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

(Effective from AY: 2022-23)

Sr. No.	Course	Code	Credits	Teaching Scheme			Examination Scheme			Total
				L	T	P	L	T	P	
1	Mass Transfer Operations – II (Core – 8)	CH301	5	3	1	2	100	25	50	175
2	Chemical Engineering Thermodynamics – II (Core – 9)	CH303	4	3	1	0	100	25	---	125
3	Chemical Reaction Engineering – II (Core – 10)	CH305	4	3	1	0	100	25	---	125
4	Institute Elective – I	CH3XX	3	3	0	0	100	---	---	100
5	Core Elective – I	CH3AA	3	3	0	0	100	---	---	100
6	Professional Ethics, economics & Business management	HU302	4	3	1	0	100	25	---	125
7	Seminar	CH307	1	0	0	2	---	---	50	50
	TOTAL		24	18	4	4	600	100	100	800
Total contact hours per week = 26										

Institute Elective – I (CH3XX)		
Sr. No	**Code**	**Elective Course**
1.	CH361	Safety , Hazard and risk analysis
2.	CH363	Cleaner Technologies in Chemical Process Industries
3.	CH365	Fuels and Combustion
4.	CH367	Introduction to Engineering Statistics

Core Elective – I (CH3AA)		
Sr. No	**Code**	**Elective Course**
1.	CH321	Bioprocess Engineering
2.	CH323	Computational Heat Transfer and Fluid Flow
3.	CH325	Fundamentals of Biochemical Engineering
4.	CH327	Introduction to Electrochemistry

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

(Effective from AY: 2022-23)

Sr. No.	Course	Code	Credits	Teaching Scheme			Examination Scheme			Total
				L	T	P	L	T	P	
1	**Instrumentation and Process Control (Core-11)**	**CH302**	**5**	**3**	**1**	**2**	**100**	**25**	**50**	**175**
2	Process Equipment Design and Drawing (Core-12)	CH304	5	3	1	2	100	25	50	175
3	**Process Modelling and Simulations (Core-13)**	**CH306**	**4**	**3**	**1**	**0**	**100**	**25**	**---**	**125**
4	Chemical Engineering Plant Design and Economics	CH308	4	3	1	0	100	25	---	125
5	Institute Elective – 2	CH3YY	3	3	0	0	100	---	---	100
6	Core Elective -2	CH3BB	3	3	0	0	100	---	---	100
7	Core Elective -3	CH3CC	3	3	0	0	100	---	---	100
	TOTAL		27	21	4	4	700	100	100	900
Total contact hours per week = 29										

Institute Elective – 2 (CH3YY)		
Sr. No	**Code**	**Elective Course**
1.	CH362	Environmental Health and Safety
2.	CH364	Petrochemical Technology
3.	CH366	Petroleum Refinery Engineering
4.	CH368	Waste to Energy Conversion
5.	CH372	Industrial Waste Management Control

Core Elective – 2 (CH3BB)		
Sr. No	**Code**	**Elective Course**
1.	CH322	Polymer Engineering
2.	CH324	Unit Processes
3.	CH326	Chemical Product Design
4.	CH328	Fundamentals of Colloid and Interface Science
5.	CH332	Corrosion and Electrochemical Engineering

Core Elective – 3 (CH3CC)		
Sr. No	**Code**	**Elective**
1.	CH334	Advanced Particle Technology
2.	CH336	Computational Fluid Dynamics
3.	CH338	Chemical Process Development and Design
4.	CH342	Advances in Chemical Engineering
5.	CH344	Enzyme science and Technology
6.	CH346	New Separation Techniques
7.	HUXXX	Innovation Incubation and Entrepreneurship (Course will be taught by Department of Mathematics and Humanities)

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)

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3. <u>Practicals (At least 9 experiments to be performed):</u>

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., Elservier, 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)

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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)

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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.

B. Tech. III (All Branches), Semester - V

L	T	P	Credit
3	1	0	04

Professional Ethics, Economics and Business Management

HU 301 **Scheme: 3-1-0**

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

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

CO1	Develop knowledge regarding Professional ethics

CO2	Develop knowledge of Economics in engineering
CO3	Develop managerial skills to become future engineering managers
CO4	Develop skills related to various functional areas of management (Marketing Management, Financial Management, Operations Management, Personnel Management etc.)
CO5	Build knowledge about modern management concepts
CO6	Develop experiential learning through Assignments, Management games, Case study discussion, Group discussion, Group presentations etc.

2. Syllabus:

- **PROFESSIONAL ETHICS** **(06 Hours)**

Introduction, Meaning of Ethics, Approaches to 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

- **ECONOMICS** **(8 Hours)**

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

- **MANAGEMENT** **(14 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, Theories of Leadership

- **FUNCTIONAL MANAGEMENT** **(12 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; 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** **(2 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: 42 + Tutorial Hours: 14 = 56 Hours)**

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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

4. Additional Reading:

1. Crane A. & Matten D., Business Ethics: Managing Corporate Citizenship and Sustainability in the Age of Globalisation, Oxford University, 2010
2. Fritzsche D. J., Business Ethics: a Global and Managerial Perspectives, McGraw Hill Irwin, Singapore, 2004
3. Mandal S. K., Ethics in Business and Corporate Governance, Tata McGraw Hill, 2011

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 Conctruction; 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)

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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 supercapicators.

- **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)

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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.

Elective: SAFETY, HAZARD AND RISK ANALYSIS

L	T	P	Credit
3	0	0	03

CH361 **Scheme**

1. <u>Course Outcomes (COs):</u>

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	Adapt the important learnings from the Case Histories.
CO6	Summarize the characteristics of various causes of incidents like toxic release, fire and explosion etc.

2. <u>Syllabus:</u>

- **SAFETY** **(10 Hours)**
  Safety Programs, Engineering Ethics, Accident Loss Statistics- FAR, OSHA, Fatality rate, Acceptable risk, Public Perceptions, Inherent safety, Nature of the accident process and their steps, Case Studies: 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.

- **HAZARDS AND ITS IDENTIFICATION** **(10 Hours)**
  Toxicology: Entry of toxicants in Biological organism (BO), Elimination of Toxicant from BO, Effect of Toxicants in BO, Dose Versus Response, TLVs; **Fire And Explosion**: 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. **Methods of Hazard Identification**: Process hazard checklists, HAZOP study, Safety Reviews, Other methods, Problem solving.

- **RISK ANALYSIS** **(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** **(12 Hours)**
  Static Static Electricity:Tank Car Loading Explosion, Explosion in a Centrifuge, Duct System Explosion; Chemical Reactivity: Bottle of Isopropyl Ether, etc; System

Designs: Ethylene Oxide Explosion, Ethylene Explosion, Butadiene Explosion, Pump Failure etc ; Procedures: Leak Testing a Vessel, Man Working in Vessel, Vinyl Chloride Explosion etc , Dangerous Water Expansion, Phenol-Formaldehyde Runaway Reaction, Conditions and Secondary Reaction Cause Explosion etc

(Total Lecture Hours: 42 Hours)

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3. <u>Books Recommended:</u>

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, New Delhi, 2005.
3. Perry's Chemical Engineers' Handbook, 8^{th} Edition
4. "Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control", Butterworth-Heinemann, 2012.
5. Raju, K.S.N., "Chemical Process Industry Safety", McGraw Hill Education Pvt Ltd. (India), 2014.

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)

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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: 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)

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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 consept 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)

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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.

B.TECH. 6th Sem

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	Developand analysethe 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	Analysesecond order system and higher order system for dynamicbehaviour 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 characrtistics

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)

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3. <u>Practicals:</u>

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. <u>Books Recommended:</u>

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. Coughnower D. R. , Koppel L. B. ,"Process system Analysis and control " McGraw Hill Inc., New York, 1stEdition, 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. <u>Course Outcomes (COs):</u>

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. <u>Syllabus:</u>

- **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)

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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.

Chemical Engineering Plant Design and Economics

L	T	P	Credit
3	1	0	04

Core-14: CH308 **Scheme**

1. Course Outcomes (COs):

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

CO1	Appraise criteria for selection of a process and explain the importance of plant location and plant layout, cost estimation and profitability analysis of process plants
CO2	Construct flow diagrams for a given reaction with known conditions.
CO3	Recognize the importance of process utilities and auxiliaries for better plant operations.
CO4	Prepare the control strategies for a given process flow diagram with known conditions.
CO5	Compare various equipment's for the same activity based on economy.
CO6	Appraise the concept of optimization in plant operation and importance of project management tools (PERT and CPM) in process industries.

2. **Syllabus:**

- **INTRODUCTION** (2 Hours)
  Basic consideration in chem. Engg. plant design, project identification, preliminary technoeconomic feasibility.

- **PROCESS DESIGN ASPECTS** (4 Hours)
  Selection of process, factors affecting process selection, types of flow diagrams.

- **SELECTION OF PROCESS EQUIPMENT** (2 Hours)
  Standard versus special equipment, materials of construction, selection criteria etc.

- **PROCESS AUXILIARIES** (3 Hours)
  Piping design, layout, support for piping insulation, types of valves, process control & instrumentation control system design.

- **PROCESS UTILITIES** (4 Hours)
  Process water, boiler feed water, water treatment & disposal, steam, oil heating system, chilling plant, compressed air and vacuum system.

- **PLANT LOCATION AND LAYOUT** (4 Hours)
  Factors affecting plant location, use of scale models.

- **COST ESTIMATION** (6 Hours)
  Factors involved in project cost estimation, total fixed & working capital, types & methods of estimation of total capital investment, estimation of total product cost, factors involved.

- **DEPRECIATION** (3 Hours)
  Types and methods of determination, evaluation.

- **PROFITABILITY** (4 Hours)
  Alternative investment & replacement methods for profitability evaluation, economic consideration in process and equipment design, inventory control.

- **OPTIMUM DESIGN** (2 Hours)
  General products rates in plant operation, optimum conditions etc.

- **PRODUCTION, PLANNING, SCHEDULING AND CONTROL** (8 Hours)
  Introduction, PERTS & CPM

(Total Lecture Hours: 42)

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3. <u>Books Recommended:</u>

1. Peters M.S., Timmerhaus, K.D., “Plant Design and Economics for Chemical Engineers”, 4th Ed., McGraw-Hill, Singapore, 1991.

2. Vilbrant F.C., Dryden, C.E., “Chemical Engineering and Plant Design”, 4th Ed., McGrawHill, New York, 1959.

3. Pant J.C. “CPM and PERT with Linear Programming”, Jain Brothers, New Delhi, 1986.

4. Davis, G.S, "Chemical Engineering Economics and Decision Analysis", CENDC, I.I.T., Madras, 1981.

5. Holland, F.A., Watson, F.A and Wilkinson, J.K., "Introduction to Process Economics", Wiley, New York, 1974.

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 BLANDS 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)

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3. <u>Books Recommended:</u>

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 chemical industries.
CO2	Apply the basic chemical process kinetics and types of reactors for different types of reaction.
CO3	Determine the selection of appropriate equipment for different processes.
CO4	Summarize all 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 CO_2 & H_2.

- **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)

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3. Books Recommended:

6. Groggins P. H., "Unit Processes in Organic Synthesis", 5th edition, Tata-McGraw Hill, New Delhi, 2001.
7. Gopalarao. M. , Sitting M., "Dryden's Outlines of Chemical Tech.", 2nd Ed., East-West Pub., New Delhi, 1997.
8. Austin G. T., "Shreve's Chemical Process Industries", 5th Ed. McGraw-Hill Pub., 1994.
9. Kent J.A., "Riggel's Handbook of Industrial Chemistry", 11th Ed.,Van Nostrant Reinhold, 1974.
10. 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 requirments.
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)

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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, Visicles, 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)

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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 COROSION 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)

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3. <u>Books Recommended:</u>

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.

Elective: Advanced Particle Technology

L	T	P	Credit
3	0	0	03

CH334 **Scheme**

1. Course Outcomes (COs):

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

CO1	Recognize the importance of powder processing and handling
CO2	Analyze the complexities involved in particles characterization
CO3	Analyze and interpret bulk powder behaviour and its interaction with surrounding.
CO4	Select and apply relevant research strategies to study behaviour and performance of particulate materials
CO5	Design particulate product based on learned concepts
CO6	Apply advanced computing techniques to understand, analyse and solve complex powder flow problems

2. Syllabus:

- **PARTICLE PROPERTIES AND MEASUREMENT – I** **(3 Hours)**

Particle size measurement, analysis, Fine particle statistics, Different types of shape descriptors, Image processing for shape characterization, Particle Packing and Product Porosity, Rheology of Emulsions and Suspensions, dispersion of particles.

- **PARTICLE PROPERTIES AND MEASUREMENT – II** **(6 Hours)**
  Overview of advanced particle measurement techniques, size measurement by Dynamic light scattering, size measurement by sedimentation techniques, Introduction to imaging techniques and surface area measurement, XRD Line broadening analysis to determine crystallite size and strain.

- **FUNDAMENTALS AND ADVANCEMENT IN PARTICULATE MATERIALS HANDLING** **(7 Hours)**
  Powder mixing for particulate product formulations and powder flow characterization, powder flowability index, Pharmaceutical powder formulation and Tabletting operations, Stresses in powder, Storage of powder in silo and silo design.

- **FLUIDIZATION OF FINE POWDERS (MICRONIC AND NANOPARTICLES)** **(4 Hours)**
  Introduction to fundamentals of fluidization, Modified Geldart's powder classification, Modified Richardson-Zaki equation for fine particles and Fluidization of nanoparticlultes assemblies, Fluidization assistance techniques, Flow additives to improve fluidization behaviour of fine powder beds.
- **DISCRETE ELEMENT METHOD (DEM) TO MODEL PARTICULATE PROCESSES** **(9 Hours)**
  Introduction to Discrete Element analysis/simulation and application, General formulation of discrete element method, Governing equation and force models, contact and non-contact forces between particles, fluid-particle interaction forces, constitutive relations for granular materials, Integration schemes and damping algorithms for DEM, Contact Detection models :Soft contact model, Hertz contact model, Adhesive elastic contact Model, Generalized methodology to run DEM simulation using LIGGHTS (Open source DEM software).

- **ADVANCED PARTICLES PRODUCTION AND STABILIZATION TECHNIQUES** **(5 Hours)**
  Introduction to Powder production techniques. Wet media milling in agitated bead mill and planetary mill, Methods of stabilization of particles dispersion, electrostatic and electrosteric stabilization, Chemical surface modification of particles in suspension, Zeta potential of suspension.

- **PREPARATION OF PARTICULATE PRODUCT** **(8 Hours)**
  Effects of powder and slurry properties on Preparation of advanced Ceramic materials, effects of particle size on Sintering of powders, dry powder inhalers, pigments and paints dispersions.

(Total Lecture Hours: 42)

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3. **Books Recommended:**

1. Rhodes M. "Introduction to Particle Technology", 2nd Edition, John Wiley & Son, Chichester, (2008).
2. Henk G. Merkus, "Particle Size Measurements: Fundamentals, Practice, Quality", Springer Particle Technology Series, Volume 17 2009.
3. Dietmar Schulze, "Powders and Bulk Solids: Behavior, Characterization, Storage and Flow", Springer-Verlag Berlin Heidelberg 2008.
4. Colin Thornton, Granular Dynamics, Contact Mechanics and Particle System Simulations: A DEM study, Particle Technology Series, Volume 24, 2015
5. Liang-Shih Fan, Chao Zhu, "Principles of Gas-Solid Flow", 1st Edition, Cambridge University Press, New York, 1998.

Elective: Computational Fluid Dynamics

L	T	P	Credit
3	0	0	03

CH336 **Scheme**

1. Course Outcomes (COs):

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

CO1	Explain fundamentals of computational methods in fluid flow applications
CO2	Analyze Initial Boundary Value problems and determine various quantities of interest
CO3	Apply appropriate solution strategy and estimate the accuracy of the results for a given flow case
CO4	Select and formulate various CFD problems by considering appropriate boundary conditions
CO5	Adapt to various commercial software for solving numerical problems
CO6	Interpret computational results

2. Syllabus:

- **INTRODUCTION AND GOVERNING EQUATIONS (5 Hours)**
  Introduction, Classification of partial differential equations, Navier-Stokes system of equations, Boundary conditions.

- **FINITE DIFFERENCE METHODS (5 Hours)**
  Basic aspects of finite difference equations, Derivation of finite difference equations, Accuracy of finite difference solutions,

- **SOLUTION METHODS OF FINITE DIFFERENCE EQUATIONS (6 Hours)**
  Methods for Elliptic, Parabolic and Hyperbolic equations, Implicit and explicit schemes, Von Neumann stability analysis, Example problems.

- **INCOMPRESSIBLE VISCOUS FLOWS (6 Hours)**
  General, Artificial compressibility method, Pressure correction methods, Vortex methods.

- **COMPRESSIBLE FLOWS (6 Hours)**
  Potential equation, Euler equations, Navier-Stokes system of equations, Preconditioning process for compressible and incompressible flows.

- **INTRODUCTION TO FINITE VOLUME METHOD (4 Hours)**
  Integral approach, discretisation & higher order schemes.

  INTRODUCTION TO FINITE ELEMENT METHOD (4 Hours)
  Finite element formulations, definition of errors, Finite element interpolation functions.

- **APPLICATIONS (6 Hours)**
  Chemically reactive flows, Heat transfer and Multiphase flow.

(Total Lecture Hours: 42)

3. Books Recommended:

1. Anderson J.D., "Computational Fluid Dynamics", McGraw-Hill International Editions, 1995.
2. Patankar S.V., "Numerical Heat Transfer and Flow" , McGraw Hill, New York, 2002.
3. Ferziger J. H. and Peric M., "Computational Methods in Fluid Dynamics ", Springer, New York, 2003.
4. Muralidhar K. and Sunderrarajan T., "Computational Fluid Flow and Heat Transfer ", Narosa Publishing House, New Delhi, 2nd Edition, 2003.
5. Chung T. J., "Computational Fluid Dynamics", Cambridge University Press, London, 2nd Edition, 2014.

Elective: Chemical Process Development and Design

L	T	P	Credit
3	0	0	03

CH338 **Scheme**

1. Course Outcomes (COs):

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

CO1	Interpret concepts of process design and development.
CO2	Develop the process based on the data available.
CO3	Evaluate the sequencing of distillation column.
CO4	Identify the importance of various unit operations and their sequence.
CO5	Describe the importance of the intensification of the process.
CO6	Evaluate the design of process based on the given data.

2. Syllabus:

- **INTRODUCTION** **(2 Hours)**
  Introduction to chemical process design. Product design and development. Product life cycle.

- **PROCESS DEVELOPMENT** **(8 Hours)**
  Process design and development, General considerations for chemical process design, Basics of process scale-up, Process synthesis, Flow sheeting, Process planning and scheduling, Optimization approaches to optimal design.
- **PROCESS INTENSIFICATION** **(8 Hours)**
  Principles of process intensification, process integration. Various ways of process intensification, Process intensification for safety, Methodology, and techniques of process intensification in industrial practice.
- **REACTIVE SEPARATIONS IN FLUID SYSTEMS** **(7 Hours)**
  Techniques of reactive absorption, reactive distillation and reactive extraction and their applications.
- **SEQUENCING OF DISTILLATION COLUMNS** **(6 Hours)**
  Basic features of tall vertical equipments/ towers, Towers/Column Internal, Sequencing of distillation towers, Heat integration in distillation columns.
- **PIPING DESIGN AND RATING** **(8 Hours)**
  Basics of piping design, Pipe sizing for single phase flow and multiphase flow.
- **RADIOGRAPHIC TESTING PROCEDURE FOR PRESSURE VESSELS** **(3 Hours)**
  Surface treatment and radiographic procedure, Quality and sensitivity of radiograph, Typical radiographic examination report.

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Coker A.K., "Ludwig's Applied Process Design for Chemical and Petrochemical Plants", Vol.1, 4th Ed., Gulf Professional Publishing, 2007.
2. Douglas J., Conceptual Design of Chemical Processes, McGraw Hill, New York, 1989.
3. Soares C., "Process Engineering Equipment Handbook", McGraw-Hill, New York, 2002.
4. Cheremisinoff N.P., "Handbook of Chemical Processing Equipment", Butterworth Heinemann, Oxford, 2000.
5. Coulson & Richardson's Chemical Engineering, Vol. 6, 4th Ed., Elsevier, Oxford, 2006.

4. Additional Reading:

1. Branan C.R., "Rules of Thumb for Chemical Engineers", 4th Ed., Elsevier, Oxford, 2005.

Elective: Advances in Chemical Engineering

L	T	P	Credit
3	0	0	03

CH342 **Scheme**

1. Course Outcomes (COs):

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

CO1	Analyze the effects of pollutants on the environment and health impacts.
CO2	Express the knowledge of basic principles of different characterization methods.
CO3	Analyze treatment technologies for water/wastewater/solid waste.
CO4	Evaluate the usefulness of nanomaterials in treatment technologies.
CO5	Classify different types of smart polymers and membranes for environment.
CO6	Estimate most advanced methods for treatment for water/wastewater/solid waste.

2. Syllabus:

- **ADVANCE SEPARATION TECHNIQUES** **(12 Hours)**
  Reverse osmosis, Forward osmosis (FO), Pressure retarded osmosis (PRO), Osmotic microbial fuel cell (OMFC), benthic microbial fuel cell (BMFC), Osmotic Membrane bio reactor (OsMBR).

- **ADVANCE CHARACTERIZATION METHODS** **(4 Hours)**
  XRD, SEM, TGA, FT-IR, EDX, Gel permeation chromatography (GPC) etc.

- **ADVANCE POLYMER** **(10 Hours)**
  Smart polymer, advanced polymer nanocomposite, Conductive polymer, bio-route prepared nano polymer, Blended polymer, self-cleaning polymer surfaces

- **RECENT ADVANCES IN MEMBRANES** **(11 Hours)**
  Principles of membrane separation, Membrane Materials, Transport phenomena of species, molecular and ionic, in porous or dense, charged or not, membranes, Layer by layer membrane, Proton exchange membrane, biopolymer based membrane, nanocomposite membrane, coated membrane, different subtract and active layer membrane.

- **SMART HYDROGELS** **(5 Hours)**
  Hydrogel, Core and shell hydrogel, shell and core hydrogel, green hydrogel, stimuli responsiveness hydrogel

(Total Lecture Hours: 42)

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3. <u>Books Recommended:</u>

1. Jornitz, M. W. and Meltzer, T. H., "Filtration and purification in biopharmaceutical industry", Second edition by, Informa Healthcare, Vol. 174. 2007.
2. Bungay P.M., Lonsdale H.K. and de Pinho M.N. (Eds.), "Synthetic Membranes: Science, Engineering and Applications", NATO ASI Series, Vol. 181, D. Reidel Publishing Company, Dordrecht, Holland,1986.
3. Schweitzer P.A. (Ed.), "Handbook of Separation Techniques for Chemical Engineers", 3rd Edition, McGraw-Hill, New York, 1997.
4. Gowariker, V.R. Viswanathan, N.V., and Sreedhar, J., "Polymer Science, Halsted Press (John Wiley & Sons), First Edition, New York, 1986.
5. Ghosh, P. "Polymer science & technology of plastic, rubber, blends and composites", Second Edition, Tata McGraw-Hill, New Delhi, 2008.

Elective: Enzyme Science and Technology

L	T	P	Credit
3	0	0	03

CH344 **Scheme**

1. Course Outcomes (COs):

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

CO1	Define the enzymes in terms of classifications, characterization, purification methods etc.
CO2	Explain the various mechanisms and kinetics of enzyme action as catalyst in biochemical reactions.
CO3	Recognize the significance of various types of enzyme inhibition and its effect on enzymatic reactions.
CO4	Adapt various methods of enzyme immobilization and their significance.
CO5	Design different types of enzymatic reactors for enzymatic reactions.
CO6	Explain various applications of enzyme in chemical and biochemical industries.

2. Syllabus:

- **INTRODUCTION TO ENZYMES** **(5 Hours)**
  Historical aspects, nomenclature and their classification, cost effective production, purification and characterization of enzymes.

- **MECHANISMS AND KINETICS OF ENZYME ACTION (7 Hours)**
  Mechanisms of enzyme action, concept of active site and energetics of enzyme substrate complex formation, specificity of enzyme action, kinetics of single substrate reactions, turn over number, estimation of Michaelis-Menten parameters, factors affecting enzymatic reaction.

- **ENZYMES INHIBITION AND MULTI-SUBSTRATE ENZYME KINETICS (7 Hours)**
  Multi substrate reaction mechanisms and kinetics- Random, Ping-Pong, Ordered; Haldane Relationships; types of inhibition- Competitive, Noncompetitive, Uncompetitive, Product, Substrate; allosteric regulation of enzymes, deactivation kinetics.

- **ENZYME IMMOBILIZATION (8 Hours)**
  Physical and chemical techniques for enzyme immobilization, adsorption, matrix entrapment, encapsulation, cross-linking, covalent binding etc., examples advantages and disadvantages of different immobilization techniques; Effect on mass transfer resistance.

- **ENZYME REACTORS AND PROCESS DESIGN (7 Hours)**
  Types of bioreactors for enzymatic reactions (i.e. continuous, batch, fed-batch etc.)

- **APPLICATIONS OF ENZYMES (8 Hours)**
  Commercial applications of enzymes in food, pharmaceutical and other industries, enzymes for analytical, diagnostic and bioremediation applications, enzymes for green technology, enzymes as biosensors.

(Total Lecture hours: 42 hours)

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3. <u>Books Recommended:</u>

1. Bisswanger, H., "Enzyme Kinetics: Principles and Methods", 3rd Ed.Wiley-VCH Verlag GmbH, Weinheim, 2017.
2. Marangoni, A.G., "Enzyme Kinetics: A Modern Approach", John Wiley & Sons, Inc., Hoboken, New Jersey, 2003
3. Dutta, R., "Fundamental of Biochemical Engineering", Springer, New York, 2008.
4. Sathishkumar, T., Shanmugaprakash, M. and Shanmugam, S., “Enzyme Technology”, 2nd Ed. I.K. International Publishing House, 2012
5. Kirst, H.A., Yeh, W.-K. and Zmijewski, M.J., “ Enzyme Technologies for Pharmaceutical and Biotechnological Applications”, Marcel DeKKerr, Inc.,2001

Elective: New Separation Techniques

L	T	P	Credit
3	0	0	03

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Scheme

1. Course Outcomes (COs):

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

CO1	Analyze the fundamental concepts of separation processes
CO2	Understand the principles and process of crystallization
CO3	Classify various membrane based separation processes and its applications
CO4	Explain the properties of colloidal separation
CO5	Interpret the surfactant-based separation
CO6	Understand the supercritical fluid extraction

2. Syllabus:

- **FUNDAMENTALS OF SEPARATION PROCESSES (4 Hours)**
  Basic definitions of relevant terms, classification, separation processes in chemical process industries, categorization of separation processes, equilibrium and rate governed processes.

- **CRYSTALLIZATION AND REACTIVE SEPARATIONS (7 Hours)**
  Concept, Different types of crystallization, phase equilibrium, different techniques, commercial applications, Cavitations and its application in crystallization, Reactive crystallization.

- **MEMBRANE BASED SEPARATION PROCESSES (15 Hours)**
  Historical background, physical and chemical properties of membranes, techniques of membrane preparation, membrane characterization, various types of membranes and modules. Details and applications of various membrane separation processes.

- **EXTERNAL FIELD INDUCED MEMBRANE SEPARATION PROCESSES FOR COLLOIDAL PARTICLES (6 Hours)**
  Fundamentals of various colloid separations. Derivation of profile of electric field strength. Coupling with membrane separation and electrophoresis.

- **SURFACTANT BASED SEPARATION PROCESSES (8 Hours)**
  Cloud point extraction, Micellar enhanced separation processes.

- **SUPERCRITICAL FLUID EXTRACTION (2 Hours)**
  Working Principle, Advantages & Disadvantages of supercritical solvents over conventional liquid solvents, commercial applications of supercritical extraction, Applications under research

(Total Lecture Hours: 42)

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3. **Books Recommended:**

1. Wankat P. C., “Rate-Controlled Separations”, Elsevier Applied Science, New York, 1990.
2. Bungay P.M., Lonsdale H.K. & de Pinho M.N. (Eds.), “Synthetic Membranes: Science, Engineering and Applications”, NATO ASI Series, Vol.181, D.Reidel Publishing Company, Dordrecht, Holland, 1986
3. Kaushik Nath, "Membrane Separation Processes" , 1st Edition, PHI pvt.Ltd., New Delhi, 2008.
4. Seader J.D., Henley E.J. & Roper D.K., "Separation Process Principles",4th Edition, John Wiley & Sons, Inc. Hoboken, New Jersey,2016
5. Kulprathipanja S. “Reactive Separation Processes” , Taylor and Francis, New York, 2002.

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)

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3. <u>Books Recommended:</u>

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

4. <u>Further Reading:</u>

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 knowledgeto solve problems arising in various petrochemical industries.**

2. Syllabus:

- **ORIGIN OF PETROLEUM AND INTRODUCTION TO PETROCHEMICALS (4 Hours)**
  Originof 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 likeindustrial grease- Manufactureof 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, ureaformaldehyde and melamine formaldehyde Elastomers: Styrene Butadiene Rubber(SBR), Poly butadiene, Nitrile rubber, **Polymides 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. <u>Books Recommended:</u>

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. <u>Course Outcomes (COs):</u>

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. <u>Syllabus:</u>

- **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)

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3. Books Recommended:

1. James H. Gary, Glenn E. Handwerk, Mark J. Kaiser, "Petroleum Refining Technology and Economics", 5th Edi., 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)

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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.

B. Tech. IV (Chemical / Electronics / Electrical / Mechanical Engineering), Semester - VI

Innovation, Incubation and Entrepreneurship (Core Elective)

HU 322 **Scheme: 3-0-0**

1. Course Outcomes (COs):

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

CO1	Explain the concepts of Entrepreneurship
CO2	Develop skills related to various functional areas of management (Marketing Management, Financial Management, Operations Management, Personnel Management etc.)
CO3	Develop skills related to Project Planning and Business Plan development
CO4	Demonstrate the concept of Innovation, Intellectual Property Rights (IPR) and Technology Business incubation
CO5	Build knowledge about Sources of Information and Support for Entrepreneurship

2. Syllabus:

- **CONCEPTS OF ENTREPRENEURSHIP** **(08 Hours)**

  Scope of Entrepreneurship, Definitions of Entrepreneurship and Entrepreneur, Entrepreneural Traits, Characteristics and Skills, Entrepreneurial Development models and Theories, Entrepreneurs Vs Managers, Classification of Entrepreneurs; Major types of Entrepreneurship – Techno Entrepreneurship, Women Entrepreneurship, Social Entrepreneurship, Intrapreneurship (Corporate entrepreneurship), Rural Entrepreneurship, Family Business etc.; Problems for Small Scale Enterprises and Industrial Sickness; Entrepreneurial Environment – Political, Legal, Technological, Natural, Economic, Socio – Cultural etc.

- **FUNCTIONAL MANAGEMENT AREA IN ENTREPRENEURSHIP** **(14 Hours)**

  Marketing Management: Basic concepts of Marketing, Development of Marketing Strategy and Marketing plan

  Operations Management: Basic concepts of Operations management, Location problem, Development of Operations strategy and plan

  Personnel Management:Main operative functions of a Personnel Manager, Development of H R strategy and plan

  Financial Management: Basics of Financial Management, Ratio Analysis, Investment Decisions, Capital Budgeting and Risk Analysis, Cash Flow Statement, Break Even Analysis

- **PROJECT PLANNING** **(8 Hours)**

  Search for Business Idea, Product Innovations, New Product Development – Stages in Product Development; Sequential stages of Project Formulation; Feasibility analysis – Technical, Market, Economic, Financial etc.; Project report; Project appraisal; Setting up an Industrial unit – procedure and formalities in setting up an Industrial unit; Business Plan Development

- **PROTECTION OF INNOVATION THROUGH IPR** **(2 Hours)**

  Introduction to Intellectual Property Rights – IPR, Patents, Trademarks, Copy Rights

- **INNOVATION AND INCUBATION** **(6 Hours)**

  Innovation and Entrepreneurship, Creativity, Green Technology Innovations, Grassroots Innovations, Issues and Challenges in Commercialization of Technology Innovations, Introduction to Technology Business Incubations, Process of Technology Business Incubation

- **SOURCES OF INFORMATION AND SUPPORT FOR ENTREPRENEURSHIP** **(4 Hours)**

  State level Institutions, Central Level institutions and other agencies

(Total Lecture Hours: 42)

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3. Books Recommended:

1. Desai Vasant, Dynamics of Entrepreneurial Development and Management, Himalaya Publishing House, India, 6th Revised Edition, 2020
2. Charantimath P. M., Entrepreneurial Development and Small Business Enterprises, Pearson Education, 3rd Edition, 2018
3. Holt David H., Entrepreneurship: New Venture Creation, Pearson Education, 2016
4. Chandra P., Projects: Planning, Analysis, Selection, Financing, Implementation and Review, Tata McGraw Hill, 9th Edition, 2019
5. Banga T. R. &Shrama S.C., Industrial Organisation & Engineering Economics, Khanna Publishers, 25th Edition, 2015

4. Further Reading:

1. Prasad L.M., Principles & Practice Of Management, Sultan Chand & Sons, 8th Edition,2015
2. Everett E. Adam, Ronald J. Ebert, Production and Operations Management , Prentice Hall of India, 5th edition, 2012
3. Kotler P., Keller K. L, Koshi A.& Jha M., Marketing Management – A South Asian Perspective, Pearson, 14th Edition, 2014
4. Tripathi P.C. , Personnel Management & Industrial Relations, Sultan Chand & sons, 21st Edition, 2013
5. Chandra P., Financial Management, Tata McGraw Hill, 9th Edition, 2015