prevention.

2. Syllabus:

- **ELECTROCHEMISTRY OF CORROSION (6Hours)**
Corrosion – introduction and definitions; Electrochemical cells - definitions and principles; Potential measurements - galvanic cells, concentration cells; EMF and Galvanic series - bimetallic couples; Eh-pH diagrams – fundamental aspects; Construction of Eh – pH diagrams; FeH₂O-O₂ diagram; Copper, Aluminium and general corrosion diagrams
- **CORROSION KINETICS AND APPLICATION OF ELECTROCHEMISTRY (10Hours)**
Overpotential; Activation Polarization; Concentration Polarization; Ohmic Drop; Graphical Presentation of Kinetic Data (Evans Diagrams); Activation Controlled Processes; Concentration Controlled Processes; Examples of Applied Electrochemistry to Corrosion; Electrochemical Polarization Corrosion Testing; Corrosion Monitoring; Cathodic Protection; Anodic Protection; Aluminum Anodizing; Chloride Extraction.
- **FORMS OF CORROSION (6 Hours)**
Recognizing Corrosion; Localized Corrosion (Pitting Corrosion, Crevice Corrosion, Galvanic Corrosion, Intergranular Corrosion, Dealloying, Hydrogen-Induced Cracking, Hydrogen Blistering, etc.); Velocity Induced Corrosion (Erosion–Corrosion, Cavitation, etc.); Mechanically Assisted Corrosion (Stress Corrosion Cracking, Corrosion Fatigue, Fretting Corrosion, etc.).
- **FACTORS AFFECTING CORROSION AND ITS MONITORING (8Hours)**
Effect of ambient conditions; Corrosion by fresh water and other types of water; Corrosion by atmosphere; corrosion in soil; Microbiologically affected corrosion; Corrosion in concrete; corrosion in petroleum industries; Corrosion Test Methods and Testing Procedure; Electrochemical Testing; Corrosion Monitoring and Inspection; Monitoring of Cathodic Protection; Inspection and Monitoring of Process Plants; Monitoring and Testing in Other Environments.
- **RISK ASSESSMENT OF CORROSION AND ITS MITIGATION (12Hours)**
Risk Assessment and Analysis; Risk Assessment Methods; Cost of Corrosion; Hazard and Operability; Failure Modes – Effects and Criticality Analysis; Risk Matrix Methods; Fault Tree Analysis; Event Tree Analysis; Industrial Example of corrosion assessment and Damage

Assessment; Cathodic Protection; Sacrificial Cathodic Protection; Impressed Current Cathodic Protection; Protective Coatings; Types of Coatings; Coatings Failure; Economic Aspects of Coating Selection and Maintenance; Organic Coatings; Inorganic (Nonmetallic) Coatings; Metallic Coatings; Coating Inspection and Testing; Surface Preparation.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Roberge, P.R., 'Corrosion engineering: principles and practice' 1st Edition, New York: McGraw-Hill, 2008.
2. Kelly, R.G., Scully, J.R., Shoesmith, D. and Buchheit, R.G., 'Electrochemical techniques in corrosion science and engineering' 1st Edition, CRC Press, 2002.
3. Bardal, E., 'Corrosion and protection' 1st Edition, Springer Science & Business Media, 2004.
4. Landolt, D., 'Corrosion and surface chemistry of metals' 1st Edition, EPFL press, 2007.
5. Ahmad, Z., 'Principles of corrosion engineering and corrosion control' 1st Edition, Elsevier Science and Technology Books, 2006.