**SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY**

**DEPARTMENT OF CHEMICAL ENGINEERING**

# B. TECH. IN CHEMICAL ENGINEERING
# 2023-24

**SARDAR VALLABHBHAI NATIONAL**

**INSTITUTE OF TECHNOLOGY**

**ICHHANATH, SURAT – 395007, GUJARAT**

## VISION & MISSION

### INSTITUTE VISION

To be one of the leading Technical Institutes disseminating globally acceptable education, effective industrial training and relevant research output.

### DEPARTMENT VISION

In-line with the vision of the institute, to be a well reputed department with global acceptance and to produce highly skilled and knowledgeable chemical engineering graduates, post graduates and doctorates capable of delivering the best output to the society.

### INSTITUTE MISSION

To be a globally accepted centre of excellence in technical education catalyzing absorption, innovation, diffusion and transfer of high technologies resulting in enhanced quality for all the stake holders.

### DEPARTMENT MISSION

To be one of the top engineering departments with excellent research work in the fields related to Chemical Engineering and offering technical knowhow to the stake holders.

## PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

Students of B. Tech. in Chemical Engineering Program will

**PEO 1:** Have successful career in the diversified area of chemical engineering industry and/or higher studies by acquiring knowledge in fundamentals of chemical engineering at global level.

**PEO 2:** Analyze and design contemporary chemical engineering issues with environmental and social awareness as well as ethical responsibility.

**PEO 3:** Exhibit professional approach, effective communication skills, leadership qualities and team work in their profession and adapt to modern trends by engaging in lifelong learning.

## PROGRAM OUTCOMES (POs)

Students of B. Tech. in Chemical Engineering Program will be able to

**PO 1. Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

**PO 2. Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

**PO 3. Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

**PO 4. Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

**PO 5. Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

**PO 6. The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

**PO 7. Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO 8. Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

**PO 9. Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO 10. Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

**PO 11. Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

**PO 12. Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## PROGRAM SPECIFIC OUTCOMES (PSOs)

**PSO 1:** To apply and evaluate Chemical Engineering Principles to design and improve chemical processes and equipments in conventional and emerging areas of chemical and allied fields.

**PSO 2:** To apply acquired knowledge of chemical engineering professionally and ethically for the benefits of society by providing sustainable solutions.

# TEACHING SCHEME

| Sr. No. | Subject | Code | Scheme L-T-P | Credits (Min.) | Notional hours of Learning (Approx.) |
|---|---|---|---|---|---|
| | **First Semester (1st year of UG)** | | | | |
| 1 | Introduction to Chemical Engineering | CH101 | 3-1-0 | 4 | 70 |
| 2 | Energy and Environment in Chemical Engineering | EG111 | 3-1-0 | 4 | 70 |
| 3 | Mathematics | MA107 | 3-1-0 | 4 | 70 |
| 4 | Engineering Drawing | ME110 | 2-0-4 | 4 | 100 |
| 5 | Applied Chemistry | CY107 | 3-0-2 | 4 | 85 |
| 6 | Workshop Practice | ME105 | 0-0-4 | 2 | 60 |
| 7 | Indian Value System Social Consiousness | HS120 | 2-0-0 | 2 | 35 |
| | | | **Total** | **24** | **490** |
| 8 | Vocational Training / Professional Experience (Optional) (Mandatory for Exit) | CHV01 / CHP01 | 0-0-10 | 5 | 200 (20 x 10) |
| | **Second Semester (1st year of UG)** | | | | |
| 1 | Process Calculations | CH102 | 3-1-0 | 4 | 70 |
| 2 | Unit Processes | CH104 | 3-0-0 | 3 | 55 |
| 3 | Numerical Methods in Chemical Engineering | CH106 | 3-1-0 | 4 | 70 |
| 4 | Fundamentals of Computer and Programming | CH108 | 3-0-2 | 4 | 85 |
| 5 | English and Professional Communication | HS110 | 3-1-0 | 4 | 70 |
| | | | **Total** | **19** | **350** |
| 6 | Vocational Training / Professional Experience (Optional) (Mandatory for Exit) | CHV02 / CHP02 | 0-0-10 | 5 | 200 (20 x 10) |
| | **Third Semester (2nd year of UG)** | | | | |
| 1 | Mechanical Operations | CH201 | 3-1-2 | 5 | 100 |
| 2 | Fluid Flow Operations | CH203 | 3-1-2 | 5 | 100 |
| 3 | Heat Transfer Operations | CH205 | 3-1-2 | 5 | 100 |
| 4 | Mass Transfer Operations-I | CH207 | 3-1-0 | 4 | 70 |
| 5 | Elective | CH2AA | 3-X-X | 3/4 | 55/70/85 |
| | | | **Total** | **22-23** | **425-455** |
| 6 | Vocational Training / Professional Experience (Optional) (Mandatory for Exit) | CHV03 / CHP03 | 0-0-10 | 5 | 200 (20 x 10) |
| | **Fourth Semester (2nd year of UG)** | | | | |
| 1 | Chemical Engineering Thermodynamics – I | CH202 | 3-1-0 | 4 | 70 |
| 2 | Mass Transfer Operations – II | CH204 | 3-1-2 | 5 | 100 |
| 3 | Chemical Reaction Engineering-I | CH206 | 3-1-2 | 5 | 100 |
| 4 | Professional Ethics, Economics and Business Management | MG210 | 3-1-0 | 4 | 70 |
| 5 | Elective | CH2BB | 3-X-X | 3/4 | 55/70/85 |
| | | | **Total** | **21-22** | **395-425** |
| 6 | Minor / Honor (M/H#1) | CH2CC | 3-X-X | 4 | 70/85 |
| 7 | Vocational Training / Professional Experience (Optional) (Mandatory for Exit) | CHV04 / CHP04 | 0-0-10 | 5 | 200 (20 x 10) |

| | | | | | |
|---|---|---|---|---|---|
| | **Fifth Semester (3rd year of UG)** | | | | |
| 1 | General Chemical Technology | CH301 | 4-0-2 | 5 | 100 |
| 2 | Chemical Engineering Thermodynamics– II | CH303 | 3-1-0 | 4 | 70 |
| 3 | Chemical Reaction Engineering – II | CH305 | 3-1-0 | 4 | 70 |
| 4 | Elective | CH3AA | 3-X-X | 3/4 | 55/70/85 |
| 5 | Elective | CH3BB | 3-X-X | 3/4 | 55/70/85 |
| 6 | Seminar | CH307 | 0-0-2 | 1 | 40 |
| | | | **Total** | **20-22** | **390-450** |
| 7 | Minor / Honor (M/H#2) | CH3CC | 3-X-X | 4 | 70/85 |
| 8 | Vocational Training / Professional Experience (Optional) (Mandatory for Exit) | CHV05 / CHP05 | 0-0-10 | 5 | 200 (20 x 10) |
| | **Sixth Semester (3rd year of UG)** | | | | |
| 1 | Instrumentation and Process Control | CH302 | 3-1-2 | 5 | 100 |
| 2 | Process Equipment Design | CH304 | 3-1-0 | 4 | 70 |
| 3 | Chemical Engineering Plant Design and Economics | CH306 | 3-0-0 | 3 | 55 |
| 4 | Elective | CH3DD | 3-X-X | 3/4 | 55/70/85 |
| 5 | Elective | CH3EE | 3-X-X | 3/4 | 55/70/85 |
| 6 | Project-I | CH308 | 0-0-4 | 2 | 60 |
| | | | **Total** | **20-22** | **395-455** |
| 7 | Minor / Honor (M/H#3) | CH3FF | 3-X-X | 4 | 70/85 |
| 8 | Vocational Training / Professional Experience (Optional) (Mandatory for Exit) | CHV06 / CHP06 | 0-0-10 | 5 | 200 (20 x 10) |
| | **Seventh Semester (4th year of UG)** | | | | |
| 1 | Process Modelling and Simulation | CH401 | 3-1-2 | 5 | 100 |
| 2 | Elements of Transport Phenomena | CH403 | 3-1-0 | 4 | 70 |
| 3 | Innovation Incubation and Entrepreneurship | MG110 | 3-1-0 | 4 | 70 |
| 4 | Elective | CH4AA | 3-X-X | 3/4 | 55/70/85 |
| 5 | Elective | CH4BB | 3-X-X | 3/4 | 55/70/85 |
| 6 | Project-II | CH405 | 0-0-4 | 2 | 60 |
| | | | **Total** | **21-23** | **410-470** |
| 7 | Minor / Honor (M/H#4) | CH4CC | 3-X-X | 4 | 70/85 |
| 8 | Vocational Training / Professional Experience (Optional) (Mandatory for Exit) | CHV07 / CHP07 | 0-0-10 | 5 | 200 (20 x 10) |
| | **Eighth Semester (4th year of UG)** | | | | |
| 1 | Industrial Internship / Professional Experience (Mandatory) | CHP08 | 0-0-40 | 20 | 800 (20 x 40) |
| | | | **Total** | **20** | **800** |

**Note: One compulsory MOOC course from Swayam – NPTEL portal of 3/4 credits at the 3rd (Third) year level with effect from the academic year 2024-25. The students have the option to complete the MOOC course at the 5th or 6th semesters.**

## List of Elective Courses

| Sr. No. | Elective Courses | Code | Scheme L-T-P |
|---|---|---|---|
| 1. | Introduction to Engineering Statistics | CH251 | 3-0-0 |
| 2. | Introduction to Macro-Molecules | CH252 | 3-0-0 |
| 3. | Micro Process Engineering | CH253 | 3-0-0 |
| 4. | Polymer Engineering | CH254 | 3-0-0 |
| 5. | Corrosion Science and Engineering | CH255 | 3-0-0 |
| 6. | Material Science and Technology | CH256 | 3-0-0 |
| 7. | Enzyme Science and Technology | CH257 | 3-0-0 |
| 8. | Sustainable Development Goals | CH258 | 3-0-0 |
| 9. | Environment Management System | CH259 | 3-0-0 |
| 10. | Sustainable Energy and Environmental Systems | CH260 | 3-0-0 |
| 11. | Polymer Nanocomposite | CH261 | 3-0-0 |
| 12. | Resource Recovery and Sustainability | CH262 | 3-0-0 |
| 13. | Lean Six Sigma | CH263 | 3-1-0 |
| | | | |
| 1. | Electrochemistry and Energy | CH351 | 3-0-0 |
| 2. | Bioprocess Engineering | CH352 | 3-0-0 |
| 3. | Cleaner Technologies in Chemical Process Industries | CH354 | 3-0-0 |
| 4. | Fundamentals of Colloid and Interfacial Science | CH355 | 3-0-0 |
| 5. | Process Integration | CH356 | 3-0-0 |
| 6. | Petroleum Refinery Engineering | CH357 | 3-0-0 |
| 7. | Waste to Energy Conversion | CH358 | 3-0-0 |
| 8. | Biomass Conversion and Biorefinery | CH359 | 3-0-0 |
| 9. | Computational Heat Transfer and Fluid Flow | CH360 | 3-0-0 |
| 10. | Smart Polymers | CH361 | 3-0-0 |
| 11. | New Separation Techniques | CH362 | 3-0-0 |
| 12. | Fluidization Engineering | CH363 | 3-0-0 |
| 13. | Advances in Chemical Engineering | CH364 | 3-0-0 |
| 14. | Industrial Waste Treatment Methods | CH365 | 3-0-0 |
| 15. | Multiphase Microfluidics | CH366 | 3-0-0 |
| 16. | Advanced Polymers | CH368 | 3-0-0 |
| 17. | Safety and Pollution Control in Chemical Process Industries | CH369 | 3-0-0 |
| 18. | Computational Fluid Dynamics | CH370 | 3-0-0 |
| | | | |
| 1. | Process Plant Safety | CH451 | 3-0-0 |
| 2. | Sustainability, Green Chemistry and Engineering | CH452 | 3-0-0 |
| 3. | Pharmaceutical Technology | CH453 | 3-0-0 |
| 4. | Computer Aided Design in Chemical Engineering | CH454 | 3-0-0 |
| 5. | Biomass & Fuel Cell Technology | CH455 | 3-0-0 |
| 6. | Basics of Soft Matter | CH456 | 3-0-0 |
| 7. | Green Technology | CH457 | 3-0-0 |
| 8. | Microfluidics and Nanofluidics | CH458 | 3-0-0 |
| 9. | Multiphase Flow | CH459 | 3-0-0 |
| 10. | Catalyst Science and Technology | CH460 | 3-0-0 |
| 11. | Advanced Chemical Engineering Thermodynamics | CH461 | 3-0-0 |

## List of Institute Elective Courses

| Sr. No. | Elective Courses | Code | Scheme L-T-P |
|---|---|---|---|
| 1. | Fuels and Combustion | CH353 | 3-0-0 |
| 2. | Design of Experiments | CH367 | 3-0-0 |
| 3. | Life Cycle Assessment | CH371 | 3-1-0 |

| B.Tech. I (Chemical Engineering) Semester – I<br>INTRODUCTION TO CHEMICAL ENGINEERING<br>CH101 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Understand the relevance of chemical engineering and its relation to other disciplines. |
| CO2 | Identify and enlist chemical processes, operations and the corresponding equipment |
| CO3 | Calculate and solve various chemical engineering related problems |
| CO4 | Implementation of chemical engineering basics to simple systems |
| CO5 | Evaluate and asses the environmental & safety aspects in chemical engineering |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(04 Hours)** |
| | Introduction: Unit Operations, Basic Laws, Useful Mathematical Methods, Unit and Dimensions, Dimensional Analysis, | |
| | **FLUID MECHANICS** | **(05 Hours)** |
| | Viscosity, Relationship Between Stress and Strain-Rate for Newtonian Fluids, Incompressible and Compressible Flows, Differences Between Laminar and Turbulent Flows, Newton's Law of Viscosity, Introduction to Non-Newtonian Behavior. | |
| | **MATERIAL AND ENERGY BALANCE** | **(05 Hours)** |
| | Introduction: Material Balance, Energy Balance, Material Balances for Reacting and Non-Reacting Chemical Systems, Energy Balances in Systems with and without Reactions | |
| | **HEAT TRANSFER** | **(07 Hours)** |
| | Introduction: Conduction, Convection, Radiation, Flow Arrangement in Heat Exchanger, Temperature Profile of Fluids in Heat Exchanger, Shell and Tube Heat Exchangers: Basic Construction and Features, TEMA Exchanger Types, Their Nomenclature, Evaporation. | |
| | **MASS TRANSFER** | **(08 Hours)** |
| | Introduction: Diffusion, Mass Transfer Operations, Absorption, Vapour-Liquid Equilibrium, Relative Volatility, Boiling Point Diagram, Distillation, Reflux, Different Types of Distillation Process, Liquid-Liquid Extraction, Classification of Industrial Liquid-Liquid Contactors, Crystallization, Drying, Adsorption, Humidification and Cooling Towers, Membrane Separations | |
| | **CHEMICAL REACTION ENGINEERING** | **(07 Hours)** |
| | Introduction to Reaction Engineering: Classification of Reactions, Definitions of Reactions Rate, Variables Affecting Reaction Rate, Speed of Chemical Reactions. Kinetics of | |

| | | |
|---|---|---|
| | Homogeneous Reactions: Simple Reactor Types, The Rate Equation, Concentration Dependent Term of Rate Equation, Introduction: Batch Reactor (BR), Continuous Stirred Tank Reactor (CSTR), Plug Flow Reactor (PFR), Packed-Bed Reactor (PBR) and their Design Equation | |
| | **MEASURING DEVICES** | **(05 Hours)** |
| | Chemical Composition, Pressure, Temperature, and Flowrate Measurement, Other Common Parameter Measurements | |
| | **CHEMICAL ENGINEERING THERMODYNAMICS** | **(04 Hours)** |
| | Basic Concepts: Thermodynamics System and Surroundings, Types of Systems, Thermodynamic, Equilibrium and Phase Rule, Zeroth Law of Thermodynamics, Different Laws of Thermodynamics, Concept of Internal Energy and Enthalpy, Application of Laws to Open Systems, Latest Software for Graphical as Well as Numerical Problems. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Find out Stress and Strain-Rate |
| 2 | Detail Material Balance |
| 3 | Energy balance in system |
| 4 | Find out Conduction, Convection, Radiation rate of the system |
| 5 | Find out Mass Transfer rate and diffusion coefficient |
| C | Calculate Reflux ratio and other distillation related term |
| 7 | Calculation % rejection, water flux and water recovery in membrane separation process |
| 8 | Find out Crystallization rate and % yield of crystallization process |
| 9 | Calculate rate of reaction, order of reaction and reaction time of chemical reaction |
| 10 | Different calculation based on CSTR and Plug Flow Reactor PFR |
| 11 | Calculations of Internal Energy, Enthalpy and other thermodynamic properties |

| **4.** | **Books Recommended** |
|---|---|
| 1 | Salil K Ghosal, Siddhartha Datta, Shyamal K Sanyal, Introduction to Chemical Engineering, Tata McGraw - Hill Publication, 2017. |
| 2 | S. Pushpavanam, Introduction to Chemical Engineering, PHI Learning Pvt. Ltd., 2012. |
| 3 | Walter L Badger and Julius T Banchero, Introduction to Chemical Engineering, McGraw – Hill Publication, 1955. |
| 4 | L. B. Andersen & L. A. Wenzel, Introduction to Chemical Engineering by McGraw Hill Publication, 1961. |
| 5 | D. M. Himmelblau, J. B. Riggs, Basic Principles & Calculations in Chemical Engineering Prentice Hall (India), 9$^{th}$ Edition, 2022 |
| 6 | Vivek Utgikar, Fundamentals Concepts and Computations in Chemical Engineering, Prentice Hall, 2017. |

| B. Tech. I (Chemical Engineering) Semester – I<br>ENERGY AND ENVIRONMENT IN CHEMICAL ENGINEERING<br>EG111 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):<br>At the end of the course, students will be able to** |
|---|---|
| CO1 | Understand the components of ecosystems, various biogeochemical cycles, sustainability and importance of Chemical Engineers towards Environmental pollution abatement |
| CO2 | Differentiate between various types of environmental pollution along with their impacts and regulatory standards |
| CO3 | Analyze various global environmental issues and their management |
| CO4 | Discuss the fundamental principles of energy, including classification, conservation and related policy frameworks and regulations**.** |
| CO5 | Get acquainted with the concept of energy systems and their components |

| 2. | **Syllabus** | |
|---|---|---|
| | **ENVIRONMENT AND ECOSYSTEMS** | **(08 Hours)** |
| | Introduction: Ecology - Concept of an ecosystem, its structure, functions and components. Food chains, food webs, ecological pyramids, energy flow in ecosystem; Bio-geochemical cycles, Environment and biodiversity, Components of environment and their relationship, closed loop cycle, interconnections between Energy, Water, Food, and Environment. Concepts of sustainability. Role of Chemical Engineers towards maintaining sustainability, transforming raw materials into useful products, developing new materials and markets, generating new and clean energy. | |
| | **ENVIRONMENTAL POLLUTION** | **(10 Hours)** |
| | Impact of urbanization and industrialization on environment, environmental degradation and its assessment, type of pollution and sources, quality standards for water, air, soil, noise, effects on living and non-living things. Primary, secondary, tertiary and advanced treatment systems and economics. Domestic and Industrial pollution, assessment and engineering control strategies, Solid waste management. | |
| | **GLOBAL ENVIRONMENTAL ISSUES AND ITS MANAGEMENT** | **(12 Hours)** |
| | Engineering aspects of climate change, concept of carbon credit, $CO_2$ sequestration, eutrophication, impact of domestic and industrial effluents and pollution abatement, concept of centralized and decentralized treatment systems and resource recovery techniques, concepts of environmental impact assessment and environmental audit, life cycle assessment, material and energy balances to produce resources sustainability without damaging environment, linear vs circular economy. Waste to resource conversion concept. | |

| | | |
|---|---|---|
| | **BASICS OF ENERGY AND ITS CONSERVATION** | **(07 Hours)** |
| | Classification of energy sources, Global and national energy scenario, Fossil and alternate fuels and its characterization. General aspects of energy conservation and management; Energy conservation act, Energy policy of company; Need for energy standards and labelling; Energy building codes. | |
| | **INTRODUCTION TO ENERGY CONSERVATION SYSTEMS** | **(08 Hours)** |
| | Energy conversion systems: Working principle, Basic components, General functioning and normal rating specifications of various energy conversion systems like Power plant, Pump, Refrigerator, Air-conditioner, Internal combustion engine, Solar PV cell, Solar water heating system, Biogas plant. Wind turbine, Fuel cells. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Demonstration of case study |
| 2 | Group Discussion |
| 3 | Quiz |
| 4 | Assignments / Mini projects & presentation on related Topics |

| **4.** | **Books Recommended** |
|---|---|
| 1 | Daniel B Botkin & Edward A Keller, Environmental Sciences, John Wiley & Sons, 2010 |
| 2 | R. Rajagopalan, Environmental Studies, Oxford University Press, 2015 |
| 3 | Benny Joseph, Environmental Studies, McGraw Hill publishers, 2017 |
| 4 | C S Rao, Environmental Pollution Control Engineering, New Age International Publishers, 2018 |
| 5 | B. H. Khan, Nonconventional Energy resources, Second Edition, Tata McGraw Hill Publishers,2009 |

| B. Tech. I (Chemical Engineering) Semester – I<br>MATHEMATICS<br>MA107 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Estimate the area and volume using integral evaluation techniques. |
| CO2 | Explain various methods for solving ordinary differential equations and their importance to engineering problems. |
| CO3 | Explain the fundamentals of partial differential equations and methods for solving linear and non-linear PDE of the first order. |
| CO4 | Explain the fundamental concepts of vector calculus and their role in applied mathematics. |
| CO5 | Apply special functions and their applications to evaluate some proper and improper integrals. |
| CO6 | Explain the basics and importance of the Laplace transform and Fourier transform. |

| 2. | **Syllabus** | |
|---|---|---|
| | **MULTIPLE INTEGRALS** | **(07 Hours)** |
| | Reorientation of concepts of integrals, Double and Triple integrals, Evaluation techniques, change of order of Integration, Change of variable, Application of double and triple integrals for evaluation of area and volume. | |
| | **ORDINARY DIFFERENTIAL EQUATION** | **(10 Hours)** |
| | Reorientation of differential equation of first order first degree, Exact differential equation and Integrating factors, Ordinary differential equation of first order higher degree, solvable for p, y and x, Solution of homogenous equations of higher order, Complementary functions, Particular Integrals, Linear differential equation with variable coefficient, Cauchy's, Euler and Legendre's equation with variable coefficients. | |
| | **INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATION** | **(07 Hours)** |
| | Basics of partial differentiation, Introduction to partial differential equation, Formation of partial differential Equation, Partial differential Equation of first order, Linear partial differential equation of first order ($P\mathbf{p} + Q\mathbf{q} = R$) and method of obtaining its general solution, Non-linear partial differential equation of first order $f(\mathbf{p}, \mathbf{q})=0$, $f(z, \mathbf{p}, \mathbf{q})=0$, $f(x, \mathbf{p})= g(y, \mathbf{q})$, $z= \mathbf{p}x + \mathbf{q}y + f(\mathbf{p}, \mathbf{q})$. | |
| | **VECTOR CALCULUS** | **(07 Hours)** |
| | Scalar and vector point function, Differential operator, Gradient, Directional derivative, Divergence, Curl and Laplacian operator with their properties, Line integral, Surface Integral, Volume integral, Green's, Gauss and Stokes theorem (Only statement) and application. | |

| | | |
|---|---|---|
| | **BETA, GAMMA AND HYPERBOLIC FUNCTION** | **(04 Hours)** |
| | Beta and Gamma function with their properties and duplications formula without proof. Introduction of hyperbolic functions, Differentiation of hyperbolic and inverse hyperbolic functions. | |
| | **LAPLACE AND FOURIER TRANSFORM** | **(10 Hours)** |
| | Laplace transform, Existence theorem, Basic properties, Laplace transform of derivatives and integrals, Inverse Laplace transform and properties, Convolution Theorem, Applications to solve simple linear and simultaneous differential equations. Introduction to Fourier transform, Basic properties. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Tutorial is based on the double and triple integrals |
| 2 | Tutorial is based on change of order of integration and change of variable |
| 3 | Tutorial is based on the application of double and triple integrals |
| 4 | Tutorial is based on complementary functions and particular integrals |
| 5 | Tutorial is based on the solution of Cauchy's Euler and Legendre's equation with variable coefficients |
| 6 | Tutorial is based on the linear partial differential equations |
| 7 | Tutorial is based on the non-linear partial differential equations |
| 8 | Tutorial is based on the gradient, divergence and curl |
| 9 | Tutorial is based on the line integral, surface integral and volume integral |
| 10 | Tutorial is based on the beta, gamma and hyperbolic functions |
| 11 | Tutorial is based on Laplace and Fourier transform |
| 12 | Tutorial is based on the applications to solve linear and simultaneous differential equations |

| **4.** | **Books Recommended** |
|---|---|
| 1 | Kreyszing E., Advanced Engineering Mathematics, Int. Student Edition, John Wiley & Sons, Singapore, 2015. |
| 2 | O' Neel Peter, Advanced Engineering Mathematics, Int. Edition, Thompson, Singapore, 2002. |
| 3 | Wiley C. R., Advanced Engineering Mathematics, New York Ed, McGraw Hill Inc., 1993. |
| 4 | Ramana D. V., Higher Engineering Mathematics, The MaGraw-Hill Inc., New Delhi, 2007. |
| 5. | H. K. Dass, Advanced Engineering Mathematics, S. Chand & Co Ltd, 2007. |

| B. Tech. I (Chemical Engineering) Semester – I<br>ENGINEERING DRAWING<br>ME 110 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 2 | 0 | 4 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, students will be able to** |
|---|---|
| CO1 | Read, understand and apply the knowledge of orthographic projections (production-related features and instructions) in the manufacturing industry, process industry and other allied engineering applications. |
| CO2 | Communicate with globally recognized engineers of different disciplines of engineering for research and development activities. |
| CO3 | Get knowledge of projections and sections of different solid objects |
| CO4 | Perceive the idea of sectional view and its advantages of it. |
| CO5 | Apply the concept of intersections of solids for various engineering applications |
| CO6 | Create the image of three-dimensional figures with the help of isometric projections |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(01 Hours)** |
| | Introduction: Importance of Engineering Drawing, drawing instruments and materials, B.I.S. and IS Conventions, First angle and third angle projection method. | |
| | **ENGINEERING CURVES** | **(03 Hours)** |
| | Classification of engineering curves, construction of conics, cycloidal, Involutes and spirals curves. | |
| | **PROJECTION OF POINTS, LINES AND PLANES** | **(04 Hours)** |
| | Introduction to principal planes of projection, Projections of the points located in the same and different quadrants, projection of lines with its inclination to the reference planes, true length of the lines and its inclination with reference planes, projection of planes with its inclination with two reference planes, concept of an auxiliary plane method for projection of planes. | |
| | **PROJECTION AND SECTION OF SOLIDS** | **(03 Hours)** |
| | Classification of the solids, projections of the solids like cylinder, cone, pyramid and prism with its inclination to two reference planes, Section of such solids and true shape of the section | |
| | **DEVELOPMENT OF THE LATERAL SURFACES** | **(03 Hours)** |
| | Method of development, parallel line development, radial line development, developments of cylinder, cone, prism, pyramid, true length of edges – oblique surface. | |

| | | |
|---|---|---|
| | **PENETRATION CURVE** | **(04 Hours)** |
| | Classification, line of interaction, line/generator method and section plane method; intersection of two prisms, two cylinders, interaction of cone and cylinder, pyramid with prism, surface development. | |
| | **ORTHOGRAPHIC PROJECTIONS** | **(04 Hours)** |
| | Projections from a pictorial view of the object on the principal planes for view from front, top, and side using a first and third angle of the projection method | |
| | **ISOMETRIC PROJECTIONS** | **(04 Hours)** |
| | Terminology, isometric scale, construction of isometric view and isometric projection, isometric axes, and lines | |
| | **INTRODUCTION TO COMPUTER-AIDED DRAFTING** | **(04 Hours)** |
| | Introduction of the drafting and modeling software and demonstration of its application on the latest machines. | |
| | **(Total Contact Time: 30 Hours + 60 Hours = 90 Hours)** | |

| **3.** | **Practicals: Practice with drawing sheets** |
|---|---|
| 1 | Orthographic views |
| 2 | Isometric views |
| 3 | Engineering curves |
| 4 | Projection of points and planes |
| 5 | Projection of solids |
| 6 | Section of solids |
| 7 | Penetration curve and surface development |
| 8 | Demonstration of computer-aided drafting and demonstration of its application in the latest machines. |
| 9 | Determination of cloud point and pour point of biodiesel and its comparison with diesel |


| **4.** | **Books Recommended** |
|---|---|
| 1 | Bhatt, N.D.,2023. Engineering Drawing. Charotar Publishing House Pvt. Limited |
| 2 | Shah P. J., 2013, Engineering Graphics, S. Chand and Company. |
| 3 | Basant Agrawal, C M Agrawal, 2019, Engineering Drawing, McGraw Hill Education (India) Private Limited |
| 4 | S.R. Singhal, O. P. Saxena, 2014, Engineering Drawing, Asian Publisher |
| 5 | R. K. Dhawan, 2019, A Textbook of Engineering Drawing, S Chand Publishing |

| B. Tech. I (Chemical Engineering) Semester – I<br>APPLIED CHEMISTRY<br>CY107 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 2 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Acquaint with the purpose and operational steps of key water treatment processes used to improve water quality |
| CO2 | Adapt corrosion chemistry to protect various metals used in industry from corrosion |
| CO3 | Adapt polymer chemistry process in industrial applications |
| CO4 | Understand the characteristics, synthesis and applications of different materials in a wide range of sectors |
| CO5 | Perform the quantitative determination of various ions by using instrumentation methods |

| 2. | **Syllabus** | |
|---|---|---|
| | **CHEMICAL ANALYSIS OF WATER** | **(08 Hours)** |
| | Specifications for water in industries, types of water (raw water, cooling water, boiler water, nuclear water), cooling water (Langelier Index and its treatment); Hardness of water, Estimation and units of Hardness, Boiler feed water, Boiler Problems - Scales & Sludge, Priming, Foaming, Carryover, Caustic Embrittlement, Boiler corrosion, Desalination. Water softening (lime-soda, zeolite and ion-exchange) methods. | |
| | **POLYMERS** | **(08 Hours)** |
| | Introduction and classification of polymers, nomenclature, functionality in polymers, number and weight average molecular weight, degree of polymerization and molecular weight distribution (PDI), Chain Architecture (Linear/Branched, Tacticity, Isomerism), homopolymers, copolymers, graft copolymers; Types of polymerizations: addition, condensation; Engineering polymers and applications, Biopolymers, conducting polymers. | |
| | **CHEMISTRY OF MATERIALS** | **(07 Hours)** |
| | Engineering materials and its classification, Ferrous metals and alloys (steel and stainless steels), Non-ferrous metals and alloys, their properties and applications; Composites-Introduction, classifications, structure-property relations and applications. | |
| | **CORROSION** | **(06 Hours)** |
| | Introduction, types and mechanism of (Chemical and Electrochemical) corrosion, Types of Electrochemical corrosion (Galvanic, Pitting, Crevice), Pourbiax diagram, Passivity, Polarization, Galvanic series, Factors influencing corrosion, Corrosion control. | |
| | **SURFACE CHEMISTRY** | **(08 Hours)** |
| | Liquid- liquid and solid liquid interfaces – contact angle, wetting and spreading, adhesion and cohesion, contact angle measurements; Colloids and its types, lyophilic and lyophobic sols; characteristics, preparations, purification and properties (optical, kinetic and electrical) and applications. Associated colloids (surfactants), emulsions (role, types and preparation) and gels (types and properties). | |
| | **BASIC INSTRUMENTATION TECHNIQUES** | **(08 Hours)** |
| | Principles and instrumentations: Conductometry, Colorimetry, Potentiometry, pH-metry; UV-Visible spectroscopy. Electrochemical measurements: methods and instruments. | |
| | **(Total Contact Time 45 Hours + 30 Hours = 75 Hours)** | |

| 3. | **Practicals** |
|---|---|
| 1 | Determination of hardness of water |
| 2 | Estimation of COD |
| 3 | Determination of DO |
| 4 | Determination of Cu in brass alloy. |
| 5 | Acid-base pH metric titration |
| 6 | Trimetric determination of *l* - Ascorbic acid (Vitamin-C). |
| 7 | Estimation of $Cl^-$ ion. |
| 8 | Estimation of corrosion by weight loss method |
| 9 | Conductometric titration to determine the strength of strong acid. |
| 10 | Demonstration: Concentration determination of Co as a Pollutant using Spectrophotometer. |

| 4. | **Books Recommended** |
|---|---|
| 1 | Jain P.C. and Jain M. 'Engg. Chemistry' Dhanpat Rai Publishing Co. New Delhi, 15th Edition 2006. |
| 2 | P. Atkins, Paula J. D., "Atkin's Physical Chemistry", Oxford (Indian Edition), Oxford University Press, 2012. |
| 3 | Tripathy S.K., Pandhy A.K. and Panda A.K. 'Material Science & Engineering', Scitech Publications (India) Pvt. Ltd., 2nd Edition, 2009. |
| 4 | Vogel A. I. and Mendham J., 'Vogel's Textbook of Quantitative Chemical Analysis Hall, 6th Edition, 2002. 5. Sharma B. K. 'Engg. Chemistry', Krishana Prakashan Media (P) Ltd, 2008 |
| 5 | D. A. Skoog, F. J. Holler, T. A. Nieman, "Principles of Instrumental Analysis", sixth edition, 2006. 5. B. K. Sharma, "Engineering Chemistry", Krishna Prakashan Media (P) Ltd., Meerut, 2001. |

| B. Tech. I (Chemical Engineering) Semester – I<br>WORKSHOP PRACTICE<br>ME105 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 0 | 0 | 4 | 02 |

| 1. | Course Outcomes (COs):<br>At the end of the course, students will be able to |
|---|---|
| CO1 | Observe safety precaution in the workshop |
| CO2 | Operate various carpentry tools and create the wood working assignments |
| CO3 | Operate various smithy tools and create the smith working assignments |
| CO4 | Operate various metal fitting tools and metal fitting working assignments |

| 2. | **Syllabus** | |
|---|---|---|
| | **UNIT 1** | **(12 Hours)** |
| | Introduction of the tools used in carpentry shop and skill development in carpentry works. | |
| | **UNIT 2** | **(12 Hours)** |
| | Introduction of the tools used in Fitting shop and skill development in fitting works | |
| | **UNIT 3** | **(12 Hours)** |
| | Introduction of the tools used in smithy shop, and skill development in smithy works | |
| | **UNIT 4** | **(12 Hours)** |
| | Introduction of the tools used in soldering and other joining processes and skill development in soldering and other joining works | |
| | **UNIT 5** | **(06 Hours)** |
| | Introduction to House writing, different types of cables. Types of power supply, types of motors, Relays and Contractors, ELCB, distribution of power supply, LED lighting, MCB, Electrical wiring symbols, Energy Meter, SPDT/DPDT switches. Earthing and Grounding, EMI & EMC issue | |
| | **UNIT 6** | **(06 Hours)** |
| | Identifications of Electronics Components, Soldering of components, Components Mounting on Bread Board, Functioning of Power supply, Function Generator, CRO, DSO. | |
| | **(Total Contact Time: = 60 Hours)** | |


| 3. | **Books Recommended** |
|---|---|
| 1 | H.S. Bava, “Workshop Technology”, Tata McGraw Hill Publishing Co. Ltd., 1995. |
| 2 | S.K. Hajra Chaudhary, “Elements of Workshop Technology Vol. I”, Asia Publishing House, 1988 |
| 3 | W.A.J. Chapman, “Workshop Technology”, ELBS Low Price Text, Edward Donald Pub. Ltd., 1961 |
| 4 | Gupta K.N. & Kaushish J.P., “Workshop Technology Vol. I, II”, New Delhi Heights Pub., New Delhi, 1991 |

| | |
|---|---|
| 5 | Raghuvanshi B. S., “Course in Workshop Technology”, Dhanpat Rai & Sons, New Delhi, 1991 |
| 6 | Tejwani V. K. “Basic Machine Shop Practice Vol. I, II”, Tata McGraw Hill Pub. Co., New Delhi, 1989. |
| 7 | Arora B. D. “Workshop Technology Vol. I, II”, Satya Prakashan, New Delhi, 1981 |

| B. Tech. I (Chemical Engineering) Semester – II<br>PROCESS CALCULATIONS<br>CH102 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Identify and calculate required process variables |
| CO2 | Describe fundamentals of stoichiometry |
| CO3 | Analyze and apply different approaches to perform Material balance |
| CO4 | Employ the concepts of material balances for successful operation of complex industrial operations. |
| CO5 | Apply energy balances for successful industrial operation. |
| CO6 | Solve complex balance problems encountered in chemical engineering |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(05 Hours)** |
| | Introduction, Dimension and Units, system of units, conversion of units and equations, dimensional homogeneity and dimensionless quantities, Dimensional analysis. | |
| | **PROCESS VARIABLES AND BASIC CHEMICAL ENGINEERING CALCULATIONS** | **(06 Hours)** |
| | Process Variables: Density, Flow rate, Pressure and Temperature, moles, average molecular weight, Chemical Composition. Equation of States for Gases, Single phase and multiphase systems. | |
| | **MATERIAL BALANCE ON NON-REACTIVE SYSTEMS** | **(04 Hours)** |
| | Law of conservation of mass, differential and integral balances, Procedure to perform Material balances, Degrees of Freedom Analysis for material balance problems for non-reactive system, specification of basis of calculations, calculation of scale factor for Scale up and scale down of balanced process, Material balances for unit operations including distillation, evaporation, drying, crystallization, extraction, mixing, gas absorption etc. | |
| | **MATERIAL BALANCE ON NON-REACTIVE SYSTEMS WITH MULTIPLE UNITS AND RECYCLE** | **(04 Hours)** |
| | Balances on multiple unit operations. The concept of recycle and bypass systems, Material balance with recycle and bypass with multiple units, calculation of recycle ratio, purge ratio in non-reactive system. | |
| | **MATERIAL BALANCE ON REACTIVE SYSTEMS** | **(04 Hours)** |
| | The chemical equation and stoichiometry, limiting an excess reactant, Calculation of percentage excess reactant, percentage conversion, yield and selectivity, reactor yield and plant yield, Extent of reaction, relation between extent of reaction and conversion, Different approaches to solve material balance problems such as molecular balance, atomic balance and extent of reaction for reactive processes. Degrees of freedom analysis for reactive systems based on different approaches. | |

| | | |
|---|---|---|
| | **MATERIAL BALANCE ON REACTIVE SYSTEMS WITH MULTIPLE UNITS AND RECYCLE** | **(04 Hours)** |
| | Material balances on reactive system with recycle. The concept of purge stream in a reactive system, concept of single pass conversion and overall conversion, calculation of recycle ratio, purge ratio in reactive system, Material balances on reactive system with recycle, purge using molecular species and atomic species balance. | |
| | **ENERGY BALANCE WITHOUT CHEMICAL REACTION** | **(07 Hours)** |
| | Law of conservation of energy, Forms of energy, Energy balance for closed and open system, calculations of enthalpy changes of processes, Energy balance procedures, Steam Tables, enthalpy calculation using hypothetical process path, Energy change due to changes in pressure at constant temperature, changes of temperature, phase change operations, Heats of solution and mixing, Enthalpy Concentration chart. | |
| | **ENERGY BALANCE WITH CHEMICAL REACTION** | **(08 Hours)** |
| | Calculations of enthalpy changes of reactions, heats of reaction, heat capacity calculations, Formation reactions and heats of formation and combustion, energy balances for reactive systems, Combustion reactions. Estimation of calorific values of fuels. | |
| | **MATERIAL BALANCES ON UNSTEADY STATE PROCESSES** | **(3 Hours)** |
| | Material balances for different types of Unsteady state processes. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1. | Solving problem for unit change and change of non-homogenous equation from one unit to another unit system |
| 2. | Problem for dimensional analysis |
| 3. | Problem for calculation of process variables |
| 4. | Problem based on equation of state and estimation of properties of mixtures of gases and liquids. |
| 5. | Problem based on material balance for unit operations |
| 6. | Problem based on material balance for multiple unit operations |
| 7. | Problem for solving material balance problems using stoichiometry |
| 8. | Problem for solving material balance problems for reactive system with multiple units |
| 9. | Problem for solving material balance problems for reactive system with recycle and purge |
| 10. | Problem for solving Energy balance problems for non-reactive/reactive system |

| 4. | **Books Recommended** |
|---|---|
| 1 | Felder R. M. & Rousseau R.W., “Elementary principles of chemical processes”, 3rd Ed., John Wiley & Sons, Inc., New York, 2000. |
| 2 | Himmelblau D.M., “Basics Principles and Calculations in Chemical Engineering” 6th Ed., Prentice-Hall India,1996. |
| 3 | Bhatt B.I. & Vora S.M., "Stoichiometry”, 4th Ed., Tata-McGraw-Hill, New Delhi, 2004. |
| 4 | Hougen O.A., Watson K.M. & Ragatz R.A., “Chemical Process Principals: Part-I”, 2nd Ed., CBS Publishers and Distributors, New Delhi, 1995. |
| 5 | K.V. Narayanan & B. Lakshmikutty, “Stoichiometry and Process Calculations”, 2nd Ed., PHI, New Delhi, 2017 |

| B. Tech. I (Chemical Engineering) Semester – II<br>UNIT PROCESSES<br>CH104 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Recognize the significance of unit processes and unit operations in chemical industries. |
| CO2 | Explain the various manufacturing processes with their process flow diagram. |
| CO3 | Determine various criteria like catalysts, reagents, appropriate equipments, kinetics and thermodynamics etc for different processes. |
| CO4 | Apply and understand chemical process kinetics and types of reactors for different types of reaction. |
| CO5 | Summarize the effect of various physical and chemical factors on different unit processes. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(04 Hours)** |
| | Definition and importance of Unit processes in Chemical Eng., Outlines of unit processes, and operations, Chemical process kinetics and Factors affecting it, types of reactors, Symbols used in Chem. Eng. Process flow diagram. | |
| | **NITRATION** | **(04 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** | **(06 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** | **(04 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** | **(05 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** | **(04 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 Benzene. | |
| | **OXIDATION** | **(05 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** | **(06 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** | **(04 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** | **(03 Hours)** |
| | Introduction, Methods of Polymerization- Polycondensation methods, Addition Polymerization methods (Bulk, Solution, emulsion and Pearl polymerization). | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Groggins P. H., “Unit Processes in Organic Synthesis”, 5th edition, Tata-McGraw Hill, New Delhi, 2001. |
| 2 | Gopalarao. M., Sitting M., “Dryden’s Outlines of Chemical Tech.”, 2nd Ed., East-West Pub., New Delhi, 1997. |
| 3 | Austin G. T., “Shreve’s Chemical Process Industries”, 5th Ed. McGraw-Hill Pub., 1994. |
| 4 | Kent J.A., “Kent & Riegel’s Handbook of Industrial Chemistry and Biotechnology”, Springer publisher, 11$^{th}$ Ed., 2007. |
| 5 | Morrison R.T., et al., “Organic Chemistry”. 7$^{th}$ Ed., Pearson Publications, 2014. |

| B. Tech. I (Chemical Engineering) Semester – II<br>NUMERICAL METHODS IN CHEMICAL ENGINEERING<br>CH106 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Apply curve fitting techniques to approximate a function in interpolating and extrapolating a given data. |
| CO2 | Analyze the different samples of data at different level of significance using various hypothesis testing. |
| CO3 | Solve system of linear and non-linear equations using direct and iterative methods. |
| CO4 | Compare various numerical methods for solving ordinary and partial differential equations. |
| CO5 | Solve chemical processes and design problems. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTERPRETATION OF ENGINEERING DATA** | **(08 Hours)** |
| | Curve fitting: Least square regression. Interpolation: Newton's Forward/Backward interpolation, Lagrange's interpolation and their applications. | |
| | **ENGINEERING STATISTICS** | **(10 Hours)** |
| | Errors and its propagation. Significance tests: Null hypothesis, alternative hypothesis, p- value, Type-I and Type-II error, confidence interval, central limit theorem. Z-test, t-test, f- test, chi square test, etc. Analysis of variance (ANOVA) | |
| | **NUMERICAL SOLUTION OF ALGEBRAIC EQUATIONS** | **(10 Hours)** |
| | Linear systems of equations, Solutions by Cramer's Rule, Matrix methods, Gauss-Jordan, Gauss Elimination, Gauss Jacobi, Gauss-Seidel and Relation methods. Non-linear equations: Bisection, Regula-falsi, Secant and Newton- Raphson methods. | |
| | **NUMERICAL SOLUTION OF DIFFERENTIAL EQUATIONS** | **(10 Hours)** |
| | Initial value problems for ordinary differential equations: Euler's, Runge-Kutta and Milne's predictor-corrector methods. Boundary value problems: Finite difference methods, Partial differential equations: Solutions of elliptic, parabolic and hyperbolic types of equations. | |
| | **FORMULATION OF PHYSICAL PROBLEMS** | **(07 Hours)** |
| | Mathematical statement and representation of problems, Exponential growth and decay, Newton's law of cooling, Batch reaction kinetics, Radial heat transfer through a cylindrical conductor, salt accumulation in a stirred tank. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| 3. | **Tutorials** |
|---|---|
| 1 | Tutorial is based using curve fitting methods. |
| 2 | Tutorial is based on interpolation methods. |
| 3 | Tutorial is related to tests of significance |
| 4 | Tutorial based on ANOVA. |
| 5 | Tutorial is based on finding solutions to linear equations by direct methods. |
| 6 | Tutorial is based on finding solutions to non-linear equations by iterative methods. |
| 7 | Tutorial is based on finding solutions to initial value problems. |
| 8 | Tutorial is based on finding solutions to boundary value problems. |
| 9 | Tutorial is based on formulation of physical problems. |

| 4. | **Books Recommended** |
|---|---|
| 1 | S.S. Sastry, Introductory Methods of Numerical Analysis, 5th Edition, PHI Learning Private Limited, 2012. |
| 2 | M. K. Jain, S.R.K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computations, 8th Edition, New Age International publications, 2022. |
| 3 | Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers, 8th Edition, Mc. Graw Hill, 2021 |
| 4 | Pradeep Ahuja, Introduction to Numerical Methods in Chemical Engineering, 2nd Edition, PHI Learning Private Limited, 2019. |
| 5 | Walpole. R.E., Myers. R.H., Myers. S.L. and Ye. K., Probability and Statistics for Engineers and Scientists, 10th Edition, Pearson Education, Asia, 2013. |
| 6 | Norman W. Loney, Applied Mathematical Methods for Chemical Engineers, 3rd Edition, CRC Press, 2016 |

| B.Tech. I (Chemical Engineering) Semester – II<br>FUNDAMENTALS OF COMPUTER AND PROGRAMMING<br>CH108 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 2 | 04 |

| 1. | Course Outcomes (COs):<br>At the end of the course, students will be able to |
|---|---|
| CO1 | Acquire knowledge about computer architecture, network and software development. |
| CO2 | Install an operating system and configure the network along with programming skills to solve the given problem. |
| CO3 | Analyse the given problem and develop the suitable algorithm. |
| CO4 | Evaluate programming solutions with different aspects. |
| CO5 | Design and develop solution for given problems. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION TO COMPUTER AND ITS ARCHITECTURE** | **(02 Hours)** |
| | Introduction and Characteristics, Computer Architecture, Generations, Classifications, Applications, Central Processing Unit and Memory, Communication between various Units, Processor Speed, Multiprocessor System, Peripheral Buses, Motherboard Demonstration. | |
| | **MEMORY AND VARIOUS INPUT AND OUTPUT DEVICES** | **(02 Hours)** |
| | Introduction to Memory, Input and Output Devices, Memory Hierarchy, Primary Memory and its Types, Secondary Memory, Classification of Secondary Memory, Various Secondary Storage Devices and their Functioning. | |
| | **NUMBER SYSTEMS** | **(01 Hour)** |
| | Introduction and type of Number System, Conversion between Number System, Arithmetic Operations in different Number System, Signed and Unsigned Number System. | |
| | **INTRODUCTION TO SYSTEM SOFTWARES AND PROGRAMMING LANGUAGES** | **(04 Hours)** |
| | Classification of Computer Languages, Introduction of Operating System, Evolution, Type and Function of OS, Unix Commands, Evolution and Classification of programming Language, Feature and Selection of good Programming Language, Development of Program, Algorithm and Flowchart, Program Testing and Debugging, Program Documentation and Paradigms, Characteristics of good Program. | |
| | **PROGRAMMING USING ‘C/ Scilab/Python’ LANGUAGE – INTRODUCTION** | **(06 Hours)** |
| | Characteristics of different Languages, Identifiers and Keywords, Data Types Constants and Variables, Declarations and Statements, Representation of Expressions, Classification of Operators and Library Functions for Data Input and Output Statements, Formatted Input and Output Statements. | |

| | | |
|---|---|---|
| | **PROGRAMMING USING 'C/ Scilab /Python' LANGUAGE – CONTROL STATEMENTS, STRUCTURES, ARRAYS, POINTERS** | **(10 Hours)** |
| | Conditional Control Statements, Loop Control Statements, One Dimensional Array of Numbers and Characters, Two-Dimensional Array, Introduction and Development of User Defined Functions, Different Types of Variables and Parameters, Structure and Union, Introduction to Pointers, Pointer Arithmetic, Array of Pointers, Pointers and Functions, Pointers and structures, File Handling Operations. | |
| | **PROGRAMMING USING 'C/Scilab/Python' LANGUAGE – FUNCTIONS** | **(10 Hours)** |
| | Functions, Passing the arguments, Return values from functions, Recursion, Header Files Design, File handling operations, Read and Write to Secondary Devices, Read and Write to Input and Output Ports. | |
| | **PROGRAMMING USING 'C/Scilab/Python' LANGUAGE – Numeric Computation** | **(10 Hours)** |
| | Linear Algebra, Non-linear equations, regression and interpolation, runge-kutta methods and error analysis, | |
| | **(Total Contact Time 45 Hours + 30 Hours = 75 Hours)** | |

| **3.** | **Practicals** |
|---|---|
| 1 | Basic commands of Windows and Linux |
| 2 | Array operations in Scilab, Python and C |
| 3 | Loops, Execution control and plotting and output in Scilab and python |
| 4 | Truncation errors, round-off errors and iterative methods |
| 5 | Build-in Scilab functions for integration and differentiation |
| 6 | Using Scilab commands like fzero and fsolve |


| **4.** | **Books Recommended** |
|---|---|
| 1. | "Introduction to Computer Science", Fourth Impression, Pearson Education, ITL Education Solutions Limited, 2009. |
| 2. | Gottfried B.S., "Programming with C Schaum's outline Series", Outline Series, 2$^{nd}$ Edition, Tata McGraw-Hill, 2006. |
| 3. | Pradip Dey, "Programming in C", 2$^{nd}$ Edition, Oxford University Press, 2012. |
| 4 | Paul Barry, Head First Python: A Learner's Guide to the Fundamentals of Python Programming, A Brain-Friendly Guide, Third Edition, O'Reilly Media, Inc., 2023 |
| 5. | Gilat, A.. MATLAB: An introduction with Applications. 4th Edition, John Wiley & Sons, 2017 |

| B.Tech. I (Chemical Engineering) Semester II<br>ENGLISH AND PROFESSIONAL COMMUNICATION<br>HS110 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Show enhanced reception towards the use of English language. |
| CO2 | Choose and employ appropriate words for professional communication. |
| CO3 | Develop sentences and text in English coherently and formally. |
| CO4 | Demonstrate overall improvement in oral communication. |
| CO5 | Analyze and infer from written and oral messages. |

| 2. | **Syllabus** | |
|---|---|---|
| | **COMMUNICATION** | **(05 Hours)** |
| | Introduction to Communication, Different forms of Communication, Barriers to Communication and some remedies, Non-Verbal Communication – Types, Non-Verbal Communication in Intercultural Context. | |
| | **VOCABULARY AND USAGE OF WORDS** | **(05 Hours)** |
| | Common Errors, Synonyms, Antonyms, Homophones, and Homonyms; One Word Substitution; Misappropriations; Indianisms; Redundant Words. | |
| | **LANGUAGE THROUGH LITERATURE** | **(09 Hours)** |
| | Selected short stories, essays, and poems to discuss nuances of English language. | |
| | **LISTENING AND READING SKILLS** | **(06 Hours)** |
| | Types of listening, Modes of Listening-Active and Passive, Listening and note taking practice, Practice and activities<br>Reading Comprehension (unseen passage- literary /scientific / technical) Skimmingand scanning, fact vs opinion, Comprehension practice. | |
| | **SPEAKING SKILLS** | **(10 Hours)** |
| | Effective Speaking, JAM, Presentation Skills- types, preparation and practice. Interviews-types, preparation and mock interview; Group Discussion- types, preparation and practice | |
| | **WRITING SKILLS** | **(10 Hours)** |
| | Prerequisites of effective writing, Memo-types, Letter Writing- types, Email etiquette and Netiquette, Résumé-types, Report Writing and its types, Editing. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| 3. | **Tutorials** |
|---|---|
| 1 | Letter and Resume |
| 2 | Group Discussion |
| 3 | Presentation Skills (Individual) |
| 4 | Role Play on Nonverbal communication |
| 5 | Group Presentation |
| 6 | Debate |
| 7 | Body language and intercultural communication |
| 8 | Listening Activities |
| 9 | Editing |
| 10 | Report Writing |
| 11 | Mock interviews |
| 12 | JAM |

| 4. | **REFERENCE BOOKS** |
|---|---|
| 1 | Kumar, Sanjay and Pushp, Lata. *Communication Skills*, 2nd Edition, OUP, New Delhi, 2015. |
| 2 | Raman, Meenakshi & Sharma Sangeeta. *Technical Communication Principles and Practice*, 3rd Edition, OUP, New Delhi, 2015. |
| 3 | Raymond V. Lesikar and Marie E Flatley. *Basic Business Communication skills for Empowering the Internet generation.* Tata McGraw Hill publishing company limited. New Delhi 2005. |
| 4 | Courtland L. Bovee, John V. Thill, and Mukesh Chaturvedi. “Business Communication Today.” Ninth Edition. Pearson, 2009. |
| 5 | Mike Markel. “Practical Strategies for Technical Communication,” Bedford/ St. Martin's Second Edition, 2016 |
| 6 | Laura J. Gurak and John M. Lannon. “Strategies for Technical Communication in the Workplace,” Pearson, 2013. |

| B.Tech. II (Chemical Engineering) Semester – III<br>MECHANICAL OPERATIONS<br>CH201 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 05 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Recognize and identify problems associated with characterization, handling, processing, and transportation of bulk solids encountered in process industries. |
| CO2 | Analyze and estimate the effects of different types of forces on fluid particle interactions in unit operations |
| CO3 | edict behavior of fluid solid system based on the process variables. |
| CO4 | Calculate efficiency and the size of the unit operations based on the desirable performance |
| CO5 | Design different fluid solid separation equipment |
| CO6 | Devise effective strategies to enhance problem solving skills. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION AND PARTICLES AND POWDER CHARACTERIZATION** | **(08 Hours)** |
| | Overview of different operations with real Industrial examples, Particle size measurements, Describing the Size of Single Particle and Populations of Particles, Particle size distribution and Conversion between Distributions, Particle shape characterization, Bulk properties measurement, characterization of powder flowability, methods of size measurements, Sieve analysis. | |
| | **SIZE REDUCTION** | **(04 Hours)** |
| | Size reduction of solids, Mechanism of size reduction, Models for Predicting Energy Requirement and Product Size Distribution, Types & Classification of size reduction equipment, Crushers and Ball mills, Types of Milling Circuit: Open and closed-circuit grinding. | |
| | **BEHAVIOUR OF SINGLE PARTICLE AND MULTIPLE PARTICLES IN A FLUID** | **(06 Hours)** |
| | Settling of a single particle in fluid, Stokes' law, Drag force and drag coefficient, Different settling regimes, Free Settling and Hindered settling, Richardson-Zaki law, Batch settling test, design of sedimentation tank, Separation of solids from liquid | |
| | **FLUID FLOW THROUGH A PACKED BED OF PARTICLES & THEORY OF FILTRATION** | **(06 Hours)** |
| | Estimation of packed bed parameters, Prediction of pressure drop using Kozeny-Carman Equation, Ergun's equation, Types of filtrations, Constant pressure and constant rate filtration, Filtration equipments: Plate and frame filter press, pressure leaf filter, and rotary filter | |
| | **FLUIDIZATION OF SOLIDS** | **(03 Hours)** |
| | Estimation of fluidized bed parameters, Prediction of pressure drop and minimum fluidization velocity using Ergun's equation, Types of fluidizations. | |

| | | |
|---|---|---|
| | **PHYSICAL SEPARATORS** | **(09 Hours)** |
| | Mechanisms of Particle separation, Gas-Cyclone separation, Electrostatic Precipitator, Fabric filters, Centrifugal Separators, Flotation, Jigging, Magnetic separation processes. | |
| | **SIZE ENLARGEMENT (AGGLOMERATION)** | **(03 Hours)** |
| | Types of Forces affecting Agglomeration, Wetting, Nucleation and Growth mechanisms, granulation, Types of granulators. | |
| | **MIXING OF PARTICULATE MATERIALS AND STORAGE OF POWDERS** | **(04 Hours)** |
| | Random mixing and perfect mixing, segregation of particles, mechanisms of segregation, Equipments for mixing of particles and powders. Solids, Storage, Transportation and Handling of Solids. | |
| | **HEALTH EFFECTS OF PARTICULATE MATERIALS** | **(02 Hours)** |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours + 30 Hours = 90 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1. | Problems to calculate equivalent spherical diameter and calculation of specific surface area. |
| 2. | Problems related to the particle size distribution and conversion of particle size distribution |
| 3. | Problems for calculation of different types of mean size of particles and specific surface area of powder. |
| 4. | Problems for calculation of energy requirement using Rittinger's law, Kick's law and Bond's law. |
| 5. | Problem for estimation of particle size distribution using selection function and breakage distribution function |
| 6. | Problems for calculation of drag force, drag coefficient and terminal settling velocity using Stokes' law, Newton's law and Ricardson-Zaki equation. |
| 7. | Problem for design of sedimentation tank using batch settling test data. |
| 8. | Problems to calculate pressure drop through packed bed using Ergun's equation. |
| 9. | Problems to calculate minimum fluidization velocity of fluidized bed system. |
| 10. | Problems related to calculation of filtration time, washing time of plate and frame filter press. |
| 11. | Problem for design of gas cyclone: Calculation of cyclone diameter, cut size and number of cyclones. |
| 12. | Problems for calculation of air to cloth ratio for fabric filter and determination of size and number of filter bags. |
| 13. | Problem for design of Electrostatic precipitator (ESP): Calculation of particle migration velocity, efficiency of ESP. |
| 14. | Problem related to measurement of quality and mixing index of solid –solid mixtures. |
| 15. | Problems related to the calculation of bulk properties of powder such as bulk density, tapped density, porosity and flowability index. |

| 4. | **Practicals** |
|---|---|
| 1. | Measurements of bulk and flow properties of different powders |
| 2. | To study powder compaction behaviour of powder |
| 3. | Measurement of angle of repose of different powders. |
| 4. | Particle size measurement and analysis by sieve analysis. |
| 5. | Particle size and shape analysis by image processing. |
| 6. | Study of particle size reduction by ball milling. |
| 7. | Study of sedimentation behaviour of $CaCO_3$ Suspension by batch settling test |
| 8. | Study of flow of fluid through packed bed and estimation of pressure drop. |
| 9. | Study of flow through fluidized bed with and estimation of minimum fluidization velocity. |
| 10. | The prediction of pressure drop through packed bed using artificial neural network and virtual lab |
| 11. | The separation of particles by cyclone separator |
| 12. | The study of powder mixing using V type blender |


| 5. | **Books Recommended** |
|---|---|
| 1 | Martin Rhodes, "Introduction to Particle Technology", 2nd Edition, John Wiley & Sons, 2008 |
| 2 | McCabe W.L., Smith J.C., Harriott P., "Unit Operations of Chemical Engineering", 6th & 7th Eds., McGraw-Hill, New York, 2001 & 2005. |
| 3 | Foust A.S., Wenzel L.A., Clump C.W., Maus L., Anderson L.B. "Principles of Unit Operations",2nd Edition, John Wiley & Sons, New York, 1980. |
| 4 | Coulson J.M., Richardson J.F., "Chemical Engineering", Vol. 2, 5th Ed., Elsevier, New Delhi, 2002. |
| 5 | http://www.ide.iitkgp.ac.in/Pedagogy_view/example.jsp?USER_ID=82 online pedagogy course. |

| B. Tech. II (Chemical Engineering) Semester – III<br>FLUID FLOW OPERATIONS<br>CH203 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 05 |

| 1. | Course Outcomes (COs):<br>At the end of the course, students will be able to |
|---|---|
| CO1 | Predict the velocity profile and flow behaviour in various types of systems |
| CO2 | Calculate pressure loss in different types of flow systems |
| CO3 | Calculate power requirement for fluid transport |
| CO4 | Compare and select appropriate types of fluid moving machineries for fluid transport |
| CO5 | Justify the use of specific fluid moving machineries |
| CO6 | Evaluate discharge coefficient of various flow meters, select appropriate flow meters, and justify the selection of flow meters for a variety of flow conditions |

| 2. | Syllabus | |
|---|---|---|
| 1 | **INTRODUCTION** | **(03 Hours)** |
| | Definition of Unit Operations, Definition and basic concepts of fluid, Properties of fluids, Stress, Deformation, Dimensional analysis. | |
| 2 | **FLUID STATICS AND ITS APPLICATIONS** | **(05 Hours)** |
| | Nature of fluids: Incompressible and compressible fluids, Pressure concepts, Hydrostatic equilibrium in gravitational and centrifugal field, Manometers, Inclined manometer, Continuous gravity decanter and centrifugal decanter. | |
| 3 | **FLUID FLOW PHENOMENA** | **(05 Hours)** |
| | Types of flow, Potential flow, One dimensional flow, Laminar flow, Reynolds number, Newtonian and non-Newtonian fluids, Velocity gradient and Rate of shear, Viscosity of gases and liquids, Turbulent flow, Nature of turbulence, Eddy viscosity, Eddy diffusivity of momentum, Flow in boundary layers, Laminar and turbulent flow in boundary layers, Boundary layer formation in straight tube and flat plates, Boundary layer thickness, Boundary layer separation and wake formation. | |
| 4 | **BASIC EQUATIONS OF FLUID FLOW AND THEIR APPLICATIONS** | **(07 Hours)** |
| | Stream line and stream tubes, Average velocity, Mass velocity, Continuity equation, Momentum balance, Navier-Stokes equations, Bernoulli's equation. | |
| 5 | **FLOW OF INCOMPRESSIBLE FLUIDS** | **(08 Hours)** |
| | Flow of incompressible fluids in pipes, Friction factor, Laminar flow of Newtonian and non-Newtonian fluids, Turbulent flow in pipes and closed channels, Effect of roughness, Friction factor chart, Drag reduction in turbulent flow Friction factor in flow through channels of noncircular cross section, Friction from changes in velocity or direction, Effect | |

| | | |
|---|---|---|
| | of fittings and valves, Practical use of velocity heads in design, Minimization expansion and contraction losses. | |
| **6** | **FLOW OF COMPRESSIBLE FLUIDS AND ITS APPLICATIONS** | **(04 Hours)** |
| | Continuity equations, Velocity of sound, Stagnation temperature, Processes of compressible flow. | |
| **7** | **FLUID FLOW MEASUREMENTS** | **(03 Hours)** |
| | Fluid flow measurement: Venturi meter, Orifice meter, Rotameter, Pitot tubes, etc. | |
| **8** | **FLUID MOVING MACHINERIES** | **(05 Hours)** |
| | Transportation and metering of fluids, Pipe, fitting and valves, Construction, working and characteristic features of various types of pumps, compressors, blowers and fans | |
| **9** | **APPLICATIONS OF FLUID MECHANICS** | **(05 Hours)** |
| | Flow past immersed bodies: Drag, Drag coefficients, Flow through beds of solids, Particle motion, Terminal velocity, Hindered settling, Settling and rise of bubbles and drops, Fluidization, Introduction to computational fluid dynamics. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours + 30 Hours = 90 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Reynolds number |
| 2 | Flow behaviour |
| 3 | Fluid statics |
| 4 | Fluid flow phenomena and basic equations |
| 5 | Flow of incompressible fluids |
| 6 | Flow of compressible fluids |
| 7 | Flow measurement |
| 8 | Fluid moving machineries, etc. |
| 9 | Quiz |
| 10 | Assignments / Mini projects & presentation on related topics |

| **4.** | **Practicals** |
|---|---|
| 1 | Experiment on equivalent length of pipe fittings |
| 2 | Experiment on Reynolds number |
| 3 | Experiment on viscosity by Stokes' law |
| 4 | Experiment on Bernoulli's theorem |
| 5 | Experiment on venturimeter |
| 6 | Experiment on rotameter |

| | |
|---|---|
| 7 | Experiment on orifice meter |
| 8 | Experiment on characteristics of the centrifugal pump |
| 9 | Experiment on flow through 'V' notch |
| 10 | Experiment on flow through rectangular notch |
| 11 | Experiment on cativation |
| 12 | Experiment on Darcy's law |
| 13 | Virtual Lab experiments |

| **5.** | **Books Recommended** |
|---|---|
| 1 | F. M. White, Fluid Mechanics, 9th Ed., McGraw Hill, 2022 |
| 2 | G. K. Batchelor, An Introduction to Fluid Dynamics, 2nd Ed., Cambridge Univ Press, 2000. |
| 3 | V. Gupta, S. K. Gupta, Fluid Mechanics and Its Applications, 3rd Ed., New Age International Publ., 2016. |
| 4 | W. L. McCabe, J. C. Smith, P. Harriott P., Unit Operations of Chemical Engineering", 7th Ed., McGraw-Hill, New York, 2017. |
| 5 | R. W.Fox,A.T.Mc Donald',J.W.Mitchell,Fox and Mc Donald's Introduction to Fluid Mechanic,10th ed.,Wiley Publ.,2021 |

| B. Tech. II ( Chemical Engineering) Semester – III<br>HEAT TRANSFER OPERATIONS<br>CH205 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 05 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Explain conduction, convection and radiation principles and applications. |
| CO2 | Mathematically model heat transfer problems |
| CO3 | Estimate heat transfer coefficient for convection. |
| CO4 | Identify the type of heat transfer model that needs to be applied. |
| CO5 | Analyze the performance of heat exchangers. |
| CO6 | Select evaporator for industrial applications. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(02 Hours)** |
| | Modes of heat transfer: conduction, convection and radiation, Mechanism and applications. | |
| | **CONDUCTION** | **(06 Hours)** |
| | General conduction equation in Cartesian coordinate, Steady state conduction through Plane, Cylindrical and Spherical walls, Steady state conduction with heat generation, Transient heat conduction and Lumped heat capacity analysis. | |
| | **EXTENDED SURFACES** | **(04 Hours)** |
| | Different types of fins, Temperature profile and heat transfer of fins, effectiveness and fin efficiency | |
| | **FORCED CONVECTION** | **(08 Hours)** |
| | Hydrodynamic and thermal and boundary layer, Internal and external forced convection in laminar and turbulent flow, Flow in circular and non-circular tubes, Cylinder in cross flow, Flow across banks of tubes, Convection correlations. | |
| | **NATURAL CONVECTION** | **(04 Hours)** |
| | Physical considerations, Laminar and turbulent free convection on a vertical surface, Empirical correlations, Free convection within parallel plate channels and encloser, Combined free and forced convection | |
| | **BOILING AND CONDENSATION** | **(06 Hours)** |
| | Boiling modes, Pool boiling, Pool boiling correlation, Forced convection boiling, Laminar and turbulent film condensation on a vertical surface, Film condensation of radial systems, Condensation in horizontal tubes, Dropwise condensation. | |
| | **HEAT EXCHANGERS** | **(06 Hours)** |
| | Heat Exchanger Types: Double pipe heat exchanger, Shell-and-tube heat exchanger, Spiral and Plate heat exchanger, Extended surface heat exchanger and Compact heat exchanger, Overall heat transfer coefficient, Heat exchanger analysis: LMTD Method and Effectiveness-NTU method, LMTD correction factor, Fouling factor, Heat exchanger design and performance calculations. | |

| | | |
|---|---|---|
| | **EVAPORATION AND CRYSTALIZATION** | **(05 Hours)** |
| | Different types of evaporators, Single effect and Multi-effect evaporators, Material and Heat balance in single and multi-effect evaporators. Equilibrium in crystallization, operation and equipment. | |
| | **RADIATION** | **(04 Hours)** |
| | Fundamental concepts, Radiation heat fluxes, Blackbody radiation, Emission from real surfaces, Absorption, reflection, and transmission by real surfaces, Kirchhoff's law, View factor, Blackbody radiation exchange, Radiation exchange between opaque, diffuse, gray surfaces in an enclosure. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours + 30 Hours = 90 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Tutorial is based on conduction through composite wall of plane, cylindrical and spherical wall |
| 2 | Tutorial is based on conduction in with heat generation of different boundary conditions |
| 3 | Tutorial is based on heat transfer in fins of infinite length and finite length with insulated end |
| 4 | Tutorial is based on heat transfer in fins of finite length with convection from fin end |
| 5 | Tutorial is based on transient heat conduction using lumped heat capacity |
| 6 | Tutorial is based on hydrodynamic and thermal boundary layers |
| 7 | Tutorial is based on forced convection on external surfaces |
| 8 | Tutorial is based on forced convection on flow across banks of tubes |
| 9 | Tutorial is based on forced convection on internal flows |
| 10 | Tutorial is based on natural convection |
| 11 | Tutorial is based on pool boiling and film condensation |
| 12 | Tutorial is based on material and energy balance for a single effect evaporator |
| 13 | Tutorial is based on overall heat transfer coefficient and LMTD method |
| 14 | Tutorial is based on Effectiveness-NTU method for heat exchanger analysis |
| 15 | Tutorial is based on radiation fluxes and view factor |

| **4.** | **Practicals** |
|---|---|
| 1 | Experiment on Heat transfer through composite wall at different temperature. |
| 2 | Experiment on Thermal conductivity of insulating powder (Asbestos powder). |
| 3 | Experiment on Heat transfer in double pipe heat exchanger in laminar flow. |
| 4 | Experiment on Heat transfer in double pipe heat exchanger in turbulent flow. |
| 5 | Experiment on Heat transfer by forced convection. |
| 6 | Experiment on Heat transfer coefficient in natural convection. |
| 7 | Experiment on Heat transfer in double pipe heat exchanger in parallel flow. |

| | |
|---|---|
| 8 | Experiment on Heat transfer in double pipe heat exchanger in counter-current flow. |
| 9 | Experiment on Shell and tube heat exchanger. |
| 10 | Experiment on Heat transfer by radiation: Stefan-Boltzmann Law. |
| 11 | Experiment on Heat Transfer in Agitated Vessel. |


| **5.** | **Books Recommended** |
|---|---|
| 1 | Hollman, J. P., Heat Transfer – Basic Approach, 10$^{th}$ Edition, McGraw-Hill Pub., 2010. |
| 2 | Incropera, F.P., DeWitt, D.P., Bergman T.L., Lavine A.S., Incropera's Principles of Heat and Mass Transfer, Global Edition, Wiley India Edition, 2019. |
| 3 | Geankoplis C. J., Transport Processes and Separation Process Principles, Pearson, 4th Edition 2012. |
| 4 | Suryanarayana, N. V., Engineering Heat Transfer, 2nd Edition, Penram International Publishing (I) Private Ltd., Mumbai, 2015. |
| 5 | Kern, D. Q., Process Heat Transfer, McGraw-Hill Int. Edition, New York, 1997. |

| B.Tech. II (Chemical Engineering) Semester – III<br>MASS TRANSFER OPERATIONS-I<br>CH207 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Explain a scope of mass transfer operations in chemical industries. |
| CO2 | Determine diffusivity and flux for compounds present in gas, liquid and solid system. |
| CO3 | Analyze the mechanism of mass transfer in various systems related to chemical engineering and estimate mass transfer coefficient. |
| CO4 | Estimate the gas-vapor properties and Estimate number of stages using graphical and analytical methods for separation operations excluding distillation. |
| CO5 | Design (process design) the equipment for distillation operation (single stage and multiple stages) using graphical and analytical methods. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(02 Hours)** |
| | Introduction to Mass Transfer Operation: classification & method. | |
| | **DIFFUSION AND MASS TRANSFER** | **(12 Hours)** |
| | Molecular diffusion in fluids, Steady state diffusion (both gases & liquids), Diffusivity of liquids & gases, Diffusion in solids. | |
| | **MASS TRANFER COEFFICIENTS** | **(06 Hours)** |
| | Mass Transfer co-efficient in laminar & turbulent flow, Mass, Heat and Momentum transfer analogies. | |
| | **INTER PHASE MASS TRANSFER** | **(06 Hours)** |
| | Equilibrium, Diffusion between phases, Material balance, Stages and efficiency. | |
| | **DISTILLATION** | **(14 Hours)** |
| | VLE data, Flash, differential and continuous distillation, McCabe-Thiele and Ponchon-Savarit method, Distillation in a packed column, Azeotropic, extractive, molecular and multicomponent distillation, Reactive distillation. | |
| | **HUMIDIFICATION** | **(05 Hours)** |
| | Vapor-gas mixtures, Psychrometric properties, Adiabatic and non-adiabatic operations, Cooling towers. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| 3. | Tutorials |
|---|---|
| | Problems based on the topics covered during the theory classes |
| | Problems based on diffusion and flux |
| | Problems based on mass transfer coefficients |

| | |
|---|---|
| | Problems based on estimation of number of stages |
| | Problems based on psychrometric properties |
| | Problems based on process design aspects of distillation |

| **4.** | **Books Recommended** |
|---|---|
| 1 | Treybal R.E., "Mass-Transfer Operations", 3rd Ed., McGraw-Hill, New York, 2017 |
| 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. "Chemical Engineering" Vol. 1. 6th Ed. Elsevier, New Delhi, 2004. |
| 4 | Dutta, B. K., "Principles of Mass Transfer and Separation Process" PHI Learning Pvt Ltd., New Delhi, (Reprint 2012) |
| 5 | Cussler E.L., "Diffusion: Mass Transfer in Fluid Systems", South Asia Ed., Cambridge University Press,2017 |

| B.Tech. II (Chemical Engineering) Semester – IV<br>CHEMICAL ENGINEERING THERMODYNAMICS - I<br>CH202 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Understand and apply the laws of thermodynamics for open and closed systems to set up the energy balances and to solve them for various thermodynamic processes |
| CO2 | Evaluate thermodynamic properties of pure substances using various PVT equations-of-state |
| CO3 | Calculate heat transfer associated with processes involving phase changes and reactions. |
| CO4 | Calculate the change in thermodynamic properties for the ideal and real fluid systems |
| CO5 | Calculate the system states and energy rate of turbine, compressor, pumps etc.<br>and asses the environmental & safety aspects in chemical engineering |
| CO6 | Estimate the energy requirement of thermodynamics cycles and processes. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION AND FIRST LAW OF THERMODYNAMICS** | **(07 Hours)** |
| | Introduction and Fundamentals of Thermodynamics Systems and variables, Work, Heat, Reversible and Irreversible Processes, internal energy, First Law: Closed and Open Systems, enthalpy, equilibrium state, phase rule, heat capacity, Steady and Transient Processes, Significance of Chemical Engineering Thermodynamics | |
| | **PROPERTIES OF PURE SUBSTANCES** | **(09 Hours)** |
| | Thermodynamics diagrams; Equation of states; Generalized correlations and acentric factor; Estimation of thermodynamic properties. | |
| | **HEAT EFFECTS** | **(05 Hours)** |
| | Heat capacities of gases as a function of temperature of liquids and solids, sensible heat, heat of vaporization, heat of reaction etc. | |
| | **SECOND AND THIRD LAW OF THERMODYNAMICS** | **(05 Hours)** |
| | Concept of entropy, reversible heat engine, entropy change and irreversibility, third law of thermodynamics. | |
| | **THERMODYNAMIC PROPERTIES OF FLUID** | **(08 Hours)** |
| | Mathematical relation among thermodynamic functions, Maxwell's relations, Interrelation between H, S, U, G, Cp, Cv, properties of single- and two-phase system. Residual properties using equation of state | |
| | **THERMODYNAMICS OF FLOW PROCESS** | **(07 Hours)** |
| | Throttling process, flow through nozzles, turbine, compressor, and pump with problems | |

| | | |
|---|---|---|
| | **REFRIGERATION AND LIQUEFACTION** | **(04 Hours)** |
| | Carnot refrigeration cycle, Vapor compression refrigeration cycle, liquefaction processes. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Problem related to Introduction and First Law of Thermodynamics |
| 2 | Problem related to Introduction and First Law of Thermodynamics |
| 3 | Problem related to Introduction and First Law of Thermodynamics |
| 4 | Problem related to Properties of pure substance |
| 5 | Problem related to Properties of pure substances |
| 6 | Problem related to Properties of pure substances |
| 7 | Problem related to Heat Effects |
| 8 | Problem related to Heat Effects |
| 9 | Problem related to Second and third law of thermodynamics |
| 10 | Problem related to Second and third law of thermodynamics |
| 11 | Problem related to Thermodynamic properties of Fluid |
| 12 | Problem related to Thermodynamic properties of Fluid |
| 13 | Problem related to Thermodynamics of flow process |
| 14 | Problem related to Thermodynamics of flow process |
| 15 | Problem related to Refrigeration and Liquefaction |


| **4.** | **Books Recommended** |
|---|---|
| 1 | 1. Smith J. M., Van Ness H. C., M.M. Abbott, “Introduction to Chemical Engineering Thermodynamics”, 6th Ed., McGraw-Hill, New York, 2001 |
| 2 | Rao Y. V. C., “Chemical Engineering Thermodynamics”, Universities Press Limited, Heydrabad, 1997. |
| 3 | Kyle, B.G., "Chemical and Process Thermodynamics”, 2nd Ed., Prentice-Hall of India, New Delhi,1990. |
| 4 | Sandler, S.I., "Chemical and Engineering Thermodynamics", 2nd Ed., Wiley, New York, 1989. |
| 5 | Koretsky, M.D., “Engineering and Chemical Thermodynamics”, 2nd Ed., Wiley, New York, 2009 |

| B.Tech. II (Chemical Engineering) Semester - IV<br>MASS TRANSFER OPERATIONS-II<br>CH204 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 05 |

| 1. | **Course Outcomes (COs):**<br>**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** | **(09 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** | **(03 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** | **(09 Hours)** |
| | Liquid equilibria, Stage-wise extraction, Graphical and analytical method for tray/ stage determination, Stage type extractor, Differential extractor. | |
| | **ADSORPTION AND ION-EXCHANGE** | **(07 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** | **(06 Hours)** |
| | Equilibrium, Batch and continuous drying, Mechanism and rate of drying, Equipments. | |
| | **LEACHING** | **(04 Hours)** |
| | Steady state and unsteady state operations, Methods of calculation, Equipments. | |
| | **CRYSTALLIZATION** | **(03 Hours)** |
| | Equilibrium, Operations and equipment. | |

| | | |
|---|---|---|
| | **INTRODUCTION TO RECENT SEPARATION TECHNIQUES** | **(04 Hours)** |
| | Membrane separation, Supercritical fluid extraction, Microwave assisted extraction, etc. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours + 30 Hours = 90 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Problems based on the topics covered during the theory classes |
| 2 | Problems based on liquid liquid extraction |
| 3 | Problems based on absorption |
| 4 | Problems based on adsorption |
| 5 | Problems based on drying |

| **4.** | **Practicals** |
|---|---|
| 1 | Diffusion coefficient and Mass transfer coefficient |
| 2 | Crystallization |
| 3 | Vapor-liquid equilibria and Psychrometric properties |
| 4 | Differential Distillation and Azeotropic Distillation |
| 5 | Steam Distillation and Hydrodistillation |
| 6 | Ternary Diagram (Selection of a solvent) |
| 7 | Liquid-liquid Extraction (Single/Multiple stages) |
| 8 | Freundlich Isotherm and Adsorption in Packed Bed Column |
| 9 | Leaching using conventional techniques (Batch stirring, Soxhlet extraction, Open reflux extraction) and novel techniques (Microwave/Ultrasound assisted extraction) |
| 9 | Demo: Gas Chromatograph and UV-Vis Spectrophotometer |
| 10 | Demo: Pervaporation and Adsorption |
| 11 | Experiments through virtual lab |


| **5.** | **Books Recommended** |
|---|---|
| 1 | Treybal R.E., "Mass-Transfer Operations", 3rd Ed., McGraw-Hill, New York, 2017 |
| 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. "Chemical Engineering" Vol. 1. 6th Ed. Elsevier, New Delhi, 2004. |
| 4 | Dutta, B. K., "Principles of Mass Transfer and Separation Process" PHI Learning Pvt Ltd., New Delhi, (Reprint 2012) |
| 5 | 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. |

| B.Tech. II (Chemical Engineering) Semester – IV<br>CHEMICAL REACTION ENGINEERING-I<br>CH206 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 05 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Discuss kinetics of homogeneous reactions and applications |
| CO2 | Solve kinetics, constant volume and variable volume batch reactor problems |
| CO3 | Design for single and multiple reactions |
| CO4 | Analyze the performance of CSTR and PFR |
| CO5 | Design for Series-parallel reaction |
| CO6 | Estimate heats of reaction from thermodynamics and product distribution |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(02 Hours)** |
| | Chemical kinetics, Classification of reactions, Variables affecting the rate of reaction, Reaction rate | |
| | **KINETICS OF HOMOGENEOUS REACTIONS** | **(05 Hours)** |
| | Concentration dependent term and temperature dependent terms of rate equation, Single and multiple reactions, Elementary and non-elementary reactions, Molecularity and order of reaction, Rate constant, Representation of reaction rate, Kinetic models, Temperature dependency from Arrhenius' law, thermodynamics, various theories, Activation energy, Searching for the reaction mechanism | |
| | **INTERPRETATION OF BATCH REACTOR DATA** | **(10 Hours)** |
| | Constant volume batch reactor, Variable volume batch reactor, Integral method and differential method of analysis of kinetic data, Temperature and reaction rate | |
| | **INTRODUCTION TO REACTOR DESIGN** | **(02 Hours)** |
| | Types of reactors, PFR, CSTR etc., Material & energy balances single ideal reactor, Space-time and space-velocity, Holding time, Introduction of non-ideal flow | |
| | **DESIGN FOR SINGLE REACTIONS** | **(10 Hours)** |
| | Size comparison of single reactors, General graphical comparison, Multiple reactor system, Recycle reactor, Autocatalytic reactions | |
| | **DESIGN FOR MULTIPLE REACTIONS SYSTEMS** | **(08 Hours)** |
| | Reaction in parallel, Reaction in series, Series-parallel reaction and applications | |
| | **TEMPERATURE & PRESSURE EFFECTS** | **(04 Hours)** |
| | Single & multiple reactions, Heats of reaction from thermodynamics, Product distribution | |

| | | |
|---|---|---|
| | **INDUSTRIAL APPLICATIONS** | **(02 Hours)** |
| | Types of reactors used in industries, Advanced chemical reactors | |
| | **INTRODUCTION TO BIOCHEMICAL REACTION ENGINEERING** | **(02 Hours)** |
| | Types of bio-reactors, Design, scale-up, operation and control of bio-reactors, Kinetics of biochemical reactions | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours + 30 Hours = 90 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Activation energy using Arrhenius law |
| 2 | Rate equation for non-elementary reaction |
| 3 | Arrhenius law and Temperature dependence |
| 4 | Representation of reaction rate and order of reaction |
| 5 | Size comparison of PFR and MFR |
| 6 | Space time and space velocity |
| 7 | Calculation of throughput for Recycle Reactor |
| 8 | Volume calculation for different arrangement of reactors |
| 8 | Series-parallel reaction |
| 9 | Production Distribution |

| **4.** | **Practicals** |
|---|---|
| 1 | Integral method of analysis of kinetic data |
| 2 | Differential method of analysis of kinetic data |
| 3 | Activation energy and frequency factor |
| 4 | Half-life method |
| 5 | Pseudo first order reaction |
| 6 | Study of reaction kinetics in Batch Reactor |
| 7 | Study of reaction kinetics in Mixed Flow Reactor |
| 8 | Study of reaction kinetics in Plug Flow Reactor |
| 8 | Testing of kinetic data using Artificial Neural Network |
| 9 | Temperature dependency on Production Distribution |

| **5.** | **Books Recommended** |
|---|---|
| 1 | Levenspiel O., “Chemical Reaction Engineering”, 3rd Ed., John Wiley & Sons, Singapore,1999. |
| 2 | Fogler H.S., “Elements of Chemical Reaction Engineering”, 4th Ed., Prentice-Hall, NJ, 2006 |
| 3 | Smith J. M., “Chemical Engineering Kinetics”, 3rd Ed., McGraw-Hill, New York, 1981. |
| 4 | Froment G.F., Bischoff K.B., “Chemical Reactor Analysis and Design”, 2nd Ed., John Wiley & Sons, Singapore, 1990. |
| 5 | Inamdar S.T.A., “Biochemical Engineering – Principles and Concepts”, Prentice-Hall of India, New Delhi, 2007. |

| B.Tech. II (Chemical Engineering) Semester – IV<br>PROFESSIONAL ETHICS, ECONOMICS AND BUSINESS MANAGEMENT<br>MG210 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**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** | **(6 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** | **(15 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 Behaviour: Theories of Motivation, Theories of Leadership | |
| | **FUNCTIONAL MANAGEMENT** | **(14 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 | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours= 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Case Study Discussion |
| 2 | Group Discussion |
| 3 | Management games |
| 4 | Assignments / Mini projects & presentation on related Topics |

| **4.** | **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. & Sharma 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 |

| **Additional Reference Books / Further 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 |

| B.Tech. III (Chemical Engineering) Semester – V<br>GENERAL CHEMICAL TECHNOLOGY<br>CH301 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 4 | 0 | 2 | 05 |

| **1.** | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Review the practical significance and relevance of processes in chemical industries. |
| CO2 | Assess and propose how raw materials are converted into useful products. |
| CO3 | Recognize the importance of Unit processes and Unit operations in industrial chemical systems. |
| CO4 | Analyze the operation of industrial chemical processes. |
| CO5 | Prepare organic and inorganic compounds using standard synthetic and purification procedures. |

| **2.** | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(03 Hours)** |
| | Chemical Process Industries – Facts and Figures, Types of Chemical Process Diagrams, Preparation of Process Flow Diagrams, Equipment Symbols. | |
| | **CHLOR-ALKALI INDUSTRIES** | **(05 Hours)** |
| | Manufacturing of Soda Ash by Solvay Process, Dual salt Process, Natural Soda Ash Process, Manufacturing of Caustic Soda, Chlorine, Hydrogen. | |
| | **INORGANIC ACIDS** | **(05 Hours)** |
| | Manufacturing of Sulphuric Acid, Nitric Acid, Hydrochloric Acid, Phosphoric Acid. | |
| | **FERTILIZERS** | **(05 Hours)** |
| | Types of Fertilizers, Manufacturing of Ammonia, Urea, Ammonium Nitrates, Ammonium Phosphates, Superphosphates, NPK. | |
| | **OILS, FATS, SOAPS, DETERGENTS** | **(05 Hours)** |
| | Vegetable Oils, Animal Fats, Fatty Acids and Alcohols, Extraction Methods, Hydrogenation of Oils, Soaps and Glycerine, Detergents. | |
| | **SUGAR & STARCH INDUSTRIES** | **(04 Hours)** |
| | Manufacturing of Sugar from Sugarcane, Starch, Ethanol by Fermentation. | |
| | **BIOMASS BASED CHEMICALS & BIOFUELS** | **(05 Hours)** |
| | Concept of Lignocellulosic Biorefinery, Biomass Platform Molecules, Manufacturing of Furan Derivatives, Lignin Derivatives, Biobutanol, Biodiesel. | |
| | **PULP & PAPER INDUSTRIES** | **(04 Hours)** |
| | Pulp and Paper, Cellulose and its Derivatives, Rayon. | |
| | **PETROLEUM REFINING** | **(05 Hours)** |
| | Types of Crude Oils, Petroleum Refining Products, Refinery Unit Processes. | |
| | **PETROCHEMICALS** | **(10 Hours)** |
| | Feedstocks, $C_1$ Derivatives, $C_2$ Derivatives, $C_3$ Derivatives, BTX Derivatives. | |

| | | |
|---|---|---|
| | **POLYMERS & SYNTHETIC FIBERS** | **(04 Hours)** |
| | Manufacturing of Phenol and Urea Formaldehyde Resins, Polyester, Nylons, Synthetic Rubbers. | |
| | **DRUGS & PHARMACEUTICALS** | **(05 Hours)** |
| | Classification of Drugs, Manufacturing of Drugs, Aspirin, Antibiotics, Vitamins. | |
| | **(Total Contact Time: 60 Hours + 30 Hours = 90 Hours)** | |

| **3.** | **Practicals** |
|---|---|
| 1 | Preparation of Boric acid |
| 2 | Preparation of $CaCl_2$ |
| 3 | Preparation of Detergent |
| 4 | Preparation of Nitro naphthalene |
| 5 | Preparation of Potash alum |
| 6 | Preparation of Soap |
| 7 | Determination of Kinematic Viscosity of given oil sample |
| 8 | Determination of Aniline point |
| 9 | Determination of Smoke point |
| 10 | Measurement of Softening point |
| 11 | Determination of Penetration index |
| 12 | Determination of Flash point and Fire point |

| **4.** | **Books Recommended** |
|---|---|
| 1 | Gopala Rao M. & Sittig M., Dryden's Outlines of Chemical Technology, 3rd Edition, Affiliated East-West Press Pvt. Ltd., 1997. |
| 2 | Austin G. T., Shreve's Chemical Process Industries, 5th Edition, Tata McGraw-Hill Education, Pvt. Ltd., 2012. |
| 3 | Rao B.K.B., Modern Petroleum Refining Processes, 6th Edition, Oxford & IBH Publishers, 2017. |
| 4 | Mall I.D., Petrochemical Process Technology, 2nd Edition, Trinity Press, 2017. |
| 5 | Mall I.D., Petroleum Refining Technology, CBS Publishers, 2017. |

| B.Tech. III (Chemical Engineering) Semester – V<br>CHEMICAL ENGINEERING THERMODYNAMICS - II<br>CH303 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Understand and apply ideal gas/solution models to reflect behavior of real mixtures based on the concepts of chemical potential, fugacity and excess free energy |
| CO2 | Apply a range of approaches to estimate fluid phase equilibrium in one and two component systems |
| CO3 | Evaluate the thermodynamic properties (Such as Partial molar properties, Fugacity coefficients, activity coefficients etc.) of pure fluid and fluid mixtures |
| CO4 | Evaluate and apply different methods for performing phase equilibrium calculations. |
| CO5 | Estimate fluid phase equilibrium in one and two component systems through solution models |
| CO6 | Evaluate the chemical reaction equilibrium for the equilibrium conversion/composition calculations/process at specified conditions using appropriate thermodynamic approaches. |

| 2. | **Syllabus** | |
|---|---|---|
| | **THERMODYNAMIC PROPERTIES OF FLUIDS** | **(17 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** | **(18 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, introduction to LLE,VLLE,SLE. | |
| | **CHEMICAL EQUILIBRIUM** | **(10 Hours)** |
| | Criteria, Reaction Extent, equilibrium constant (K), effect of Temp. & Pressure on K, evaluation of K, evaluation of equilibrium conversion for gas and liquid phase reaction. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| 3. | **Tutorials** |
|---|---|
| 1 | Problem related to Thermodynamic properties of fluids |
| 2 | Problem related to Thermodynamic properties of fluids |
| 3 | Problem related to Thermodynamic properties of fluids |
| 4 | Problem related to Thermodynamic properties of fluids |
| 5 | Problem related to Thermodynamic properties of fluids |
| 6 | Problem related to Phase equilibrium |
| 7 | Problem related to Phase equilibrium |
| 8 | Problem related to Phase equilibrium |
| 9 | Problem related to Phase equilibrium |

| | |
|---|---|
| 10 | Problem related to Phase equilibrium |
| 11 | Problem related to Phase equilibrium |
| 12 | Problem related to Phase equilibrium |
| 13 | Problem related to Chemical Equilibrium |
| 14 | Problem related to Chemical Equilibrium |
| 15 | Problem related to Chemical Equilibrium |

| **4.** | **Books Recommended** |
|---|---|
| 1 | Smith J. M., Van Ness H. C., M.M. Abbott, “Introduction to Chemical Engineering Thermodynamics”, 6th Ed., McGraw-Hill, New York, 2001 |
| 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, M.D., “Engineering and Chemical Thermodynamics”, 2nd Ed., Wiley, New York, 2009 |

| B. Tech. III (Chemical Engineering) Semester – V<br>CHEMICAL REACTION ENGINEERING – II<br>CH305 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, 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** | **(07 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** | **(06 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** | **(06 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 including Multiphase Reactors** | **(10 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. | |
| | **LABORATORY REACTORS** | **(02 Hours)** |
| | **CATALYSIS** | **(06 Hours)** |
| | Typical Catalysts used in chemical processes, Catalyst Characterizations, Catalyst Deactivation and Regeneration, Temperature Progression, Moving Bed Reactors, Metal recovery from the Spent Catalysts, Nano catalysis | |
| | **ZEOLITE CATALYSIS** | **(03 Hours)** |
| | Synthesis, Applications in Refining and Petrochemical Processes, Rise of Acidity, Modifications, Shape Selectivity | |

| | | |
|---|---|---|
| | **ENVIRONMENTAL CATALYSIS** | **(01 Hour)** |
| | Importance, Applications, Reactions involved | |
| | **Hydrogen** | **(02 Hour)** |
| | Liquid Organic Hydrogen Carriers: Catalysts involved | |
| | **STRUCTURED REACTORS** | **(02 Hours)** |
| | Configurations, Preparation, Hydrodynamics and Applications, Accelerated Deactivation of catalysts, Laboratory reactors, Oscillatory motion of reactants in catalyst pores, Microreactors. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Demonstration of case study |
| 2 | Group Discussion |
| 3 | Quiz |
| 4 | Assignments / Mini projects & presentation on related Topics |

| **4.** | **Books Recommended** |
|---|---|
| 1 | Fogler H.S., "Elements of Chemical Reaction Engineering", 4$^{th}$ 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", 3$^{rd}$ 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", 2$^{nd}$ Ed., John Wiley & Sons, Singapore, 1990. |

| B. Tech. III (Chemical Engineering) Semester – VI<br>Instrumentation and Process Control<br>CH302 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 05 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, students will be able to** |
|---|---|
| CO1 | Understand the differential equation models of first and second order system |
| CO2 | Analyse first order system and higher order system for various real systems and apply the concepts in practical knowledge |
| CO3 | Apply and estimate dynamic behaviour for various disturbances |
| CO4 | Recognize closed loop transfer functions and various controllers and stability of control system |
| CO5 | Evaluate frequency response to systems and Design control system by controller tuning methods to industrial control systems |
| CO6 | Recognize advanced controllers and their requirement and apply the concepts for practical knowledge in industries |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(01 Hour)** |
| | Steady and unsteady state design equation for an agitated heated tank. Introduction to P, PI, and PID controls. | |
| | **DYNAMICS OF FIRST ORDER SYSTEMS** | **(05 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** | **(06 Hours)** |
| | Dynamics of second order systems subjected to various disturbances like step, impulse, sinusoidal. | |
| | **LINEAR CLOSE LOOP SYSTEM** | **(03 Hours)** |
| | Linear close loop system, Servo and Regulator problem. | |
| | **CLOSED LOOP TRANSFER FUNCTION** | **(04 Hours)** |
| | Closed loop transfer function, block diagrams for various simple systems, Transient response of the control system. | |
| | **STABILITY OF CONTROL SYSTEM** | **(05 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) | |
| | **ADVANCED CONTROL and USE OF MATLAB IN PROCESS CONTROL** | **(07 Hours)** |
| | Cascade Control, Feed forward Control, Ratio control, Split Range Control, Auctioneering Control and Multivariable Control. | |

| | | |
|---|---|---|
| | **CONTROLLER TUNING AND PROCESS IDENTIFICATION, CONTROLLERS AND CONTROL ELEMENTS** | **(06 Hours)** |
| | Controller, control elements, control valves. | |
| | **DISTRIBUTED CONTROL SYSTEM (DCS)** | **(02 Hours)** |
| | Distributed control system (DCS), Programmable Logical Control System (PLC). | |
| | **FLOW, LEVEL, PRESSURE AND TEMPERATURE MESUREMENT** | **(02 Hours)** |
| | Construction, working principle, selection criteria and application of the measurement devices | |
| | **SENSOR AND TRANSDUCER, INSTRUCTION PANELS, INTERFACE** | **(02 Hours)** |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours+30 Hours = 90 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Derivations/Numericals based on first order systems |
| 2 | Numericals/Derivations based on second order systems |
| 3 | Numericals/Derivations based on Closed Loop Transfer Function |
| 4 | Stability of control system, Routh test criterion, Concept of Root Locus, |
| 5 | Frequency analysis |
| 6 | Bode diagrams for simple order system (first order system, second order system, P, PI, PD controllers) |
| 7 | Z-N Tuning |

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


| **5.** | **Books Recommended** |
|---|---|
| 1 | Coughnowr D.R., Steven E. LeBlanc “Process Systems Analysis and Control”, 3rd Edition, McGraw Hill Inc., New York, 2009. |
| 2 | Stephanopoulos G.,” Chemical Process Control”, Prentice Hall of India Private Ltd., New Delhi, 2001. |
| 3 | Luben W.L. & Luben M.L., “Essentials of Process Control”, McGraw Hill Inc., New York, 1997. |
| 4 | Dale E.Seborg,Thomas F.Edgar,Duncan A. Mellichamp,Franchis J.Doyle III,’’Process Dynamics and Control”,4th Edition,Wiley Eastern Limited,2021. |
| 5 | Eckman D.P., “Industrial Instrumentation”, Wiley Eastern Limited, 1990. |

| B. Tech. III (Chemical Engineering) Semester – VI<br>PROCESS EQUIPMENT DESIGN<br>CH304 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | Course Outcomes (COs):<br>At the end of the course, 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 | Design process equipments including pressure vessels, heat exchangers, distillation columns, extraction columns, absorbers, strippers, etc. |
| CO4 | Design process equipments subjected to internal pressure and external pressure |
| CO5 | Analyze the environmental, plant, and personnel safety criteria and implement them in designing process vessels. |
| CO6 | Evaluate design of various process equipments like storage tanks, distillation columns, etc. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(3 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** | **(12 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** | **(4 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 | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Numericals |
| 2 | Design problems |
| 3 | Quiz |
| 4 | Assignments / Mini projects & presentation on related topics |

| **4.** | **Books Recommended** |
|---|---|
| 1 | V. V. Mahajani, S. B. Umarji, Joshi's Process Equipment Design, 5$^{rd}$ Ed., Laxmi Publ., 2016. |
| 2 | B. C. Bhattacharyya, Introduction to Chemical Equipment Design: Mechanical Aspects, CBS Publishers, New Delhi, 2017. |
| 3 | Indian Standard 2825 (1969). |
| 4 | C. Soares, Process Engineering Equipment Handbook, McGraw-Hill, New York, 2002. |
| 5 | N. P. Cheremisinoff, Handbook of Chemical Processing Equipment, Butterworth Heinemann, Oxford, 2000. |
| 6 | D. Q. Kern, Process Heat Transfer, McGraw-Hill, New York, 1982. |
| 7 | S. Hall, Rules of Thumb for Chemical Engineers, 6$^{th}$ Ed., Elsevier, Oxford, 2017. |
| 8 | Coulson & Richardson's Chemical Engineering, Vol. 6, 4$^{th}$ Ed., Elsevier, New Delhi, 2006. |

| B.Tech. III (Chemical Engineering) Semester – VI<br>CHEMICAL ENGINEERING PLANT DESIGN AND ECONOMICS<br>CH306 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**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 for the same activity based on the economy. |
| CO6 | Appraise the concept of optimization in plant operation and the importance of project management tools (PERT and CPM) in process industries. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(02 Hours)** |
| | Basic consideration in chem. Engg. plant design, project identification, preliminary technoeconomic feasibility. | |
| | **PROCESS DESIGN ASPECTS** | **(04 Hours)** |
| | Selection of process, factors affecting process selection, types of flow diagrams. | |
| | **SELECTION OF PROCESS EQUIPMENT** | **(03 Hours)** |
| | Standard versus special equipment, materials of construction, selection criteria etc. | |
| | **PROCESS AUXILIARIES** | **(03 Hours)** |
| | Piping design, layout, support for piping insulation, types of valves, process control & instrumentation control system design. | |
| | **PROCESS UTILITIES** | **(04 Hours)** |
| | Process water, boiler feed water, water treatment & disposal, steam, oil heating system, chilling plant, compressed air, and vacuum system. | |
| | **PLANT LOCATION AND LAYOUT** | **(04 Hours)** |
| | Factors affecting plant location, use of scale models | |
| | **COST ESTIMATION** | **(06 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** | **(04 Hours)** |
| | Types and methods of determination, evaluation. | |
| | **PROFITABILITY** | **(04 Hours)** |
| | Alternative investment & replacement methods for profitability evaluation, economic consideration in process and equipment design, inventory control. | |

| | | |
|---|---|---|
| | **OPTIMUM DESIGN** | **(03 Hours)** |
| | General products rates in plant operation, optimum conditions etc. | |
| | **PRODUCTION, PLANNING, SCHEDULING AND CONTROL** | **(08 Hours)** |
| | Introduction, PERTS & CPM. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 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. " Project Management CPM PERT GERT and Linear Programming",$4^{th}$ edition, Jain Brothers, New Delhi, 2001 |
| 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, 1983. |

| B.Tech. IV (Chemical Engineering) Semester – VII<br>PROCESS MODELLING AND SIMULATION<br>CH401 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 2 | 05 |

| **1.** | **Course Outcomes (COs): At the end of the course, the students will be able to** |
|---|---|
| CO1 | Formulate mathematical models of chemical engineering systems |
| CO2 | Solve and validate the developed model |
| CO3 | Analyze various phenomena in chemical processes |
| CO4 | Analyze experimental data and calculate error |
| CO5 | Solve chemical engineering problems using simulation software |
| CO6 | Develop decision-making skills based on mathematical models of chemical systems |

| **2.** | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(05 Hours)** |
| | Introduction to modelling and simulation, Classification of mathematical models, Principle of formulations, Mathematical consistency of model, Degree of freedom analysis, Conservation equations (Mass, Energy, Momentum), Principles of similarity, Parameters and Boundary conditions, Chemical kinetics with examples. | |
| | **NUMERICAL METHODS** | **(05 Hours)** |
| | Classification of partial differential equations (PDE's), solution of PDEs by Finite difference techniques, method of weighted residuals. Orthogonal collocation to solve PDEs with their application to chemical engineering systems models. | |
| | **MODELS OF HEAT TRANSFER EQUIPMENT** | **(08 Hours)** |
| | Mathematical Models of Heat Exchangers, Boiler, Condenser, Evaporators, use of Numerical Methods for solving evaporator problems. | |
| | **MODELS OF SEPARATION PROCESSES** | **(10 Hours)** |
| | Separation of multicomponent mixtures by use of a single equilibrium stage, flash calculation under isothermal and adiabatic conditions.<br>Tridiagonal formulation of component material balances and equilibrium relationships for Distillation, Absorption, Stripping, Extraction, Leaching, Drying and Crystallization. | |
| | **MODELS OF REACTORS** | **(07 Hours)** |
| | CSTR, Plug flow reactor, Fixed bed reactor (one dimensional and two-dimensional fixed bed reactor models), Fluidized bed reactor. | |
| | **SIMULATION** | **(10 Hours)** |
| | Simulation of the models, Sequential modular approach, Equation oriented approach, Partitioning and tearing, Introduction and use of process simulation software in chemical engineering processes. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours + 30 Hours = 90 Hours)** | |

| 3. | **Tutorials** |
|---|---|
| 1 | Tutorial is based on mathematical formulation |
| 2 | Tutorial is based on degree of freedom analysis and conservation equations |
| 3 | Tutorial is based on principle of similarity, parameters and boundary conditions |
| 4 | Tutorial is based on application of numerical methods to chemical engineering systems |
| 5 | Tutorial is based on models of heat transfer equipment |
| 6 | Tutorial is based on models of heat transfer equipment |
| 7 | Tutorial is based on models of heat transfer equipment |
| 8 | Tutorial is based on models of separation processes |
| 9 | Tutorial is based on models of separation processes |
| 10 | Tutorial is based on models of separation processes |
| 11 | Tutorial is based on models of chemical reactors |
| 12 | Tutorial is based on models of chemical reactors |
| 13 | Tutorial is based on models of chemical reactors |
| 14 | Tutorial is based on numerical simulation of chemical systems |
| 15 | Tutorial is based on numerical simulation of chemical systems |

| 4. | **Practicals** |
|---|---|
| 1 | MATLAB basics for solving chemical engineering problems |
| 2 | Simulation of the model for mixer using process simulator |
| 3 | Simulation of the model for two interacting tanks |
| 4 | Simulation of the model for laminar flow in a pipe |
| 5 | Simulation of heat transfer model using process simulator |
| 6 | Simulation of heat exchanger model using process simulator |
| 7 | Simulation of the model for reaction in series |
| 8 | Simulation of the model for non-isothermal plug flow reactor |
| 9 | Simulation of the system of reactions in a constant volume, constant temperature batch reactor |

| 5. | **Books Recommended** |
|---|---|
| 1 | Lubyen W. L., "Process Modeling, Simulation and Control for Chemical Engineers", 2nd Ed., McGraw-Hill,New York, 1989. |
| 2 | Pushpavanam S., "Mathematical Methods in Chemical Engineering", Prentice-Hall of India, New Delhi, 1st Edition, 2001. |
| 3 | Ramirez, W.; "Computational Methods forProcess Simulation", 2nd Edn., Butterworths Publishers, New York, 1997 |
| 4 | Franks, R. G. E., "Mathematical Modelling in Chemical Engineering ", John Wiley, 1967. |
| 5 | Jensen V.G., Jeffreys G.V., "Mathematical Methods in Chemical Engineering", 2nd Ed., Academic Press, London, 1978. |

| B.Tech. IV (Chemical Engineering) Semester – VII<br>ELEMENTS OF TRANSPORT PHENOMENA<br>CH403 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Describe basic of momentum, heat and mass transfer |
| CO2 | Write shell balance equation for conservation of momentum, energy and mass; to obtain desired profiles for velocity temperature and concentration |
| CO3 | Solved and analyze generalized macroscopic balance for conservation of momentum, energy and mass to obtain engineering quantities of interest |
| CO4 | Solved and analyze appropriate equations of change to obtain desired profile for velocity temperature and concentration. |
| CO5 | Recognize and apply analogies amount momentum, heat and mass transfer |
| CO6 | Explain interface transport |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(01 Hour)** |
| | **TRANSPORT BY MOLECULAR MOTION** | **(14 Hours)** |
| | Momentum transport by viscosity and momentum-flux. Energy transport by thermal conductivity and heat-flux. Mass transport by diffusivity and mass-flux | |
| | **TRANSPORT IN ONE DIMENSION (SHELL BALANCE METHODS)** | **(17 Hours)** |
| | Shell momentum balances and velocity distributions. Shell energy balances and temperature distributions. Shell mass balances and concentration distributions | |
| | **USE OF GENERAL TRANSPORT EQUATIONS** | **(06 Hours)** |
| | Equations of change and their use in momentum transport (isothermal) | |
| | **VELOCITY DISTRIBUTIONS IN TURBULENT FLOW** | **(01 Hour)** |
| | Comparisons of laminar and turbulent flows. Time-smoothed equations of change for incompressible fluids. | |
| | **INTERPHASE TRANSPORT IN ISOTHERMAL SYSTEMS** | **(02 Hours)** |
| | Friction factors for flow in tubes, flow around spheres, and packed columns. | |
| | **MACROSCOPIC BALANCES FOR ISOTHERMAL FLOW SYSTEMS** | **(02 Hours)** |
| | Macroscopic mass balance for steady and unsteady-state problems | |
| | **INTRODUCTION TO EQUATIONS OF CHANGE FOR NONISOTHERMAL SYSTEMS AND MULTICOMPONENT SYSTEMS.** | **(02 Hours)** |
| | Energy transport and mass transport | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| 3. | **Tutorials** |
|---|---|
| 1 | Various types of viscosity measurement instruments and their principles |
| 2 | Viscosity estimation of gases |
| 3 | Viscosity estimation of liquids |
| 4 | Velocity distribution in different geometric systems |
| 5 | Using Equations of change for isothermal systems in different geometric systems to derive velocity distributions |
| 6 | Friction factors in different geometric systems |
| 7 | Macroscopic balances for isothermal flow systems in different geometric systems |
| 8 | Thermal conductivity estimation of gases |
| 9 | Temperature distribution in different geometric systems |
| 10 | Diffusivity estimation for gases |
| 11 | Mass transfer due to diffusion and concentration distribution |

| 4. | **Books Recommended** |
|---|---|
| 1 | Bird R.B., Stewart W.E. and Lightfoot E.N., "Transport Phenomena", 1$^{st}$ and 2$^{nd}$ Eds., John Wiley & Sons, Singapore, 1960 & 2002. |
| 2 | Plawsky J.L., "Transport Phenomena Fundamentals", Marcel Dekker, New York, 2001. |
| 3 | Thomson, W.J. "Introduction to Transport Phenomena" Pearson Education Asia, Singapore, 2000 |
| 4 | Geankoplis C.J., "Transport Processes and Separation Process Principles", 4$^{th}$ Ed., PHI, New Delhi, 2009. |
| 5 | Welty J.R., Wicks C.E., Wilson R.E. and Rorrer G., "Fundamentals of Momentum, Heat, and Mass Transfer", 4$^{th}$ Ed., Wiley India, 2007. |
| 6 | Brodkey R.S. and Hershey H.C., "Transport Phenomena: A Unified Approach" McGraw-Hill, 1989. |
| 7 | Slattery J.C., Sagis L., and Oh E.S., "Interfacial Transport Phenomena", 2$^{nd}$ Ed., Springer, 2007. |

| B.Tech. IV (Chemical Engineering) Semester – VII<br>INNOVATION, INCUBATION AND ENTREPRENEURSHIP<br>MG110 | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**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 |
| CO6 | Develop experiential learning through Assignments, Management games, Case study discussion, Group discussion, Group presentations etc. |

| 2. | **Syllabus** | |
|---|---|---|
| | **CONCEPTS OF ENTREPRENEURSHIP** | **(08 Hours)** |
| | Scope of Entrepreneurship, Definitions of Entrepreneurship and Entrepreneur, Entrepreneurial 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 Environnent – Political, Legal, Technological, Natural, Economic, Socio – Cultural etc. | |
| | **FUNCTIONAL MANAGEMENT AREA IN ENTREPRENEURSHIP** | **(16 Hours)** |
| | Marketing Management: Basic concepts of Marketing, Development of Marketing Strategy and Marketing plan<br>Operations Management: Basic concepts of Operations management, Location problem, Development of Operations strategy and plan<br>Personnel Management: Main operative functions of a Personnel Manager, Development of H R strategy and plan<br>Financial Management: Basics of Financial Management, Ratio Analysis, Investment Decisions, Capital Budgeting and Risk Analysis, Cash Flow Statement, Break Even Analysis | |
| | **PROJECT PLANNING** | **(08 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** | **(03 Hours)** |
| | Introduction to Intellectual Property Rights – IPR, Patents, Trademarks, Copy Rights | |
| | **INNOVATION AND INCUBATION** | **(06 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 | |
| | **SOURCES OF INFORMATION AND SUPPORT FOR ENTREPRENEURSHIP** | **(04 Hours)** |
| | State level Institutions, Central Level institutions and other agencies | |
| | **TUTORIAL:** Case Study Discussion, Group Discussion, Management games andAssignments / Mini projects & presentation on related Topics | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours= 60 Hours)** | |

| **3.** | **Tutorials** |
|---|---|
| 1 | Case Study Discussion |
| 2 | Group Discussion |
| 3 | Management games |
| 4 | Assignments / Mini projects & presentation on related Topics |


| **4.** | **Books Recommended** |
|---|---|
| 1 | Desai Vasant, Dynamics of Entrepreneurial Development and Management, HimalayaPublishing House, India, $6^{th}$ Revised Edition, 2020 |
| 2 | Charantimath P. M., Entrepreneurial Development and Small Business Enterprises, Pearson Education, $3^{rd}$ 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, $9^{th}$ Edition, 2019 |
| 5 | Banga T. R. &Sharma S.C., Industrial Organisation & Engineering Economics, Khanna Publishers, $25^{th}$ Edition, 2015 |

| | **Additional Reference Books / Further Reading** |
|---|---|
| 1 | Prasad L.M., Principles & Practice of Management, Sultan Chand & Sons, $8^{th}$ 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, $14^{th}$ Edition, 2014 |
| 4 | Tripathi P.C., Personnel Management & Industrial Relations, Sultan Chand & sons, $21^{st}$ Edition, 2013 |
| 5 | Chandra P., Financial Management, Tata McGraw Hill, $9^{th}$ Edition, 2015 |

| B.Tech. II (Chemical Engineering)<br>INTRODUCTION TO ENGINEERING STATISTICS<br>CH251<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Understanding of descriptive statistics by quantitative reasoning and data visualization |
| CO2 | Knowledge of the basics of inferential statistics from sample data analysis |
| CO3 | Understanding the concept of the probability and regression analysis |
| CO4 | Apply statistical reasoning and procedures in the analysis of real data |
| CO5 | Employ the concept of parametric and non-parametric test for statistical analysis |
| CO6 | Solve statistical problem using software package |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(04 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** | **(05 Hours)** |
| | Mean, Median, Mode. Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation. | |
| | **DATA ANALYSIS** | **(05 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** | **(06 Hours)** |
| | Elementary probability rules, conditional probability, normal distribution, binomial distribution, probability distribution function | |
| | **HYPOTHESIS TESTING** | **(05 Hours)** |
| | Null hypothesis, alternative hypothesis, p-value, Type-I and Type-II error, confidence interval, central limit theorem | |
| | **REGRESSION** | **(06 Hours)** |
| | Lines of regression, properties of regression coefficients, Multiple and Partial correlation coefficients in three variables and their properties | |
| | **PARAMETRIC AND NON-PARAMETRIC TESTS** | **(06 Hours)** |
| | One Sample t-test, paired t-test, ANOVA, two-way ANOVA, sign test, Wilcoxon's signed rank test | |

| | | |
|---|---|---|
| | **DESIGN OF EXPERIMENTS** | **(03 Hours)** |
| | Basic principles of Design, Steps in experimentation, Different techniques of Design of experiments | |
| | **APPLICATION OF STATISTICAL ANALYSIS IN ENGINEERING** | **(05 Hours)** |
| | Case Studies, Elementary statistics using software package like MINITAB, Excel. | |
| | **(Total Contact Time: 45 Hours)** | |

| **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 | Walpole. R.E., Myers. R.H., Myers. S.L. and Ye. K., Probability and Statistics for Engineers and Scientists, 9th Edition, Pearson Education, Asia, 2011. |
| 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. II (Chemical Engineering)<br>INTRODUCTION TO MACRO-MOLECULES<br>CH252<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Describe the macro-molecules based on chemical constitution and architecture of chains |
| CO2 | Correlate macroscopic properties using microscopic chemical structure |
| CO3 | Predict the thermo-dynamic behavior of macro-molecular mixture by using the microscopic chemical structure |
| CO4 | Characterize the macroscopic materials using the mechanical and electrical respose |
| CO5 | Have the knowledge of recent advances in the thermal property enhancement methods |
| CO6 | Able to understand mechanical response of macromolecules |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(06 Hours)** |
| | Concepts, Nomenclature, Synthesis of Macro-molecules, Basic definitions, Molar mass and degree of polymerization | |
| | **SINGLE CHAIN CONFORMATIONS** | **(08 Hours)** |
| | Conformation of single macro-molecule, ideal chain, expanded chain, persistent chain | |
| | **POLYMER SOLUTIONS** | **(08 Hours)** |
| | Dilute and semi-dilute solutions, excluded volume interaction, polyelectrolyte solutions, flory-huggins theory, phase separation mechanism, critical fluctuations and spinodal decomposition. | |
| | **BIO-MACROMOLECULES, NATURAL MACROMOLECULES, FIBERS** | **(07 Hours)** |
| | Proteins, Polynucleotides, polysaccharides, naturally occurring elastomers, natural and synthetic fibre, cellusics, non-cellulolosics, fibre-spinning operations | |
| | **ENGINEERED MACRO-MOLECULES, SPECIALTY MACRO MOLECULES** | **(08 Hours)** |
| | Conjugated polymers, microscopic dynamics, non-linear mechanism, Polyamides, acetal, ABS, engineering polyesters, Ionic polymers | |
| | **POLYMER PROCESSING AND RHEOLOGY** | **(08 Hours)** |
| | Extrusion, molding, coating, rheometers, thermal analysis, mechanical response, elastic response, types of response, response function | |
| | **(Total Contact time: 45 Hours)** | |

| 3. | Books Recommended |
|---|---|
| 1 | Gert Strobl, The physics of polymer: Concept for understanding their structures, and behaviours, Springer, 3rd edition, 2007 |
| 2 | L. Mandelkern, An introduction to macromolecules, Springr-Verlag, 2nd edition, 2012 |
| 3 | Fried J R, polymer science and technology, Prentice hall of indiaPvt ltd, new delhi, Eastern economy edition, 2000 |
| 4 | George odian, Principles of Polymerization, John Wiley & Sons Inc., 2004 |
| 5 | Premamoy ghosh, Polymer science and Technology, Tata McGraw hill Publishing Company, new Delhi, 3rd Edition, 2010 |

| B.Tech. II (Chemical Engineering)<br>MICRO PROCESS ENGINEERING<br>CH253<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Understand the concept of process intensification and hydrodynamics in the micro scale devices |
| CO2 | Employ key transport equations to describe the fluid flow in microchannels |
| CO3 | Describe the effect of micromixing on the reactor performance |
| CO4 | Design of single, multiphase, and integrated micro-reactors |
| CO5 | Evaluate the impact of various technologies on mixing, heat transfer and mass transfer in micro devices. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION AND OVERVIEW** | **(10 Hours)** |
| | Overview and benefits of micro process engineering, general principle of process intensification and benefits; process intensification technologies (rotating packed beds, thin-film and rotor-stator spinning-disc reactors, oscillatory baffled reactors / crystallizers, coiled tube heat exchangers); moving from batch to continuous | |
| | **MINIATURIZATION** | **(05 Hours)** |
| | Characteristic process times; coupling of physico-chemical phenomena; effect of scale on process parameters | |
| | **MIXING IN MICROCHANNELS** | **(05 Hours)** |
| | Flow regimes in microchannels; mixing by pure diffusion; mixing time for laminar mixing in a shear field | |
| | **MICRO HEAT EXCHANGERS** | **(05 Hours)** |
| | Heat transfer in various geometries; thermal sensitivity; multipoint injection, type of micro heat exchangers, heat management in micro and milli-reactors | |
| | **EFFECT OF MIXING ON CHEMICAL REACTIONS** | **(10 Hours)** |
| | Macro-, meso- and micro-mixing; segregation; effect of total segregation on reactor performance; effect of partial segregation on reactor performance and selectivity; experimental mixing time characterization via physical and chemical methods | |
| | **MICROREACTORS** | **(10 Hours)** |
| | Overview and benefits; passive micromixers (parallel lamination, serial lamination, chaotic mixers and segmented flow): flow regimes, mixing principles & examples; active micromixers (pressure disturbance, electrokinetic); commercial systems; industrial examples,<br>RTD in microreactors (Microchannels; fixed-beds; static mixers; coiled tubes and flow inverters; segmented flow) | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Hessel, V., A. Renken, J.C. Schouten and J.-I. Yoshida (eds.). Micro Process Engineering-A Comprehensive Handbook. 2009. Wiley-VCH. |
| 2 | Poux, M., P. Cognet and C. Gourdon. Green Process Engineering from Concepts to Industrial Applications. 2015. CRC Press. |
| 3 | Boodhoo, K. and A. Harvey. Process Intensification for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing. 2013. John Wiley & Sons Inc. |
| 4 | Kashid, M., A. Renken and L. Kiwi-Minsker. Microstructured Devices for Chemical Processing. 2015. Wiley-VCH. |
| 5 | Hessel, V., Kralisch, D. and N. Kockmann. Novel Process Windows, 2015. Wiley. |
| 6 | Poux, M., P. Cognet and C. Gourdon. Green Process Engineering. 2015. CRC Press. |

| B.Tech. II (Chemical Engineering)<br>POLYMER ENGINEERING<br>CH254<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br><br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Explain the basic concept of monomer, polymer and repeating units with properties. |
| CO2 | Classify different polymerization reactions and their mechanisms/kinetics |
| CO3 | Analyse the polymer characteristics using different techniques |
| CO4 | Identify the concept of polymer compounding, blends and composites |
| CO5 | Appraise the concept of polymer processing and polymer degradation |
| CO6 | Summarize various polymers and their properties |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(04 Hours)** |
| | Monomers, polymers, classification of polymers | |
| | **POLYMER CHEMISTRY** | **(06 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** | **(05 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** | **(06 Hours)** |
| | Difference between blends and composites, their significance, choice of polymers for blending, FRP, particulate, long and short fibre reinforced composites, Nanocomposites. | |
| | **POLYMER TECHNOLOGY** | **(05 Hours)** |
| | Polymer compounding, need and significance of polymer compounding, different compounding ingredients for polymer, crosslinking and vulcanization. | |
| | **POLYMER PROCESSING** | **(06 Hours)** |
| | Compression molding, transfer molding, injection molding, blow molding, reaction injectionmolding, extrusion, pultrusion, calendaring, rotational molding, thermoforming, rubber processing in two-roll mill, internal mixer. | |

| | | |
|---|---|---|
| | **POLYMER DEGRADATION** | **(05 Hours)** |
| | Definition, Types of degradation, some new research on polymer degradation. | |
| | **POLYMER SYNTHESIS AND PROPERTIES** | **(08 Hours)** |
| | Commodity and general-purpose thermoplastics and thermosetting polymers: PE, PP, PS, PVC, PF, MF, UF, Epoxy, Unsaturated polyester etc. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Gowariker, V.R., Viswanathan, N.V., and Sreedhar, J.,“Polymer Science” 5th Edition, New Age International Private Limited, 2023. |
| 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 | DG Baird, “Polymer Processing - Principles and Design”, 2nd Edition, John Wiley & Sons Inc., 2014. |
| 5 | Paul C. Painter; Michael M. Coleman , “Essentials of Polymer Science and Engineering”, DEStech Publications, Inc., 2008. |

| B.Tech. II (Chemical Engineering)<br>CORROSION SCIENCE AND ENGINEERING<br>CH255<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>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 and select suitable technique for corrosion prevention. |

| 2. | Syllabus | |
|---|---|---|
| | **ELECTROCHEMISTRY OF CORROSION** | **(06 Hours)** |
| | 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; $FeH_2O$-$O_2$ diagram; Copper, aluminium and general corrosion diagrams | |
| | **CORROSION KINETICS AND APPLICATION OF ELECTROCHEMISTRY** | **(10 Hours)** |
| | Overpotential; Activation Polarization; Concentration polarization; Ohmic drop; Graphical presentation of kinetic data (Evan's 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** | **(07 Hours)** |
| | Identification of 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** | **(10 Hours)** |
| | 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 | (12 Hours) |
|---|---|---|
| | 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 Contact Time: 45 Hours)** | |


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

| B. Tech. II (Chemical Engineering)<br>MATERIAL SCIENCE AND TECHNOLOGY<br>CH256<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Define the relationships between structure and properties of different classes of materials |
| CO2 | Apply basic elements of alloy thermodynamics and reaction kinetics and develop quantitative analysis of phase transformations in material processing |
| CO3 | Evaluate the role of modes of failures in design of engineering materials |
| CO4 | Interpret the influence of composition of a material on its corrosion behaviour and propose commercially viable preventive measures |
| CO5 | Identify and select proper materials for relevant engineering applications |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION AND CONCEPTS FROM PHYSICAL METALLURGY** | **(05 Hours)** |
| | Basic concepts and significance of materials science and engineering, Classes of engineering materials and their salient properties, Atomic structure and interatomic bonding in solids, Crystal structures, Crystallographic directions and planes, Determination of crystal structures | |
| | **CRYSTALLINE IMPERFECTIONS AND DIFFUSION IN SOLIDS** | **(06 Hours)** |
| | Point, line, surface and volume defects; Diffusion mechanisms, Fick's first and second law of diffusion, Solid phases and phase diagrams, solid solutions. | |
| | **PHASE DIAGRAMS** | **(05 Hours)** |
| | Solid solutions, Gibbs phase rule, phase diagrams for binary isomorphous and eutectic alloy systems, Iron-Iron carbide phase diagram, Phase transformations and kinetics | |
| | **FERROUS METALS AND ALLOYS** | **(05 Hours)** |
| | Cast iron, wrought iron, Effects of alloying elements, Steel, Low and High Alloy steels | |
| | **NON-FERROUS METALS AND ALLOYS** | **(05 Hours)** |
| | Aluminum, Copper, Tin, Nickel and Titanium | |
| | **POLYMERIC, CERAMIC AND COMPOSITE MATERIALS** | **(05 Hours)** |
| | Types, properties and applications of polymeric, ceramic and composite materials, Methods of fabrication of polymeric and composite materials. | |
| | **ENGINEERING PROPERTIES AND FAILURE OF MATERIALS** | **(04 Hours)** |
| | Important mechanical, thermal and electrical properties, plastic and elastic deformation, Failure modes viz. creep, fracture, fatigue. | |
| | **BIOMATERIALS** | **(05 Hours)** |
| | Introduction to biomaterials, concept of biocompatibility, properties of biomaterials, bimetallic alloys, ceramic biomaterials, polymeric biomaterials. | |

| | | |
|---|---|---|
| | **CORROSION AND ITS PREVENTION** | **(05 Hours)** |
| | Electrochemical principles involved, Types of corrosion, Corrosive environments and prevention of corrosion, Factors determining the choice of materials of construction in chemical process industries | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Callister, W.D. and Rethwisch, D.G., Fundamentals of Materials Science and Engineering: AnIntegrated Approach, John Wiley & Sons, $4^{th}$ Edition, 2011. |
| 2 | Smith, W.F., Hashemi, J. and Prakash, R., Materials Science and Engineering, McGraw Hill, $4^{th}$ Edition, 2010. |
| 3 | Shackelford, J.F. and Muralidhara, M.K., Introduction to Materials Science for Engineers, $6^{th}$ Edition, Pearson Education, 2009. |
| 4 | Raghavan, V., Materials Science and Engineering – A First Course, $5^{th}$ Edition, PHI Learning, 2009. |
| 5 | Jastrzebski, Z. D., Nature and Properties of Engineering Materials, John Wiley & Sons, $2^{nd}$ Edition, 1976. |

| B. Tech. II (Chemical Engineering)<br>ENZYME SCIENCE AND TECHNOLOGY<br>CH257<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**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 and identify them from the data. |
| 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** | **(05 Hours)** |
| | Historical aspects, nomenclature and their classification, cost effective production, purification and characterization of enzymes. | |
| | **MECHANISMS AND KINETICS OF ENZYME ACTION** | **(08 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** | **(08 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, Problems solving. | |
| | **ENZYME IMMOBILIZATION** | **(08 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. | |
| | **DESIGN OF ENZYMATIC REACTORS** | **(08 Hours)** |
| | Design of various types of bioreactors for enzymatic reactions (i.e., continuous, batch, fed-batch etc.), Problems solving. | |
| | **APPLICATIONS OF ENZYMES** | **(08 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 Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Palmer,T. and Bonner, P.L., " ENZYMES: Biochemistry, Biotechnology and Clinical Chemistry", *2nd Ed.* Woodhead Publishing,2007 |
| 2 | Dutta, R., "Fundamental of Biochemical Engineering", Springer, New York, 2008. |
| 3 | Blanch, H.W. and Clark, D.S., "Biochemical Engineering", Marcel Dekker, Inc., 2007. |
| 4 | Marangoni, A.G., "Enzyme Kinetics: A Modern Approach", John Wiley & Sons, Inc., Hoboken, New Jersey, 2003 |
| 5. | Bisswanger, H., "Enzyme Kinetics: Principles and Methods", 3rd Ed.Wiley-VCH Verlag GmbH, Weinheim, 2017. |
| 6. | Sathishkumar, T., Shanmugaprakash, M. and Shanmugam, S., "Enzyme Technology", 2nd Ed. I.K. International Publishing House, 2012. |

| B. Tech. II (Chemical Engineering)<br>SUSTAINABLE DEVELOPMENT GOALS<br>CH258<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Principles and concepts of SDGs |
| CO2 | Understanding the need of SDGs for Sustainable development concept |
| CO3 | Scope, Awareness, future of SDGs |
| CO4 | Hurdals in the implementation of SDGs |
| CO5 | Design concept and implementation of SDGs |
| CO6 | Critical evaluations of SDGs in countries |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(02 Hours)** |
| | Overview of the SDGs, Principles Underlying the SDGs, Review of the 2030 Agenda for Sustainable Development, Importance of Sustainable Development, and Critiques and Challenges: Assessing the limitations and potential shortcomings etc. | |
| | **NO POVERTY (SDG1) and ZERO HUNGER (SDG2)** | **(05 Hours)** |
| | SDG1: Definition and dimensions of poverty, Multidimensional aspects: income, education, health, and social inclusion, Targets and Indicators for SDG 1, Root Causes of Poverty, Inequality and Poverty etc.<br>SDG2: Historical context: Global efforts to eradicate hunger, Targets and Indicators for SDG 2, Agriculture and Food Systems, Food Security and Nutrition etc. | |
| | **GOOD HEALTH AND WELL BEING (SDG3), QUALITY EDUCATION (SDG4), AND GENDER EQUALITY (SDG5)** | **(06 Hours)** |
| | SDG3: Overview of SDG 3 and its importance in sustainable development, Targets and Indicators for SDG 3, Global Health Issues, Healthcare Systems and Access etc.<br>SDG4: Overview of SDG 4 and its significance in sustainable development, Targets and Indicators for SDG 4, Access to Education, and Quality of Education etc.<br>SDG5: Historical context: Evolution from gender-related Millennium Development Goals (MDGs), Detailed examination of specific targets under SDG 5, Gender-Based Violence, Economic Empowerment and Equal Opportunities etc. | |
| | **CLEAN WATER AND SANITATION (SDG6)** | **(04 Hours)** |
| | Overview of SDG 6 and its significance for global health and well-being, Key indicators for monitoring progress in water and sanitation, Water Quality and Ecosystems, Importance of proper sanitation and hygiene practices, and Innovations in sanitation technologies etc. | |
| | **AFFORDABLE AND CLEAN ENERGY (SDG7)** | **(04 Hours)** |
| | The transition to clean and sustainable energy, Targets and Indicators for SDG 7, Exploration of renewable energy sources (e.g., solar, wind, hydropower), Energy Access and Poverty Alleviation, etc. | |

| | | |
|---|---|---|
| | **DECENT WORK AND ECONOMIC GROWTH (SDG8) AND INDUSTRY, INNOVATION, AND INFRASTRUCTURE (SDG9)** | **(05 Hours)** |
| | SDG8: Overview of SDG 8 and its importance in sustainable development, Targets and Indicators for SDG 8, Labor Market Trends and Challenges, Small and Medium-sized Enterprises (SMEs), etc.<br>SDG9: Overview of SDG 9 and its role in fostering sustainable development, Targets and Indicators for SDG 9, Sustainable Industrialization, and Innovation for Sustainable Development, etc. | |
| | **REDUCING INEQUALITIES (SDG10), SUSTAINABLE CITIES AND COMMUNITIES (SDG11), AND RESPONSIBLE CONSUMPTION AND PRODUCTION (SDG12)** | **(08 Hours)** |
| | SDG10: Historical context: The evolution of goals related to reducing inequalities, In-depth examination of specific targets under SDG 10, Income Inequality, Social Inclusion and Equal Opportunities etc.<br>SDG11: Overview of SDG 11 and its importance in urban development, Targets and Indicators for SDG 11, Urban Planning and Design, Community Engagement and Participation etc.<br>SDG12: The evolution of goals related to responsible consumption and production, Targets and Indicators for SDG 12, Sustainable Supply Chains, Circular Economy and Waste Management, etc. | |
| | **CLIMATE ACTION (SDG13), LIFE BELOW WATER (SDG14), AND LIFE ON LAND (SDG15)** | **(06 Hours)** |
| | SDG13: Overview of SDG 13 and its critical role in addressing climate change, Climate Science and Impacts, Mitigation and Adaptation Strategies, etc.<br>SDG14: Evolution of goals related to life below water, Biodiversity and Ecosystem Services, Sustainable Fisheries and Aquaculture, etc.<br>SDG15: Overview of SDG 15 and its importance in preserving terrestrial ecosystems and biodiversity, Deforestation and Land Degradation, and Biodiversity Conservation, etc. | |
| | **PEACE, JUSTICE AND STRONG INSTITUTIONS (SDG16) AND PARTNERSHIP FOR THE GOALS (SDG17)** | **(05 Hours)** |
| | SDG16: Evolution of goals related to peace and justice, Rule of Law and Access to Justice, Corruption and Good Governance, etc. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Hazra Somnath And Bhukta Anindya, Sustainable Development Goals An Indian Perspective-Hardbound by Springer, 2022 |
| 2 | Mishra, P K & J K Verma, Managing Sustainable Development Concepts Issues and Challenges, Associated Publishing Company, 2019 |
| 3 | Peter P. Rogers, Kazi F. Jalal, John A. Boyd, An Introduction to Sustainable Development, 2007 |
| 4 | Niko Roorda, Peter Blaze Corcoran & Joseph P Weakland, Fundamentals Of Sustainable Development 2nd Edition, T&F INDIA Publishers, 2019 |

| B.Tech. II (Chemical Engineering)<br>ENVIRONMENT MANAGEMENT SYSTEM<br>CH259<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Describe, develop and interpret methods of the Environmental Management Systems. |
| CO2 | Justify the need for the knowledge of various environmental protection rules, standards, and EIA guidelines. |
| CO3 | Apply the applications of environmental management systems on different chemical industries. |
| CO4 | Understand the concept of environmental impact assessment |
| CO5 | Implement the Environmental Auditing in various Industries/Projects |
| CO6 | Prepare the post-project monitoring activities |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION TO ENVIRONMENT MANAGEMENT SYSTEM** | **(05 Hours)** |
| | Introduction to environment, basic Definitions and terms of environmental management system, framework for environmental management system | |
| | **RESOURCE MANAGEMENT AND SUSTAINABLE DEVELOPMENT** | **(04 Hours)** |
| | **ENVIRONMENTAL PROTECTION ACTS, RULES AND STANDARDS, EIA GUIDELINES** | **(06 Hours)** |
| | The Water (Prevention and Control of Pollution) Act, Air (Prevention and Control of Pollution) Act, Environmental Protection Act | |
| | **ENVIRONMENT IMPACT ASSESSMENT** | **(06 Hours)** |
| | Definition and scope, preliminary screening requiring EIA of projects. Impact identification, Assessment of Impact; Impact Evaluation. Types of EIA, rapid and comprehensive, Methods of environment impact assessment | |
| | **ENVIRONMENT MANAGEMENT** | **(06 Hours)** |
| | Natural Resources Conservation, Conservation of Energy, Pollution prevention, Disposal of Treated effluents, Solid Waste Disposal, Concept of green cities | |
| | **INTRODUCTION TO ENVIRONMENTAL AUDITING** | **(07 Hours)** |
| | Introduction to Environmental Auditing, Category “A” & “B” types of projects. Procedures and Guidelines to conduct Environmental Audit | |
| | **APPLICATIONS OF ENVIRONMENTAL MANAGEMENT SYSTEM** | **(06 Hours)** |
| | Applications EMS in terms of Process flow chart, effluent Generation, composition and treatment of effluents from different chemical industries | |
| | **POST PROJECT MONITORING** | **(05 hours)** |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Environmental Management Systems: An Implementation Guide for Small and Medium-Sized Organizations, Second Edition, NSF International, Ann Arbor, Michigan, January 2001. |
| 2 | M. N Rao, “Waste Water Treatment” Oxford and IBH publishing Co. Pvt Ltd, 2007. |
| 3 | Peavy, H.S, D.R. Rowe & T.George, “Environmental Engineering”, New York: McGraw Hill, 1987. |
| 4 | Christopher Sheldon and Mark Yoxon, “Installing Environmental management Systems – a step by step guide” Earthscan Publications Ltd, London, 1999. |
| 5 | Uberoi, N. K. (2004) Environmental Management. Excel Book, New Delhi. |

| **B. Tech. II (Chemical Engineering)**<br>**SUSTAINABLE ENERGY AND ENVIRONMENTAL SYSTEMS**<br>**CH260**<br>**Elective** | **Scheme** | **L** | **T** | **P** | **Credit** |
|---|---|---|---|---|---|
| | | **3** | **0** | **0** | **03** |

| **1.** | **Course Outcomes (COs):**<br>**At the end of the course, students will be able to** |
|---|---|
| CO1 | Understand the prominence of Energy and Environmental Systems and Sustainability**,** Importance of contemporary materials and nanomaterials |
| CO2 | Learn benefits of synthesis methods of contemporary materials and nanomaterials and aspects involved in methods of synthesis |
| CO3 | Learn features involved in Environmental Systems and degradation for environmental applications |
| CO4 | Understand the aspects involved in Energy systems and contemporary materials and nanomaterials required |
| CO5 | Learn aspects involved in Energy systems and energy sectors and aspects for controlling operating parameter involved |
| CO6 | Learn Waste to energy applications and limitations and future aspects |

| **2.** | **Syllabus** | |
|---|---|---|
| | **OVERVIEW** | **(05 Hours)** |
| | Understand the prominence of Energy and Environmental Systems and Sustainability, Importance of contemporary materials and nanomaterials, and types of synthesis methods and their applications. | |
| | **SUSTAINABLE ENERGY AND ENVIRONMENTAL SYSTEMS: SYNTHESIS METHODS AND ASPECTS INVOLVED** | **(09 Hours)** |
| | Chemical synthesis methods and other synthesis methods, Characterization by SEM, XRD, AFM, TEM | |
| | **ENVIRONMENTAL SYSTEMS AND DEGRADATION FOR ENVIRONMENTAL APPLICATIONS** | **(09 Hours)** |
| | Preparation methods, Aspects involved in methods, | |
| | **ENERGY SECTORS: NANOMATERIALS IN ENERGY SECTORS** | **(09 Hours)** |
| | Nanomaterials synthesis and thin film preparation for energy sectors, various types of thin film synthesis methods, Coater and CVD, aspects and controlling operating parameter involved, Applications of nanomaterials in Energy sectors such as various types of solar cell. | |
| | **CLEAN ENERGY SECTORS** | **(09 Hours)** |
| | Fuel cell, water splitting, energy storage etc. nanowires/nanorods/nanotubes synthesis. | |
| | **WASTE TO ENERGY APPLICATIONS AND LIMITATIONS** | **(04 Hours)** |
| | Issues, Waste to energy applications and limitations | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Callister W. D., Materials Science and Engineering – An Introduction, 12th Edition, John Wiley, 2014 |
| 2 | Vollath D., Nanomaterials – An introduction to synthesis, properties and applications, Wiley-VCH, Second Edition 2013 |
| 3 | Hirscher M., Handbook of Hydrogen Storage: New Materials for Future Energy Storage, Wiley- VCH 2010 |
| 4 | Azaroff L.V.,, "Introduction to Solids", Second Edition, Tata McGraw- Hill Publishing Company Limited, 2006 |
| 5 | Nelson J., "The Physics of Solar Cells", First Edition, Imperial College Press, 2003. |

| B. Tech-II (Chemical Engineering)<br>POLYMER NANOCOMPOSITE<br>CH261<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | To understand the basics and chemistry of nano size materials and their synthesis, characterization and applications. |
| CO2 | To know the manufacturing and processing of clay/polymer nanocomposites. |
| CO3 | To learn about the flow behaviour of nanofiller/polymer systems and their processing and applications |
| CO4 | To provide knowledge of the advantages of using different types of nanocomposites. |
| CO5 | To make the students familiar with the mechanism of nanocomposites. |
| CO6 | To make them aware the manufacturing and testing methods of nanocomposites.10 |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION TO NANOCOMPOSITE MATERIALS** | **(10 Hours)** |
| | Definition of nanocomposites, Classification based on matrix and topology, Constituent of nanocomposites, General characteristics of particle reinforced composites- classification, Terminology used in fiber reinforced composites, Core-Shell nanocomposites. | |
| | **BASIC CONSTITUENTS MATERIALS IN NANOCOMPOSITES** | **(06 Hours)** |
| | Role and Selection of reinforcement materials, Glass fibers, Carbon fibers, Boron Fibers, Natural fibers, Multiphase fibers, Aramid fibers. | |
| | **INORGANIC AND ORGANIC POLYMER NANOMATERIALS** | **(06 Hours)** |
| | General introduction to nanocomposites; Basics of Inorganic Materials Chemistry and Nanochemistry. Inorganic-Organic and Inorganic-Polymer Nanocomposite Materials. | |
| | **POLYMER/GRAPHENE NANOCOMPOSITES** | **(08 Hours)** |
| | Nanocomposites: particulate, clay, and carbon nanotube, graphene nanocomposites.<br>Nanocomposite: synthesis, characterization, properties, and applications. | |
| | **POLYMER/CLAY NANOCOMPOSITES** | **(05 Hours)** |
| | Clay/Polymer Nanocomposites: Physical and chemical properties of clay nanoparticles; Synthesis; Potential Applications. | |
| | **POLYMER/METAL NANOCOMPOSITES** | **(05 Hours)** |
| | Metal/Polymer Nanocomposites: Physical and chemical properties of metal nanoparticles; Synthesis; Potential Applications. Carbon Nanotubes Polymer nanocomposites: Structure, Properties, Synthesis Methods; Potential Applications. | |

| | | |
|---|---|---|
| | **POLYMER/NANOCOMPOSITES APPLICATIONS** | **(05 Hours)** |
| | Rheology and processing, Applications and economics of polymer nanocomposites. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Ramanan Krishnamoorti, editor; Richard A. Vaia, Polymer nanocomposites: synthesis, characterization, and modelling, editor. Washington, D.C.: American Chemical Society: Distributed by Oxford University Pres, 2002 |
| 2 | T.J. Pinnavaia and G.W. Beall,Chichester Polymer-clay nanocomposites, edited by; New York:John Wiley, 2000. |
| 3 | McCrum, N.G., Buckley, C.P. and Bucknall, C.B., "Principles of Polymer Engineering", 2$^{nd}$ edition,Oxford Science Publication, 1997. |
| 4 | Gowariker, V.R., Viswanathan, N.V., and Sreedhar, J., "Polymer Science", Halsted Press (John Wiley & Sons), New York, 1986. |
| 5 | Billmeyer, F.W., "Text Book of Polymer Science, 3$^{rd}$ edition, John Wiley & Sons, New York, 1984. |
| 6 | Ghosh, P. "Polymer Science & Technology of Plastic, Rubber, Blends and Composites" Second addition, Tata McGraw-Hill, New delhi, 2008. |

| B. Tech. II (Chemical Engineering)<br>RESOURCE RECOVERY AND SUSTAINABILITY<br>CH262<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Principles and understanding of concepts for organic waste treatment |
| CO2 | Understanding the need of 3 Rs and Sustainable development concept |
| CO3 | Commercial perspectives of waste-to-wealth concept |
| CO4 | Selection of suitable technologies for the optimum energy/chemical production from biomass |
| CO5 | Design and operation of energy/chemical production systems |
| CO6 | Critical evaluations of organic wastes and sustainability within the circular economy |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(03 HOURS)** |
| | Identification of materials being disposed and locate resources on existing disposal data.Meaning of Sustainable development and resource recovery concept, reasons why wasting occurs and the various systems needed to manage waste and resources more sustainably, prediction of what materials currently have high levels of disposal. | |
| | **RECOVERY AND SUSTAINABLE DEVELOPMENT** | **(05 HOURS)** |
| | Fundamental principles and practices related to waste reduction and reuse; recycling and composting, categories of resources or materials, meaning of the various technical terms and language used in a Resource recovery and sustainability system. | |
| | **WASTE MANAGEMENT STRATEGIES** | **(05 HOURS)** |
| | Types of liquid and solid waste, origin and its current scenario. Conventional treatment systems/schemes and associated problems/limitations, public perception, waste management laws/guidelines | |
| | **ADVANCES IN WASTE MANAGEMENT FOR RESOURCE RECOVERY** | **(12 HOURS)** |
| | Close loop concept, biogeochemical cycles, glycolysis; TCA (TriCarboxylicacid) Cycle, insight into the various systems needed to collect resources from residential, commercial and industrial establishments, importance of properly sorting materials prior to disposal, decentralization at the source, advanced schemes available (commercial/research) for resource generation and their feasibility, fuel cells etc., product formation, outcome, zero | |
| | **BASICS OF COMMODITIES AND THEIR MARKETS** | **(06 HOURS)** |
| | Basics of how facilities sort, process and market commodities to secondary markets, Market Categories of discarded commodities and their values, secondary markets process and reutilize the commodities, scope of generated and processed products, market need and supply, relevant industries. | |

| | | |
|---|---|---|
| | **WASTE AUDITS** | **(05 HOURS)** |
| | Waste analysis and auditing and their steps, plan and safely carry out a waste audit, waste analysis at home or at a business, reduction of waste and save businesses money, linear and circular economy difference and implementation, calculations, case study of various business models, examination of the data from a waste audit and create a strategy for home/school/businesses to reduce or eliminate wasteful practices. | |
| | **GREEN HOUSE GAS CONNECTIONS TO SUSTAINABLE RESOURCE MANAGEMENT** | **(06 HOURS)** |
| | Group discussion, presentation regarding Greenhouse Gas (GHG) emissions and reductions, climate change philosophy, Sustainable Materials Management and Lifecycle Analysis, comparison of models measuring GHG impacts, fundamental principles and practices relating to resource management greenhouse gas emissions and reductions | |
| | **DEVELOPING OUTREACH STRATEGIES TO ENHANCE SUSTAINABLE RESOURCERECOVERY PROGRAMS AND PRACTICE** | **(03 HOURS)** |
| | Different types of outreach and education strategies, motivation, behaviours through messaging, building a communications plan | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Wenshan Guo, Huu Hao Ngo, Rao Y. Surampalli, Tian C. Zhang, Sustainable Resource Management, Volume I: Technologies for Recovery and Reuse of Energy and Waste Materials, Wiley, 2021 |
| 2 | Mohammad Taherzadeh, Kim Bolton, A. Pandey, Jonathan W. C. Wong, Sustainable Resource Recovery and Zero Waste Approaches, 2019, Elsevier |
| 3 | Vladimir Strezov, Hossain Md. Anawar, Abhilash, Sustainable and Economic Waste Management Resource Recovery Techniques, 2019, CRC Press |
| 4 | Donald A. Fuller, Sustainable Marketing Managerial - Ecological Issues, 1999, SAGE Publications |
| 5 | Dalia Štreimikienė, Climate Change and Sustainable Development Mitigation and Adaptation, 2021, CRC Press |

| B.Tech. II (Chemical Engineering) Semester – IV<br>LEAN SIX SIGMA<br>CH263<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | To utilize the process data and develop process maps. |
| CO2 | To analyze the data for process improvements. |
| CO3 | To apply the structured DMIAC methodology for problem-solving and carrying out improvement in processes. |
| CO4 | To evaluate the process by applying Lean and Six Sigma for eliminating the waste and defects. |
| CO5 | To apply statistical tools and techniques for continuous and breakthrough improvements. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(03 Hours)** |
| | Goal of organization, Six Sigma and other methodologies, Significance of Six Sigma and DMAIC model, Road map of Six Sigma, Lean principles, Design for Six Sigma methodologies. | |
| | **DEFINE PHASE** | **(05 Hours)** |
| | Project identification, Voice of the customer, Project management and planning, Management and planning tools, Outcomes of the projects, Team dynamics and performance. | |
| | **MEASURE PHASE** | **(12 Hours)** |
| | Process analysis and documentation, Probability and statistics, Statistical distributions, Collection and summarizing data, Measurement system analysis, Process and performance capability. | |
| | **ANALYZE PHASE** | **(10 Hours)** |
| | Exploratory data analysis, Hypothesis testing, | |
| | **IMPROVE PHASE** | **(10 Hours)** |
| | Design of Experiments, Root cause analysis, Lean tools, | |
| | **CONTROL PHASE** | **(05 Hours)** |
| | Statistical process control, Control plan, Lean tools for process control. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| 3. | Tutorials |
|---|---|
| | Problems based on the topics covered during the theory classes*<br>Define Phase<br>Measure Phase<br>Analyze Phase<br>Improve Phase<br>Control Phase<br>*Includes use of statistical software. |

| 4. | **Books Recommended** |
|---|---|
| 1 | Munro R. A., Ramu G., Zrymiak D. J., “The Certified Six Sigma Green Belt Handbook”, 2nd Ed., ASQ Quality Press, Wisconsin, 2015. |
| 2 | Gitlow H. S., Melnyck R. J., Levine D. M., “A Guide to Six Sigma and Process Improvement for Practitioners and Students”, 2nd Ed., Pearson Education, Inc., New Jersey, 2015. |
| 3 | Donahue W., “Unlocking Lean Six Sigma”, Centrestar Learning (Amazon Digital Services LLC - Kdp), Pennsylvania, 2021. |
| 4 | Morgan J., Brenig-Jones M., “Lean Six Sigma for Dummies”, 3rd Ed., John Wiley & Sons Ltd., West Sussex, 2016. |
| 5 | Evans J. R., Lindsay W. M., “An Introduction to Six Sigma and Process Improvement”, 2nd Ed., Cengage Learning, Stamford, 2015. |

| 5. | **Additional Reading** |
|---|---|
| 1 | United States Environmental Protection Agency (EPA), “The Environmental Professional’s Guide to Lean and Six Sigma”, Washington, 2009. |
| 2 | United States Environmental Protection Agency (EPA), “The Lean and Chemicals Toolkit”, Washington, 2009. |
| 3 | United States Environmental Protection Agency (EPA), “The Lean and Water Toolkit”, Washington, 2011. |
| 4 | United States Environmental Protection Agency (EPA), “The Lean, Energy & Climate Toolkit”, Washington, 2011. |

| B. Tech. III (Chemical Engineering)<br>ELECTROCHEMISTRY & ENERGY<br>CH351<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | To describe the fundamentals of electrochemical reactions |
| CO2 | To apply knowledge of the principles of electrochemical reactions and electrochemical techniques |
| CO3 | To evaluate the information that can be obtained from the electrochemical techniques studied during analysis |
| CO4 | To understand the application in various fuel cell technology |
| CO5 | To understand the various advance techniques |
| CO6 | To design the commercialization of electrochemical system for energy recovery. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION TO ELECTROCHEMISTRY** | **(4 HOURS)** |
| | Basic electrochemical concepts, Electrochemical concepts of oxidation and reduction; Electrode Reaction; Simple Electron Transfer Reactions; Equilibrium Potentials; Potential differences at interfaces. Application of Electrochemistry in Energy generation from waste | |
| | **ELECTROCHEMICAL CELLS** | **(6 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. | |
| | **ELECTROCHEMICAL AND BIOELECTROCHEMICAL CELLS FOR ENERGYGENERATION** | **(15 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. Principles and mechanisms, operation, limitations, advancements, Energy generation from waste/urine and scale up studies. | |
| | **VARIOUS ADVANCED TECHNIQUES FOR PERFORMANCE** | **(10 Hours)** |
| | 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. | |

| | | |
|---|---|---|
| | **DESIGNING OF ENERGY STORAGE DEVICES** | **(5 Hours)** |
| | Principle of battery, advanced rechargeable battery, Li-ion batteries, nanostructured materials for Li-ion batteries, Power management system, capacitors, and super capacitors. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | J.O.M.Bockrisand A.K.N.Reddy, "Modern Electrochemistry –Vol. I & II" , Plenum Press, NewYork, 2000. |
| 2 | Logan B. E., "Microbial Fuel Cells", First Edition, Wiley (2007) |
| 3 | Hoogers G, "Fuel Cell Technology Hand Book", CRC Press, 2003. |
| 4 | Bard, A.J., Faulkner, L. R. "Electrochemical Methods" 2nd Edition, John Wiley & Sons, Inc., 2000. |
| 5 | A.J. Bard and L.R. Faulkner, "Electrochemical Methods – Fundamentals and applications" III edition John Wiley & Sons Inc, 2001. |

| B. Tech. III (Chemical Engineering)<br>BIOPROCESS ENGINEERING<br>CH352<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Recognize the basic of microbiology and bioprocess engineering which include classification of microorganisms based on various factors that affect microbial growth, media classification, and the techniques involving isolation and measurements of cell mass. |
| CO2 | Explain the fundamentals of metabolic reaction and their regulation occurred in micro-organism and their role in various industrial applications. |
| CO3 | Analyze the kinetics of microbial growth and various types of microbial inhibition and their importance in various industrial applications. |
| CO4 | Perform stoichiometric calculations on microbial growth and product formation. |
| CO5 | Design different types of bioreactors and summarize various techniques involved in downstream processes for the recovery of bio-compounds. |

| 2. | Syllabus | |
|---|---|---|
| | **AN OVERVIEW OF BIOLOGICAL BASICS** | **(05 Hours)** |
| | Classification of cells; Cell Conctruction; Cell Nutrients, Media classification, biomolecules. | |
| | **MAJOR METABOLIC PATHWAYS** | **(08 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** | **(10 Hours)** |
| | Batch Growth; Quantifying growth kinetics; Continuous growth, types of microbial inhibition and their kinetics, Stoichiometry of microbial growth and product formation. | |
| | **BIOREACTORS** | **(10 Hours)** |
| | Introduction to bioreactors; Batch and fed-batch bioreactors; Continuous bioreactors; Bioreactor operation; Immobilized Cell Systems; Sterilization; Aeration. | |
| | **BIOSEPARATIONS** | **(06 Hours)** |
| | Biomass removal; Biomass disruption; Membrane based techniques; Extraction; Adsorption and Chromatography. | |
| | **INDUSTRIAL PROCESSES** | **(06 Hours)** |
| | Description of industrial processes- aerobic and anaerobic fermentations and products, Process flow diagrams | |
| | **(Total Contact Time: 45 Hours)** | |

| 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. |

| B. Tech. III (Chemical Engineering)<br>FUELS AND COMBUSTION<br>CH353<br>Institute Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**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 fuels |
| CO3 | Solve combustion stoichiometry and thermodynamics problems |
| CO4 | Describe origin, classification, analysis, properties of liquid, gaseous fuels |
| CO5 | Analyze the performance of combustion appliances |
| CO6 | Explain the social and environmental responsibility of engineers in the global community |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(06 Hours)** |
| | Classification of energy sources, Global energy consumption, Global warming and contribution of different fuels, Mitigating climate change by reduction of Greenhouse gas emission, Concept of carbon credit, $CO_2$ sequestration | |
| | **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** | **(05 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** | **(02 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 gasesfor known fuel composition, calculation of the composition of fuel & excess air supplied, flue gas analysis. | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Sarkar, S., "Fuels and Combustion", 3rd. ed., Universities Press,2019 |
| 2 | Dawe, R.A. (Ed.), "Modern Petroleum Technology", Vol. 1, Upstream, 6th ed., John Wiley & Sons Ltd,2002. |
| 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", 6th ed., Oxford & IBH Publishing Co. Pvt.Ltd,2018 |

| B.Tech. III (Chemical Engineering)<br>CLEANER TECHNOLOGIES IN CHEMICAL PROCESS INDUSTRIES<br>CH354<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**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. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION TO CLEANER TECHNOLOGY** | **(04 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** | **(05 Hours)** |
| | Cleaner production tools, techniques and methodology, Assessment of cleaner production. | |
| | **GREEN CHEMISTRY AND GREEN ENGINEERING** | **(08 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** | **(07 Hours)** |
| | Industrial process safety strategies, Hazard prevention by cleaner technology alternatives, HAZOP, HAZAN, Inherent safety concepts and strategies. | |
| | **LIFE CYCLE ASSESSMENT** | **(06 Hours)** |
| | ISO 14000, Life cycle analysis of products and processes, LCA methodologies. | |
| | **ENERGY AND ENVIRONMENTAL AUDIT** | **(06 Hours)** |
| | Energy conservation, Energy audit and its methodology, Environmental auditing. | |
| | **WASTE MINIMIZATION CIRCLES** | **(04 Hours)** |
| | Concept, Need and benefits, Methodology, Techniques and barriers. | |

| | | |
|---|---|---|
| | **INDUSTRIAL CASE STUDIES** | **(05 Hours)** |
| | Typical case studies from industrial sectors viz. Petrochemicals, Polymers, Chloro-alkali industry, Dyes, Pharmaceuticals, Pesticides, Food processing, Textile and Specialty chemicals. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Lennart Nilsson, Per Olof Persson, Lars Ryden, Siarhei Darozhka, Audrone Zaliauskiene, Cleaner Production: Technologies and Tools for Resource Efficient Production, Baltic University Press, 2007. |
| 2 | David T. Allen, David R. Shonnard, Green Engineering: Environmentally Conscious Design ofChemical Processes, Prentice Hall, 2001. |
| 3 | Concepción Jiménez-González, David J.C. Constable, Green Chemistry and Engineering: A Practical Design Approach, John Wiley & Sons, 2011. |
| 4 | Kenneth L. Mulholland, Identification of Cleaner Production Improvement Opportunities, John Wiley & Sons, 2006. |
| 5 | Centre for Chemical Process Safety (CCPS), Inherently Safer Chemical Processes: A Life Cycle Approach, John Wiley & Sons, 2010. |

| B.Tech. III (Chemical Engineering)<br>FUNDAMENTALS OF COLLOID AND INTERFACIAL SCIENCE<br>CH355<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Describe the basic concepts in colloid and interface science. |
| CO2 | Apply the concepts in various surface and interfacial measurement techniques. |
| CO3 | Understand interparticle interactions and electrical phenomena governing colloidal systems. |
| CO4 | Develop surfactant systems and colloidal dispersions for consumer applications. |
| CO5 | Understand the rheological behavior of dispersions and interfaces. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(03 Hours)** |
| | Basic concepts: Colloids and their classification, Properties of colloidal dispersions, Surfaces and interfaces, Applications and scope of colloids, and interfacial science. | |
| | **SURFACE AND INTERFACIAL TENSION** | **(08 Hours)** |
| | Surface and interfacial tension, Surface free energy, Surface tension for curved interfaces, Shape of the surfaces and interfaces, Measurement of surface and interfacial tension, contact angle and its measurement, Wetting and Spreading | |
| | **INTERMOLECULAR AND SURFACE FORCES** | **(09 Hours)** |
| | van der Waals forces: Keesom, Debye, and London interactions, Derjaguin approximation, Hamaker's approach. Electrostatic double-layer force: Electrostatic double layer and its mathematical models, electrostatic double layer around spherical particles and repulsion between two surfaces, zeta potential. DLVO theory and non-DLVO forces. Stability of colloids, Coagulation kinetics, Smoluchowski equation. | |
| | **SURFACTANTS & SELF-ASSEMBLY SYSTEMS** | **(09 Hours)** |
| | Surfactants and their properties: Anionic surfactants, cationic surfactants, zwitterionic surfactants, nonionic surfactants, Gemini surfactants and biosurfactants, micellization and thermodynamics of micellization of surfactants, kraft and cloud point, liquid crystals, hydrophilic-lipophilic balance (HLB), monolayers, thin liquid films. | |
| | **EMULSIONS, MICROEMULSIONS, AND FOAMS** | **(08 Hours)** |
| | Emulsion: Preparation, stability, and applications. Microemulsions: Winsor's classification, stability, rheology, and applications. Foam: Preparation, stability, structure, and applications. | |

| | | |
|---|---|---|
| | **RHEOLOGY** | **(08 Hours)** |
| | Definition and importance, Newtonian and non-Newtonian behaviour, viscoelasticity, phenomenological models of non-linear viscoelastic behaviour, experimental methods of rheology, rheology of suspensions, rheology of emulsions, interfacial rheology | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Ghosh, P., Colloid and Interface Science, PHI Learning Private Limited, India, 2009. |
| 2 | Myers, D., Surfaces, Interfaces, and Colloids: Principles and Applications, John Wiley & Sons,2nd Edition, United Kingdom, 2002. |
| 3 | Hiemenz, P.C., and Rajagopalan, R., Principles of Colloid and Surface Chemistry, CRC Press, 3rd Edition, Boca Raton, 2017. |
| 4 | Adamson, A.W., and Gast, A.P., Physical Chemistry of Surfaces, Wiley India Pvt Ltd., 6th Edition,2011. |
| 5 | Israelachvili, J.N., Intermolecular and Surface Forces, Academic Press (Elsevier), 3rd Edition, 2011 |
| 6 | Larson, R. G., The Structure and Rheology of Complex Fluids, Oxford University Press, 1st Edition,Newyork, 1999. |

| B.Tech. III (Chemical Engineering)<br>PROCESS INTEGRATION<br>CH356<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Knowledge of the basics of process integration and its applications |
| CO2 | Understanding the concept of pinch technology |
| CO3 | Design and analyse a heat exchange network |
| CO4 | Apply process integration techniques in various heat and mass transfer processes |
| CO5 | Employ the concept of green engineering in various separation processes |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(08 Hours)** |
| | Definition and scope of process integration and its building blocks, methods and areas of application, process integration techniques, role of thermodynamics in process design | |
| | **PINCH ANALYSIS** | **(12 Hours)** |
| | Basic Elements of Pinch Technology: Data extraction, Targeting, Designing, Grid diagram, Composite curve, Problem table algorithm, Grand composite curve, Heat Exchanger Network (HEN) | |
| | **HEAT INTEGRATION OF DIFFERENT EQUIPMENTS** | **(15 Hours)** |
| | Heat engine, Heat pump, Distillation column, Reactor, Evaporator, Furnace, Drier, Refrigeration system | |
| | **SUSTAINABLE CHEMICAL ENGINEERING PROCESSES** | **(06 Hours)** |
| | Integration of different green chemistry and green engineering principles into the chemical design processes, divided wall column, reactive distillation, micro-reactor, hybrid separation processes | |
| | **CASE STUDIES** | **(04 Hours)** |
| | **(Total Contact Time: 45 Hours)** | |


| 3. | Books Recommended |
|---|---|
| 1 | Robin Smith, Chemical Process: Design and Integration, John Wiley and Sons, 2005 |
| 2 | B. Linnhoff, D.W. Townsend, D. Boland, G.F. Hewitt, B.E.A. Thomas, A.R. Guy and R.H. Marsland,. Pinch Analysis and Process Integration A User Guide on Process Integration for the Efficient Uses of Energy, Inst. of Chemical Engineers. |
| 3 | V. Uday Sheno, Heat Exchanger network synthesis, Gulf Publishing Co, USA, 1995 |
| 4 | Ian C. Kemp, Pinch Analysis and Process Integration: A user Guide on Process Integration for the Efficient Use of Energy", Butterworth-Heinemann, 2nd Ed 2007 |
| 5 | James M. Douglas, Conceptual Design of Chemical Process, McGraw Hill, New York, 1988. |

| B.Tech. III (Chemical Engineering)<br>PETROLEUM REFINERY ENGINEERING<br>CH357<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>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 | Elaborate all the refining processes and effect of the process variables on conversion. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(02 Hours)** |
| | Brief Overview of Refinery Flow, Importance. | |
| | **PRODUCTS** | **(03 Hours)** |
| | Low-Boiling Products, Distillate Fuels, Heating Oils, Residual Fuel Oils and their specification and applications. | |
| | **REFINERY FEEDSTOCKS** | **(03 Hours)** |
| | Crude Oil Properties, Composition of Petroleum, Crudes Suitable for Asphalt Manufacture, Crude Distillation Curves like ASTM and TBP. | |
| | **CRUDE DISTILLATION** | **(05 Hours)** |
| | Desalting Crude Oils, Atmospheric Topping Unit, Vacuum Distillation, Auxiliary Equipments. | |
| | **COKING AND THERMAL PROCESSES** | **(04 Hours)** |
| | Types, Properties, and Uses of Petroleum Coke, Process Description—Delayed Coking, Flexicoking, Fluid Coking, Yields from Flexicoking and Fluid Coking, Visbreaking. | |
| | **CATALYTIC CRACKING** | **(05 Hours)** |
| | Fluidized-Bed Catalytic Cracking, Cracking Reactions, Cracking Catalysts, FCC Feed Pretreatment, Process Variables, Heat Recovery. | |
| | **HYDROCRACKING** | **(04 Hours)** |
| | Hydrocracking Reactions, Feed Preparation, Hydrocracking Process, Hydrocracking Catalyst, Process Variables, Hydrocracking Yields. | |
| | **HYDROPROCESSING AND RESID PROCESSING** | **(04 Hours)** |
| | Composition of Vacuum Tower Bottoms, Processing Options, Hydroprocessing, Expanded-Bed Hydrocracking Processes, Moving-Bed Hydroprocessors, Solvent Extraction. | |
| | **HYDROTREATING** | **(03 Hours)** |
| | Hydrotreating Catalysts, Aromatics Reduction, Reactions, Process Variables, Construction and Operating Costs. | |
| | **CATALYTIC REFORMING AND ISOMERIZATION** | **(05 Hours)** |
| | Reactions, Feed Preparation, Catalytic Reforming Processes, Reforming Catalyst, Reactor Design, Yields and Costs, Isomerization. | |

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|---|---|---|
| | **ALKYLATION AND POLYMERIZATION** | **(04 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** | **(03 Hours)** |
| | Reid Vapour Pressure, Octane Blending, Blending for Other Properties like flash point, pour point etc. | |
| | **(Total Contact Time: 45 Hours)** | |


| **3.** | **Books Recommended** |
|---|---|
| 1 | Gary J. H., Handwerk G. E., Kaiser M. J., Petroleum Refining Technology and Economics, 5th Ed., CRC Press 2007. |
| 2 | Nelson W. L., Petroleum Refinery Engineering, 4th Ed., McGraw-Hill Book Company, New York, 1958. |
| 3 | David S. J. J., Peter R. P., 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. |
| 5 | Mohamed A. F. I., Taher A. A., Amal E., Fundamentals of Petroleum Refining, Revised 1st Ed., Elsevier, 2009. |

| B.Tech. III (Chemical Engineering)<br>WASTE TO ENERGY CONVERSION<br>CH358<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>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** | **(03 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** | **(06 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** | **(08 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** | **(06 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** | **(08 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** | **(08 Hours)** |
| | Polarization, Electrochemical Impedances spectroscopy, Cyclic voltammetry, columbic efficiency, Tafel plots, etc. | |

| | | |
|---|---|---|
| | **HYBRID SYSTEMS AND CASE STUDY** | **(06 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 Contact Time: 45 Hours)** | |

| **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. |

| B. Tech. III (Chemical Engineering)<br>BIOMASS CONVERSION AND BIOREFINERY<br>CH359<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Understand the basic chemical and technological concepts underlying the biobased value chain |
| CO2 | Describe composition and energy-related properties of biomass and explain their impact on energy conversion processes |
| CO3 | Position biofuels and biochemicals in the wider framework of the future biobased economy |
| CO4 | Describe, illustrate and compare the different biomass conversion routes |
| CO5 | Analyse new developments in fundamental aspects of biorefineries |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION AND OVERVIEW** | **(03 Hours)** |
| | Scenario of energy and chemicals, Need for renewable feedstock, Transition from the linear to the circular economy, Biofuels and Biobased products overview, Biobased economy | |
| | **BIOMASS PROPERTIES, CHARACTERIZATION AND CHEMISTRY** | **(06 Hours)** |
| | Biomass resources, composition, types and properties relevant to their thermochemical conversion, Physicochemical properties and characterization, Chemistry of plant materials: saccharides & polysaccharides, lignin, triglycerides, etc.<br><br>Feedstock preparation, Role of pretreatment and different techniques, Size reduction, Densification, Torrefaction, Recalcitrance of lignocellulosic biomass | |
| | **BIOMASS CONVERSION TO BIOFUELS** | **(08 Hours)** |
| | First, second, third and fourth generation biofuels, Thermo-chemical conversion (pyrolysis, combustion, gasification, liquefaction) Bio-chemical conversion (hydrolysis, fermentation, transesterification, anaerobic digestion), drop-in fuels | |
| | **BIOREFINERY** | **(05 Hours)** |
| | Basic concept and principles, Types of biorefineries, Biorefinery feedstocks and properties, Current status of biorefineries, Economics of biorenewables | |
| | **PLATFORM CHEMICALS** | **(08 Hours)** |
| | Introduction to Platform chemicals, Chemocatalytic conversion of lignocellulosic platform molecules into biochemicals, Production of Furfural, Levulinic acid, HMF, Ethyl levulinate, Succinic acid and derivatives, etc. | |
| | **PERSPECTIVES ON LIGNIN AND GLYCEROL VALORIZATION** | **(04 Hours)** |
| | Lignin utilization, Catalytic conversion of glycerol to valuable commodity chemicals | |

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|---|---|---|
| | **LIFE CYCLE ASSESSMENT (LCA)** | **(05 Hours)** |
| | Life cycle assessment (LCA) principles and methodologies, LCA of biorefineries and few casestudies on biofuels and bioproducts. | |
| | **PROCESS INTENSIFICATION APPROACHES IN BIOREFINERIES** | **(06 Hours)** |
| | Ultrasound and Microwave-assisted processes, Green solvents (sub and supercritical fluids, ionic liquids, deep eutectic solvents, GXLs, etc.)for extraction and processing, Recent developments in intensified processes relevant to biorefineries | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Birgit Kamm, Patrick R. Gruber and Michael Kamm (Eds.), Biorefineries - Industrial Processes and Products: Status Quo and Future Directions. Volume 1 & 2, Wiley-VCH, 2006. |
| 2 | Mark Crocker (Ed.), Thermochemical Conversion of Biomass to Liquid Fuels and Chemicals,RSC Publishing, 2010. |
| 3 | James Clark and Fabien Deswarte, Introduction to Chemicals from Biomass, 2nd Edition, John Wiley & Sons, 2015. |
| 4 | Robert C. Brown (Ed.), Thermochemical Processing of Biomass, 2nd Edition, John Wiley & SonsLtd., 2019. |
| 5 | Caye M. Drapcho, Nhuan Phu Nghiem and Terry H. Walker, Biofuels Engineering Process Technology, 2nd Edition, McGraw Hill, 2020. |

| B.Tech. III (Chemical Engineering)<br>COMPUTATIONAL HEAT TRANSFER AND FLUID FLOW<br>CH360<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Understanding of computational methods |
| CO2 | Formulate and analyse the heat transfer and fluid flow problems |
| CO3 | Knowledge of the discretization techniques |
| CO4 | Employ the numerical methods to solve diffusion problems |
| CO5 | Adapt the appropriate algorithm to solve the chemical engineering problems. |
| CO6 | Solve heat transfer and fluid flow problems using appropriate software tools |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(05 Hours)** |
| | Mathematical description of fluid flow and heat transfer, conservation equations for mass, momentum, energy and chemical species, coordinate systems | |
| | **DISCRETIZATION TECHNIQUES** | **(10 Hours)** |
| | Partial differential equations, 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** | **(10 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** | **(10 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** | **(05 Hours)** |
| | Large Eddy Simulation (LES). Direct Numerical Simulation (DNS). Modelling of multiphase problems: volume of fluid (VOF) and Level Set Methods. | |

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|---|---|---|
| | **SOFTWARE TOOLS AND CASE STUDIES** | **(05 Hours)** |
| | CFD software packages and tools, solving simplified problems with coarse/fine grids, applying appropriate boundary and initial conditions, post-processing and interpretation of results | |
| | **(Total Contact Time: 45 Hours)** | |

| **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. |

| B. Tech. III (Chemical Engineering)<br>SMART POLYMERS<br>CH361<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Examine knowledge in the basic concepts of polymer science and polymer characterization |
| CO2 | Identify various classes of stimuli responsive materials |
| CO3 | Introduced to 'intelligence' and smart behaviour in materials |
| CO4 | Explain the huge potential/crucial role of smart materials/systems in the future technology development |
| CO5 | Apply smart polymer in detail and to design them for specific applications |
| CO6 | Aware of the potential of polymers in electric, electronic, optical and structural applications |

| 2. | **Syllabus** | |
|---|---|---|
| | **POLYMERIZATION** | **(06 hours)** |
| | Mechanism of different polymerization, Newer methods of synthesis of polymers, Special purpose polymers. | |
| | **POLYMER CHARACTERIZATION** | **(03 hours)** |
| | Polymer Characterization i.e., Fourier Transform Infrared Spectroscopy, Microscopy, FTIR spectrophotometry, Thermal Analysis, X-ray Diffraction, Electrical Properties, Optical Properties. | |
| | **RHEOLOGICAL PROPERTIES OF POLYMERS** | **(03 hours)** |
| | Simple shear flows, elongation flows. Polymer solutions. Relation between properties and structure, crystallinity and orientation. Crosslinking of polymers and elastomers, | |
| | **POLYMER NANOCOMPOSITES AND BLENDS** | **(04 hours)** |
| | Classification of nano-composites & their comparison with normal composites & blends. Different methods of preparation of Polymer nanocomposite and blend | |
| | **RESPONSIVE POLYMERS** | **(08 hours)** |
| | Polymers responding to various stimuli such as heat, light, pressure, fluids/chemicals etc. Conducting polymers classification/ requirements for conductivity, doping of polymers, light emitting polymers, liquid crystal polymers, their classification (LCPs). | |

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|---|---|---|
| | **SMART POLYMERS** | **(11 hours)** |
| | Thermally responsive polymers, Electroactive polymers microgels, Synthesis, Properties and Applications, Protein-based smart polymers, pH-responsive and photo-responsive polymers, Self-assembly, Molecular imprinting using smart polymers, Approaches to molecular imprinting, Drug delivery using smart polymers, Photo resists polymers in solar energy utilization, Biodegradable polymers, Hydrolysis, and other newer type of polymers, Engineering polymers, self-cleaning polymer. | |
| | **SMART HYDROGELS** | **(05 hours)** |
| | Synthesis, Fast responsive hydrogels, Molecular recognition, Smart hydrogels as actuators, Controlled drug release, artificial muscles, Hydrogels in microfluidics | |
| | **POLYMER DEGRADATION** | **(05 hours)** |
| | Recycling of polymers & environment and Polymer coding, various latest methods of polymer degradation and its impact on Environment. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | N. Yui, R. J. Mrsny, K. Park (Eds.), Reflexive Polymers and Hydrogels: Understanding and Designing Fast Responsive Polymeric Systems, CRC Press, 2004. |
| 2 | Galaev, B. Mattiasson (Eds.), Smart Polymers: Applications in Biotechnology and Biomedicine,2nd ed., CRC Press, 2008. |
| 3 | Principles of Polymer Science, by Bahadur and Sastry, Narosa Publishing House 2002. |
| 4 | Encyclopedia of Polymer Science and Engineering, Johan Wiley and Sons, Inc 1988. |
| 5 | Composite Material Handbook, M. M. Schwartz, McGraw-Hill company, 1984. |

| B.Tech. III (Chemical Engineering)<br>NEW SEPARATION TECHNIQUES<br>CH 362<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**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 chromatography |
| 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** | **(04 Hours)** |
| | Basic definitions of various relevant terms in separation processes in chemical and allied industries. Classification of separation processes, equilibrium and rate governed processes. Introduction to various separation processes | |
| | **MEMBRANE BASED SEPARATION PROCESSES** | **(25 Hours)** |
| | Historical background, physical and chemical properties of membranes. Techniques of membrane preparation, membrane characterization, various types of membranes and modules. Reverse osmosis, Nanofiltration, Ultrafiltration, Microfiltration, Dialysis, Electrodialysis, Gas permeation, Pervaporation, Membrane distillation, etc. | |
| | **REACTIVE SEPARATIONS** | **(02 Hours)** |
| | **CRYSTALLIZATION FROM MELT** | **(02 Hours)** |
| | **EXTERNAL FIELD INDUCED MEMBRANE SEPARATION PROCESSES FOR COLLOIDAL PARTICLES** | **(02 Hours)** |
| | Fundamentals of various colloid separations. Derivation of profile of electric field strength, Coupling with membrane separation and electrophoresis | |
| | **SURFACTANT BASED SEPARATION PROCESSES** | **(04 Hours)** |
| | Foam fractionation. Liquid membranes. | |
| | **SUPERCRITICAL FLUID EXTRACTION** | **(02 Hours)** |
| | **CHROMATOGRAPHIC SEPARATIONS** | **(04 Hours)** |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Wankat P. C., "Rate-Controlled Separations", Elsevier Applied Science, New York, 1990 |
| 2 | Baker R.W., "Membrane Technology and Applications", 3rd Ed., John Wiley and Sons, Chichester (UK), 2012. |
| 3 | 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. |
| 4 | Kaushik Nath, "Membrane Separation Processes", 2nd Ed., PHI, New Delhi, 2017. |
| 5 | Seader, J.D., Henley, E.J., Roper, D.K., "Separation Process Principles", 3rd Ed., John Wiley & Sons, Chichester (UK), 2011. |
| 6 | Kulprathipanja S. "Reactive Separation Processes", Taylor and Francis, New York, 2002. |

| B. Tech. III (Chemical Engineering)<br>FLUIDIZATION ENGINEERING<br>CH363<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Understand the concept of fluidized bed and their application in the chemical engineering operations |
| CO2 | Understand the different fluidization regime based on the process variables. |
| CO3 | Calculate operating parameters of fluidized bed system |
| CO4 | Predict the behaviour of gas-solid and liquid-solid fluidized bed system. |
| CO5 | Design of gas-solid contacting system based on different fluidized bed models. |
| CO6 | Solve problem based on fluidized bed system |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(03 Hours)** |
| | Introduction to phenomenon of fluidization; Types of fluidization operations; Typical industrial applications of fluidized beds. | |
| | **FLUIDIZED BED HYDRODYNAMICS** | **(06 Hours)** |
| | Estimation of minimum fluidization velocity; Mapping of Fluidization regimes, Gas distributor types; Fluidity and power consumption | |
| | **BUBBLING BED BEHAVIOUR AND BUBBLE DYNAMICS** | **(10 Hours)** |
| | Bubbles in liquid and fluidized bed, jet penetration and bubble formation, bubble shape, size and stability, models of bubbling beds, Davidson's isolated bubble model, two phase theory of fluidization, coalescence and splitting of bubbles, slugging conditions in fluidized bed, Kuni-levenspiel model. | |
| | **ELUTRIATION IN FLUIDIZED BED** | **(04 Hours)** |
| | Basics of elutriation, Estimation of transport disengaging height (TDH), Empirical correlations for estimation of elutriation rate. Estimation of TDH for Geldart's A group powder. | |
| | **FLUIDIZATION OF POWDERS AND NANOPARTICULATE ASSEMBLIES** | **(04 Hours)** |
| | Modified Richardson zaki equation for nanoparticles fluidization, Nanoparticle fluidization and Geldart's classification. | |
| | **HEAT AND MASS TRANSFER IN FLUIDIZED BED** | **(05 Hours)** |
| | General characteristics and correlations of heat transfer in fluidized bed, Heat transferbetween gas-particle and bed surfaces, Effects of parameters on rate of heat transfer, General characteristics and correlations of mass transfer in fluidized bed, Mass transfer between different phases of fluidized bed. | |

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|---|---|---|
| | **FLUIDIZED BED REACTOR DESIGN** | **(07 Hours)** |
| | Basics of reactor design, Different approaches of reactor design, Reactor design using Kuni-levenspiel model | |
| | **SCALE UP OF FLUIDIZED BED** | **(03 Hours)** |
| | Generalized scaling laws for fluidized bed system | |
| | **CASE STUDIES ON TYPICAL APPLICATIONS OF FLUIDIZED BED SYSTEMS** | **(03 Hours)** |
| | Coating and granulation, FCC, Gasification. | |
| | | **(Total Contact Time: 45 Hours)** |


| **3.** | **Books Recommended** |
|---|---|
| 1 | Kunii, D. and Levenspiel, O., “Fluidization Engineering”, 2nd ed., Elsevier, New Delhi, 2005. |
| 2 | Wen-Ching Yang, "Handbook of Fluidization and Fluid-Particle Systems", Marcel Dekker. |
| 3 | Davidson, J.F. and Harrison, D., “Fluidized Particle”, Book Chapter Cambridge University Press. |
| 4 | Gibilaro, L. G., "Fluidization Dynamics, The formulations & applications of predictive",1st Edition,Butterworth-Heinemann (2001). |
| 5 | Howard, J.R. *Fluidized Bed Technology: Principles and Applications.* 1 st ed., CRC press (1989) |

| B.Tech. III (Chemical Engineering)<br>ADVANCES IN CHEMICAL ENGINEERING<br>CH364<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**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** | **(06 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** | **(12 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** | **(05 Hours)** |
| | Hydrogel, Core and shell hydrogel, shell and core hydrogel, green hydrogel, stimuli responsiveness hydrogel. | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 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), New York, 1986. |
| 5 | Ghosh, P. “Polymer science & technology of plastic, rubber, blends and composites”, Second addition, Tata McGraw-Hill, New Delhi, 2008 |

| B. Tech. III (Chemical Engineering)<br>INDUSTRIAL WASTE TREATMENT METHODS<br>CH365<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>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 and solve the problems related to wastewater treatment methods. |
| CO4 | Design different types of wastewater treatment equipment and reactors. |
| CO5 | Apply treatment of sludge and its disposal and manage various types of solid wastes. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(05 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** | **(05 Hours)** |
| | Types of wastewaters, Significance of wastewater contaminants, Discharge limit of wastewater, handling and storage of wastewater. | |
| | **WASTEWATER TREATMENT METHODS** | **(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** | **(08 Hours)** |
| | Sequence of operations for sludge treatment: Concentration, Digestion, Conditioning, Dewatering, Oxidation. | |
| | **SOLID WASTE TREATMENT** | **(07 Hours)** |
| | Definition, Types of solid waste, storage and handling of solid waste, Different treatment of solid waste, E-waste treatment, Hazardous waste management | |
| | **(Total Contact Time: 45 Hours)** | |

| 4. | **Books Recommended** |
|---|---|
| 1 | Tchobanoglous G. , Burton F.L., Stensel H.D., " Wastewater Engineering Treatment and Reuse" 4th Ed. Metcalf & Eddy 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. " Environment 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. III (Chemical Engineering)<br>MULTIPHASE MICROFLUIDICS<br>CH366<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Understand the multiphase flow hydrodynamics in the microscale devices |
| CO2 | Employ key transport equations to describe the interfacial phenomena |
| CO3 | Describe the analytical models for bubble shape and thickness and their applications |
| CO4 | Design of single, multiphase, and integrated micro-reactors |
| CO5 | Evaluate the impact of various technologies on mixing, heat transfer and mass transfer in micro devices. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION AND OVERVIEW** | **(04 Hours)** |
| | Introduction: Motivation, applications, definitions, size effects | |
| | **INTERFACIAL PHENOMENA** | **(05 Hours)** |
| | Capillarity, wetting and dewetting behaviour, Contact line dynamics | |
| | **MULTIPHASE FLOW IN MICROCHANNELS** | **(05 Hours)** |
| | Gas liquid and liquid-liquid flow in microchannels: Flow regimes; pressure drop and phase distribution | |
| | **TAYLOR FLOW IN MICROCHANNELS** | **(05 Hours)** |
| | Mass Balance, Bubble Velocity, Analytical models for bubble shape and film thickness; Mechanism of heat and mass Transfer; Models for heat and mass transfer | |
| | **BUBBLE AND DROPLET GENERATION** | **(08 Hours)** |
| | Formation of bubble and droplet, mechanism of break-up; annular and slug-annular flow regimes | |
| | **MULTIPHASE MICROREACTORS** | **(10 Hours)** |
| | Gas-solid flow in microchannels; Inertial microfluidics; RTD in microreactors (Microchannels; fixed-beds; static mixers; coiled tubes and flow inverters; segmented flow) | |
| | **ANALYSYS TECHINIQUES FOR MICROCHANNELS** | **(08 Hours)** |
| | Experimental and computational techniques to study multiphase flow in microchannels | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Hessel, V., A. Renken, J.C. Schouten and J.-I. Yoshida (eds.). Micro Process Engineering-A Comprehensive Handbook. 2009. Wiley-VCH. |
| 2 | Poux, M., P. Cognet and C. Gourdon. Green Process Engineering from Concepts to Industrial Applications. 2015. CRC Press. |
| 3 | Boodhoo, K. and A. Harvey. Process Intensification for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing. 2013. John Wiley & Sons Inc. |
| 4 | Kashid, M., A. Renken and L. Kiwi-Minsker. Microstructured Devices for Chemical Processing. 2015. Wiley-VCH. |
| 5 | Hessel, V., Kralisch, D. and N. Kockmann. Novel Process Windows, 2015. Wiley. |
| 6 | Poux, M., P. Cognet and C. Gourdon. Green Process Engineering. 2015. CRC Press. |

| B. Tech. III (Chemical Engineering)<br>DESIGN OF EXPERIMENTS<br>CH367<br>Institute Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Explain the importance of statistical approach in research and experimental planning. |
| CO2 | Select suitable data set for analysis of the results. |
| CO3 | Devise effective ways to conduct experiments and obtain optimum conditions. |
| CO4 | Perform analysis of variance for analysing effect of various factors studied. |
| CO5 | Apply various methods of factorial designs (2K method, Response surface method, Taguchi method) for a given set of parameters. |
| CO6 | Able to use software for analysis of the experimental results. |

| 2. | Syllabus | |
|---|---|---|
| | REVIEW OF BASIC STATISTICAL CONCEPTS | (08 Hours) |
| | Measures of central tendency, sampling distribution, hypothesis testing, p-value, Type-I and Type-II error, confidence interval, central limit theorem | |
| | FUNDAMENTALS OF EXPERIMENTAL DESIGN | (10 Hours) |
| | Experimentation, basic principles of design, steps in experimentation, linear regression, multiple and partial correlation coefficients | |
| | INTRODUCTION TO THE ANALYSIS OF VARIANCE (ANOVA) | (08 Hours) |
| | Understanding variation, No-way ANOVA, One-way ANOVA, Two-way ANOVA, Three-way ANOVA | |
| | $2^K$ FACTORIAL EXPERIMENTS AND DESIGNS | (06 Hours) |
| | $2^2$ Factorial design, $2^3$ Factorial design, $2^k$ Factorial design, Blocking and confounding | |
| | SINGLE, MULTI-FACTORIAL EXPERIMENTS | (05 Hours) |
| | Completely randomized design, Block Design, Latin and Graeco-latin square design, Degree of freedom and sum of squares, Use of Excel and relevant software | |
| | RESPONSE SURFACE METHODS | (04 Hours) |
| | Response surface designs (Central composite design; Box-behnken design), Use of Excel and relevant software | |
| | TAGUCHI METHOD | (04 Hours) |
| | Nominal-the better case, Smaller-the better case, Larger-the better case, Estimation of quality loss, Introduction to orthogonal designs, Robust design; Data analysis, Multi-response optimization, Use of Excel and relevant software | |
| | | (Total Contact Time: 45 Hours) |

| 3. | **Books Recommended** |
|---|---|
| 1 | Ross P. J., “Taguchi Techniques for Quality Engineering”, 2nd Edition, McGraw-Hill Education, 2017. |
| 2 | Krishnaiah K., Shahabudeen P., “Applied Design of Experiments and Taguchi Methods”, PHI Learning, India, 2012. |
| 3 | Taguchi G., Chowdhury S., Wu Y., “Taguchi’s Quality Engineering Handbook”, John Wiley and Sons, New York, U.S.A., 2005. |
| 4 | Montgomery D. C., “Design and Analysis of Experiments”, 5th edition, John Wiley and Sons, New York, U.S.A., 2001. |
| 5 | Lazic Z. R., “Design of Experiments in Chemical Engineering”, Wiley-VCH Verlag GmbH & Co., Germany, 2004. |

| B.Tech. III (Chemical Engineering)<br>**ADVANCED POLYMERS**<br>**CH368**<br>**Elective** | **Scheme** | **L** | **T** | **P** | **Credit** |
|---|---|---|---|---|---|
| | | **3** | **0** | **0** | **03** |

| **1.** | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Examine knowledge in the basic concepts of polymer science and polymer characterization |
| CO2 | Identify various classes of stimuli responsive materials |
| CO3 | Introduced to ‘intelligence’ and smart behaviour in materials |
| CO4 | Explain the huge potential/crucial role of smart materials/systems in the future technology development |
| CO5 | Apply advaced polymer in detail and to design them for specific applications |
| CO6 | Aware of the potential of polymers in electric, electronic, optical and structural applications |

| **2.** | **Syllabus** | |
|---|---|---|
| | **POLYMERIZATION** | **(03 Hours)** |
| | Mechanism of different polymerization, Newer methods of synthesis of polymers, Special purpose polymers. | |
| | **POLYMER CHARACTERIZATION** | **(10 Hours)** |
| | Polymer Characterization i.e., Fourier Transform Infrared Spectroscopy, Microscopy, FTIR spectrophotometry, Thermal Analysis, X-ray Diffraction, Electrical Properties, Optical Properties. | |
| | **POLYMER BLANDS AND NANOCOMPOSITES** | **(05 Hours)** |
| | Difference between blends and composites, their significance, choice of polymers for blending, FRP, particulate, long and short fibre reinforced composites, Nanocomposites. | |
| | **RESPONSIVE POLYMERS** | **(10 Hours)** |
| | Polymers responding to various stimuli such as heat, light, pressure, fluids/chemicals etc. Conducting polymers classification/ requirements for conductivity, doping of polymers, light emitting polymers, liquid crystal polymers, their classification (LCPs). | |
| | **SMART POLYMERS** | **(12 Hours)** |
| | Photo resists polymers in solar energy utilization, Biodegradable polymers, Hydrolysis, and other newer type of polymers, Engineering polymers, self-cleaning polymer, Responsive hydrogel. | |
| | **POLYMER DEGRADATION** | **(05 Hours)** |
| | Recycling of polymers & environment and Polymer coding, various latest methods of polymer degradation and its impact on Environment. | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Gowariker, V.R., Viswanathan, N.V., and Sreedhar, J., "Polymer Science", 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" Second addition, Tata McGraw-Hill, New delhi, 2008 |
| 4 | Morton-jones, D.H., Chapman and Hall, "Polymer Processing", Springer, London, 1989. |
| 5 | McCrum, N.G., Buckley, C.P. and Bucknall, C.B., "Principles of Polymer Engineering", 2nd Edition, Oxford Science Publication, 1997. |

| B.Tech. III (Chemical Engineering)<br>SAFETY AND POLLUTION CONTROL IN CHEMICAL PROCESS INDUSTRIES<br>CH369<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Express knowledge about types of pollution, its sources, effects and control. |
| CO2 | Be aware of the Industrial Laws and Act. |
| CO3 | Describe different methods of hazard analysis and control of hazards. |
| CO4 | Analyse different types of fire and explosions and its control. |
| CO5 | Explain about the quantification and analysis of wastewater and treatment. |
| CO6 | Propose various analysis and quantification of hazardous and non-hazardous solid waste, treatment and disposal. |

| 2. | **Syllabus** | |
|---|---|---|
| | **ENVIRONMENTAL AND POLLUTION IN CHEMICAL INDUSTRIES** | **(02 Hours)** |
| | Definitions, scope and importance, need for public awareness, sources of pollution from Chemical industries | |
| | **ENVIRONMENTAL LAWS AND STANDARDS** | **(03 Hours)** |
| | Laws related to solid, liquid and gases effluents, standards and legislations, Health and environmental effects, case studies for specific industries like petrochemicals, fertilizers, desalination, petroleum refining | |
| | **POLLUTION PREVENTION THROUGH PROCESS MODIFICATION** | **(12 Hours)** |
| | Recovery of by-products, Energy recovery, Waste utilization and recycle and reuse and waste generation minimization | |
| | **AIR POLLUTION CONTROL** | **(05 Hours)** |
| | Air pollution control through mechanical separation, adsorption, etc | |
| | **WATER POLLUTION CONTROL** | **(05 Hours)** |
| | Water pollution control by physical, chemical and biochemical methods | |
| | **DESIGN OF CONTROL EQUIPMENT AND SYSTEMS** | **(06 Hours)** |
| | Designs to prevent fires and explosions, fire triangles, fault tree analysis, case studies | |
| | **SOLID WASTE TREATMENT AND DISPOSAL** | **(04 Hours)** |
| | Types of solid waste, generation, onsite handling, storage & processing, Disposal techniques, recovery of resources, conversion products and energy | |

| | SAFETY IN CHEMICAL PROCESS INDUSTRIES | (08 Hours) |
|---|---|---|
| | Safety and loss prevention, safety systems, Hazardous properties of chemicals, characterization of chemical processes, the nature and impact of chemical plant accidents, occupational safety and industrial hygiene, Toxicology, toxic release, case studies. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Crowl D. A., Louvar J. F., "Chemical Process Safety", Prantice-Hall, 4th Ed., New York, 2019 |
| 2 | Metcalf & Eddy, "Waste Water Engineering: Treatment, Disposal and Reuse", 4th Ed Tata-McGraw- Hill, New Delhi, 2017 |
| 3 | MaCarty S., "Chemistry for Environmental Engineering",4th Ed Tata-McGraw-Hill, New Delhi,1994 |
| 4 | Rao C.S., Environmental Pollution Control Engineering,3rd Ed New Age Zuternational Publisher,2018 |
| 5 | Sanders R E., "Chemical Process Safety: Learning from case histories" Butterworth-Heinemann, New Delhi, 2005 |

| B.Tech. III (Chemical Engineering)<br>COMPUTATIONAL FLUID DYNAMICS<br>CH370<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>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 and interpret the computational results |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION AND GOVERNING EQUATIONS** | **(05 Hours)** |
| | Introduction, Classification of partial differential equations, Navier-Stokes system ofequations, Boundary conditions. | |
| | **FINITE DIFFERENCE METHODS** | **(06 Hours)** |
| | Basic aspects of finite difference equations, Derivation of finite difference equations, Accuracy of finite difference solutions. | |
| | **SOLUTION METHODS OF FINITE DIFFERENCE EQUATIONS** | **(06 Hours)** |
| | Methods for Elliptic, Parabolic and Hyperbolic equations, Implicit and explicit schemes, Von-Neumann stability analysis, Example problems. | |
| | **INCOMPRESSIBLE VISCOUS FLOWS** | **(06 Hours)** |
| | General, Artificial compressibility method, Pressure correction methods, Vortex methods. | |
| | **COMPRESSIBLE FLOWS** | **(06 Hours)** |
| | Potential equation, Euler equations, Navier-Stokes system of equations, Preconditioning process for compressible and incompressible flows. | |
| | **INTRODUCTION TO FINITE VOLUME METHOD** | **(05 Hours)** |
| | Integral approach, discretisation & higher order schemes. | |
| | **INTRODUCTION TO FINITE ELEMENT METHOD** | **(05 Hours)** |
| | Finite element formulations, definition of errors, Finite element interpolation functions. | |

| | | |
|---|---|---|
| | **APPLICATIONS** | **(06 Hours)** |
| | Chemically reactive flows, Heat transfer and Multiphase flow. | |
| | **(Total Contact Time: 45 Hours)** | |

| **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, 2$^{nd}$ Edition, 2014. |

| B.Tech. III (Chemical Engineering) Semester – VI<br>LIFE CYCLE ASSESSMENT<br>CH371<br>Institute Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 04 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Explain the concept of life cycle assessment (LCA) including underlying principles and assumptions. |
| CO2 | Assess the inventory involved in product/ process development. |
| CO3 | Evaluate the results of an LCA study in order to provide information to support decision-making. |
| CO4 | Assess the environmental impact across the entire product/ process life cycle using LCA software. |
| CO5 | Examine the role of LCA in contributing to the development of sustainable value chains. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(03 Hours)** |
| | Carbon footprint, Definition of life cycle assessment (LCA), History, The structure of LCA, Standardization of LCA. | |
| | **GOAL AND SCOPE** | **(04 Hours)** |
| | Goal definition, Scope, Case studies. | |
| | **LIFE CYCLE INVENTORY ANALYSIS** | **(06 Hours)** |
| | Basics, Energy analysis, Allocation, Procurement, Origin and quality of data, Data aggregation and units, Presentation of inventory results, Case studies. | |
| | **LIFE CYCLE IMPACT ASSESSMENT** | **(12 Hours)** |
| | Basic principle of life cycle impact assessment, Method of critical volumes, Structure of impact assessment according to ISO14000 series, Method of impact categories, Impact categories, Impact indicators and characterization factors, Case studies. | |
| | **LIFE CYCLE INTERPRETATION, REPORTING AND CRITICAL REVIEW** | **(12 Hours)** |
| | Development and rank of the interpretation phase, The phase interpretation according to ISO, Techniques for result analysis, Reporting, Critical review, Use of software, Case studies. | |
| | **WATER FOOTPRINT** | **(04 Hours)** |
| | Terminology, Water elementary flow, Regionalization, Impact assessment. | |
| | **FROM LCA TO SUSTAINABILITY ASSESSMENT** | **(04 Hours)** |
| | Sustainability, The three dimensions of sustainability, State of the art of methods. | |
| | **TUTORIALS WILL BE BASED ON THE COVERAGE OF THE ABOVE TOPICS SEPARATELY** | **(15 Hours)** |
| | **(Total Contact Time: 45 Hours + 15 Hours = 60 Hours)** | |

| 3. | **Tutorials** |
|---|---|
| | Problems based on the topics covered during the theory classes*<br>Goal and Scope Definition<br>Life Cycle Inventory Analysis<br>Life Cycle Impact Assessment<br>Life Cycle Interpretation<br>Water Footprint<br>*Includes use of LCA software. |

| 4. | **Books Recommended** |
|---|---|
| 1 | Klöpffer W., Grahl B., "Life Cycle Assessment (LCA): A Guide to Best Practice", Wiley-VCH Verlag, Weinheim, 2014. |
| 2 | Bauman H., Tillman A. M., "The Hitch Hiker's Guide to LCA: An Orientation in Life Cycle Assessment Methodology and Application", Studentlitteratur, Gothenburg, 2004. |
| 3 | Brondi C., Maranghi S., "Life Cycle Assessment in the Chemical Product Chain: Challenges, Methodological Approaches and Applications", 1st Ed., Springer, Cham, 2020. |
| 4 | Hauschild M., Rosenbaum R. K., Olsen S., "Life Cycle Assessment - Theory and Practice", Springer International Publishing, Berlin, 2018. |
| 5 | Jolliet O., Saade-Sbeih M., Shaked S., Jolliet A., Pierre C. P., "Environmental Life Cycle Assessment", CRC Press, Florida, 2015. |

| 5. | **Additional Reading** |
|---|---|
| 1 | Curran M. A., "Life Cycle Assessment Handbook: A Guide for Environmentally Sustainable Products", Scrivener Publishing, Beverly, 2012. |
| 2 | ISO 14040, Environmental management - Life cycle assessment - Principles and framework. International Organization for Standardization, Geneva, 2006. |
| 3 | ISO 14044, Environmental management - Life cycle assessment - Requirements and guidelines. International Organization for Standardization, Geneva, 2006. |
| 4 | ISO 14046, Environmental management - Water footprint - Principles, requirements and guidelines. International Organization for Standardization, Geneva, 2014. |

| B. Tech. IV (Chemical Engineering)<br>PROCESS PLANT SAFETY<br>CH451<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Recognize the importance of safety, accident loss statistics, the nature of accidents and steps of accidents involved in any chemical process industries. |
| CO2 | Understand the working of different relief systems which are used in chemical process industries |
| CO3 | Apply various methods of hazard identification for any chemical process. |
| CO4 | Perform the risk analysis and risk assessment for any system to minimize the hazards. |
| CO5 | Analyse the case histories occurred in chemical process industries in terms of the principles of inherent safety, causes and consequences |
| CO6 | Evaluate the characteristics of various causes of incidents like toxic release, fire and explosion, flammability diagram etc. |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION** | **(05 Hours)** |
| | Safety Programs, Accident Loss Statistics- FAR, OSHA, Fatality rate, Acceptable risk, Inherent safety, Nature of the accident process and their steps. | |
| | **TOXICOLOGY** | **(04 Hours)** |
| | Entry of toxicants in biological organism (BO), Elimination of Toxicant from BO, Effect of Toxicants in BO, Dose Versus Response, TLVs. | |
| | **INTRODUCTION TO RELIEFS** | **(05 Hours)** |
| | Relief Concepts, Definitions, Location of Reliefs, Relief Types, Relief Systems. | |
| | **FIRE AND EXPLOSION** | **(08 Hours)** |
| | The fire triangle, Distinction between Fire and explosion, estimation of flammability characteristics of vapor and liquids using Flammability diagram, Limiting oxygen characteristics and inerting, Detonation and deflagration, BLEVE, Vapor-cloud explosion, Fire extinguisher, Problem solving. | |
| | **HAZARD IDENTIFICATION** | **(08 Hours)** |
| | Process hazard checklists, HAZOP study, Safety Reviews, Other methods, Problem solving. | |
| | **RISK ASSESSMENT** | **(10 Hours)** |
| | Review of Probability theory, Probability of Coincidence, Revealed & Unrevealed failures, Fault tree analysis, Cut Sets, Path sets, Reliability diagram, Event tree analysis, Quantitative risk analysis, Layer of Protection analysis, Consequence, Frequency, Problems solving, Problem solving. | |
| | **CASE HISTORIES** | **(05 Hours)** |

| | |
|---|---|
| | Flixborough, England, Bhopal Gas Tragedy, A massive explosion in Pasadena, Leakage of 2,3,7,8-tetrachlorodibenzoparadioxin in Seveso, Related to Static Electricity, Chemical Reactivity, System Designs, Procedures. |
| | **(Total Contact Time: 45 Hours)** |



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

| B.Tech. IV (Chemical Engineering)<br>SUSTAINABILITY, GREEN CHEMISTRY AND ENGINEERING<br>CH452<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Apply the concepts of sustainability in professional life. |
| CO2 | Explain the importance of twelve principles of green chemistry and engineering. |
| CO3 | Evaluate various techniques based on twelve principles of green chemistry and engineering. |
| CO4 | Appraise novel concepts (new techniques and novel solvents) in processes in line with sustainable and green concepts. |
| CO5 | Infer the given conventional process and operations and recommend modification requiredin the system. |
| CO6 | Analyze various processes/products based on life cycle assessment. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(02 Hours)** |
| | Chemistry- from past to future, Importance of sustainability, Need of green chemistry | |
| | **CONCEPT OF SUSTAINABILITY** | **(04 Hours)** |
| | Sustainability: concept and requirement, fundamentals of sustainable development, Sustainable development at different scales, Ten commandments, Sustainable development goals | |
| | **GREEN CHEMISTRY AND ENGINEERING** | **(03 Hours)** |
| | Principles and applications in green chemistry and green engineering | |
| | **SYNTHESIS AND GREEN CHEMISTRY** | **(04 Hours)** |
| | Micro-reactor technology, Solvent-less reactions, Use of green solvents, Green materials | |
| | **ALTERNATE SOLVENTS** | **(04 Hours)** |
| | Green solvents, Water as a solvent, Amphiphillic compounds | |
| | **CONVENTIONAL PROCESS AND OPERATIONS** | **(10 Hours)** |
| | Current status and modification (reactive distillation, divided wall distillation column, heat integration using pinch analysis) | |
| | **NEW DEVELOPMENT IN PROCESSES** | **(13 Hours)** |
| | Overview of green separation processes, Distillation, Chromatography, Membrane processes, Extraction using neoteric solvents, Nanotechnology in separation, green extraction, Green buildings, etc. | |

| | | |
|---|---|---|
| | **LIFE CYCLE ASSESSMENT** | **(05 Hours)** |
| | Basics and case studies | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Doble, M., Kruthiventi, A. K., "Green Chemistry and Processes", Academic Press, London, UK, 2007. |
| 2 | Manahan S. E., "Green Chemistry and The Ten Commandments of Sustainability", 2nd Ed. Chem Char Research, Inc Publishers, Missouri USA, 2006. |
| 3 | Afonso C. A. M., Crespo J. G. (Ed), "Green Separation Processes", Wiley-VCH Verlag GmbH &Co., Weinheim, Germany, 2005. |
| 4 | Clark J., Macquarrie D. (Ed), "Handbook of Green Chemistry and Technology", Blackwell Series, UK, 2002. |
| 5 | Atkinson G., Dietz S., Neumayer E. (Ed), "Handbook of Sustainable Development", Edward Elgar Publishing Limited, Cheltenham, UK, 2007. |

| B.Tech. IV (Chemical Engineering)<br>PHARMACEUTICAL TECHNOLOGY<br>CH453<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Understand various physicochemical properties of drug molecules. |
| CO2 | Summarize unit operations in pharmaceutical processing. |
| CO3 | Formulate pure drug substance into an appropriate dosage form. |
| CO4 | Apply the principles of pharmacodynamics and pharmacokinetics for the development of mathematical models. |
| CO5 | Devise an appropriate drug delivery system |
| CO6 | Develop pharmaceutical products by optimizing process parameters. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(04 Hours)** |
| | Physical pharmaceutics: Properties and states of matter, solutions, phase equilibria, surfaceand interfacial phenomena, dispersions. Drugs: Definition, classification, sources, physicochemical properties, bioavailability, and bioequivalence. | |
| | **MICROMERITICS AND UNIT OPERATIONS** | **(08 Hours)** |
| | Particle size, size reduction, size distribution, powder flow, and compaction. Mixing, evaporation, crystallization, filtration, centrifugation, extraction, distillation, and drying. | |
| | **DOSAGE FORMS** | **(08 Hours)** |
| | Classification of dosage forms based on physical state (solid, semi-solid, liquid, and gaseous) and route of administration (oral, parenteral, topical, rectal, and nasal), excipients, formulations, pressurized dosage forms, factors affecting bioavailability in dosage forms, Packaging: Development of packaging units including recent advances in packaging techniques for various types of sterile and non-sterile dosage forms, stability aspects of packaging. | |
| | **PHARMACODYNAMICS AND PHARMACOKINETICS** | **(08 Hours)** |
| | Physicochemical principles, Pharmacodynamics: Mechanism of drug action, drug receptors, physiological receptors. Pharmacokinetics: Drug absorption, drug distribution, drug metabolism, drug elimination, Determination of pharmacokinetic parameters, BCS, and IVIVC. | |
| | **DRUG DELIVERY SYSTEMS** | **(08 Hours)** |
| | The rationale for controlled drug delivery, physicochemical properties and factors influencing controlled release, Drug delivery vehicles: Polymers, hydrogels, liposomes, niosomes, dendrimers, solid lipid nanoparticles, carbon nanotubes, quantum dots, etc., Drug encapsulation. | |

| | | |
|---|---|---|
| | **OPTIMIZATION IN PHARMACEUTICAL PRODUCT DEVELOPMENT** | **(09 Hours)** |
| | Optimization techniques, Quality by design (QbD), Design of Experiments (DOE) like factorialdesign, response surface methodology, etc., identifying formulation and process variables, formulation optimization, and in-vitro test systems to evaluate and monitor the performanceof different types of dosage forms. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Martin, A.N., Sinko, P.J., & Singh, Y., Martin's Physical Pharmacy and Pharmaceutical Sciences, Wolters Kluwer Health, 8th Edition, Baltimore, 2023. |
| 2 | Lachman / Lieberman's, "The Theory and Practice Industrial Pharmacy", 4th edition, CBS Publishers, 2020 (Paperback). |
| 3 | McCabe, W.L., Smith, J.C., & Harriott, P., Unit Operations of Chemical Engineering, 7th Edition, McGraw Hill, U.S.A, 2017. |
| 4 | Ranabir Chanda et.al., Textbook of Novel Drug Delivery System, 1st Edition, AITBS Publishers, 2019. |
| 5 | Montgomery D. C., Design and Analysis of Experiments, 8th edition, John Wiley and Sons, NewYork, U.S.A., 2012. |

| B. Tech. IV (Chemical Engineering)<br>COMPUTER AIDED DESIGN IN CHEMICAL ENGINEERING<br>CH454<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, students will be able to** |
|---|---|
| CO1 | Understand steady state process, Decide and select appropriate separation synthesis/process and decide and select appropriate separation Equipments. |
| CO2 | Analyse for best sequence with Heuristics and Apply practical knowledge for process simulation. |
| CO3 | Design Multicomponent Distillation, shortcut method and Evaluate Column Diameter |
| CO4 | Understand process design/synthesis concepts, flow-sheet with input output structure, recycle structure etc. |
| CO5 | Design of heat integration with pinch technology and heat exchanger network design. Apply<br>CAD in heat integration of distillation column |
| CO6 | Design and schedule the batch processes for optimal design. Apply process simulation such asASPEN PLUS in CAD with practical knowledge. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(03 Hour)** |
| | Introduction to Computer aided design in chemical engineering, Steady state and dynamic Simulation, Process simulation program (ASPEN PLUS), grass root design and retrofitting. | |
| | **CAD IN CHEMICAL PROCESS EQUIPMENT** | **(10 Hours)** |
| | Multicomponent distillation column design, Methods including Heuristics for Best sequence selection, Column Design for Distillation and Absorption, optimum design, parameter optimization etc. Computer aided design of chemical process equipment's | |
| | **CHEMICAL PROCESS DESIGN AND FLOW SHEETING** | **(04 Hours)** |
| | Process synthesis/synthesis, spread sheeting, flow sheeting, Conceptual Process Design input output structure, Decision for the input output structure, Flow sheet alternatives: guidelines, Number of product streams, Gas recycle and purge | |
| | **SEPARATION PROCESS SELECTION** | **(05 Hours)** |
| | Separation process selection criteria's and general thumb rules | |
| | **EQUIPMENT SELECTION** | **(03 Hours)** |
| | Equipment selection criteria's and general thumb rules | |

| | | |
|---|---|---|
| | **APPLICATION OF CAD IN HEAT EXCHANGER NETWORK DESIGN** | **(09 Hours)** |
| | Pinch technology, Heat integration, and Optimum number of heat exchanger. | |
| | **APPLICATION OF CAD IN HEAT INTEGRATION OF DISTILLATION COLUMNAND REACTORS** | **(03 Hours)** |
| | Characteristics, Appropriate placement of column, Distillation across pinch, Grand composite curve, Design of simple distillation column to improve heat integration, heat integration of reactors | |
| | **DESIGN AND SCHEDULING OF BATCH PROCESSES** | **(05 Hours)** |
| | Design and scheduling of batch processes, transfer policy, size factor and multicomponent process design | |
| | **APPLICATIONS OF CAD IN OTHER AREAS** | **(03 Hours)** |
| | Applications of CAD in other areas such as heat transfer, mass transfer etc. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Smith R., "Chemical Process Design", McGraw-Hill, New York, 2nd Edition, 2016. |
| 2 | Biegler L. T., Grossmann E. I., Westerberg A. W., "Systematic Methods of Chemical ProcessDesign", Prentice-Hall, New Jersey, 1997. |
| 3 | Sinnott R. K., "Coulson & Richardson's Chemical Engineering", Vol. 6, 4th Ed., Elsevier Publications, New York, 2005. |
| 4 | W.D.Seider,J.D.Seader,D.R.Lewin ,"Product and Process Design Principles",John-Wiley,New York,4th Edition,2016 |
| 5 | Alexandre C.Dimian and Costin Sorlin Bildea, " Chemical Process Design -Computer-Aided Case Studies",WILEY-VCH Verlag GmbH & Co.,KGaA,Weinheim,2008 |

| B. Tech. IV (Chemical Engineering)<br>BIOMASS & FUEL CELL TECHNOLOGY<br>CH455<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | To describe about the origin of Biomass and its scope. |
| CO2 | To explain the conversion of biomass into liquid as a fuel. |
| CO3 | To explain about basics of fuel cells, and their working principle. |
| CO4 | To estimate various types of fuel cells, their applications and performance parameters. |
| CO5 | To analyse the potential of energy storage devices and new opportunity |
| CO6 | To design the commercialization of fuel cell technology for resource recovery. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(03 Hours)** |
| | Biomass, formation on the earth, photosynthesis, Chemistry and composition of Biomass, conversion, utilization for energy and its requirement, current scenario and its scope, fuel cell technology systems and their importance, resource recovery and future of fuel cells | |
| | **WASTE AS BIOMASS** | **(06 Hours)** |
| | Types of liquid and solid waste, origin, and its current scenario. Conventional treatment systems/schemes and associated problems. Public perception, Waste as Biomass, composition, properties, characterization, proximate and ultimate analysis, heating values, | |
| | **BIOMASS CONVERSION TECHNOLOGIES** | **(10 Hours)** |
| | Chemical engineering principles of biomass processing, details, merits, demerits, and mechanisms of physical, thermochemical, and biochemical methods for fuel generation, Biomass degrading enzymes and microorganisms. Bioethanol production from lignocellulosic feed stocks, algae, and sea weeds. Algae Biodiesel; Technical challenges in biodiesels production. Biomass to gaseous fuel production, Bio hydrogen Production, Concept of Bio refinery, conversion of domestic waste to fuels. | |
| | **VARIOUS BIOENERGETICS** | **(05 Hours)** |
| | Glycolysis; TCA (Tricarboxylic acid) Cycle, Respiration, Control Sites in Aerobic Glucose Metabolism, Overview of Biosynthesis, Overview of Anaerobic Metabolism, Overview of Autotrophic Metabolism. | |
| | **OVERVIEW OF FUEL CELLS** | **(10 Hours)** |
| | What is a fuel cell, brief history, classification, how does it work, why do we need fuel cells, Fuel cell basic chemistry and thermodynamics, heat of reaction, theoretical electrical work and potential, theoretical fuel cell efficiency. Types of fuel cells, bioelectrochemical fuel cells,and their types, Hydrogen fuel cells, their components, conditions, and advancements. | |

| | | |
|---|---|---|
| | **FUEL CELL ELECTROCHEMISTRY** | **(06 Hours)** |
| | Electrochemical techniques, Electrochemical impedance spectroscopy (EIS) and its application, cycling voltammetry and linear polarization, galvanostatic intermittent titration, electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents, Power management system, capacitors, and super capacitors | |
| | **ADVANCEMENT SCHEMES** | **(05 Hours)** |
| | Commercialization aspects of Biomass to Energy from waste materials, fuel cell technology, stacking, integration and feasibility study, case studies. | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Dahiya, A. "Bioenergy: Biomass to Biofuels", Academic Press; 1 edition (2014). |
| 2 | Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store,2nd Edition, Kindle Edition, 2011. |
| 3 | Logan B. E., "Microbial Fuel Cells", First Edition, Wiley (2007) |
| 4 | Hoogers G, "Fuel Cell Technology Hand Book", CRC Press, 1 edition 2019. |
| 5 | Bard, A.J., Faulkner, L. R. "Electrochemical Methods" 2nd Edition, John Wiley & Sons, Inc., 2000. |

| **4.** | **Further Reading** |
|---|---|
| 1 | Vaughn, C. Nelson, Kenneth L. Starcher Introduction to Bioenergy (Energy and the Environment) by CRC Press ISBN 13: 978-1-4987-1699-4, 2016 |
| 2 | Vijai K. Gupta et al. Biofuel Technologies-Recent Developments Springer-Verlag Berlin Heidelberg ISBN 978-3-642-34519-7, 2013. |

| B.Tech. IV (Chemical Engineering)<br>BASICS OF SOFT MATTER<br>CH456<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Identify types of soft matter and their interactions. |
| CO2 | Explain interfaces and methods to measure them. |
| CO3 | Summarize the behaviour of various surfactant systems. |
| CO4 | Interpret the behaviour of polymers at the molecular level. |
| CO5 | Discuss the properties of colloids and their stability. |
| CO6 | Explain the mechanical behaviour of biological materials. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION** | **(04 Hours)** |
| | Classification, Equilibrium, Energies, and time scales, Self-organization, and phase transitions in soft matter | |
| | **INTERACTIONS IN SOFT MATTER AND SELF ASSEMBLY** | **(06 Hours)** |
| | Intramolecular interactions (Ionic, covalent, metallic and hydrogen bond), Intermolecular interactions (Double layer forces, Dipole Interactions, van der Waals, Electrostatic), Structural forces, Hydrodynamic interactions. Aggregation and Self-assembly, Mechanical properties (viscosity/elasticity) of soft matter. | |
| | **INTERFACES** | **(07 Hours)** |
| | Definition, Energy-based characterization, wetting, spreading, and contact angle. Young-Laplace and Kelvin equations for curved interfaces, Thermodynamics of interfacial tension, Methods to measure surface and interfacial tension. | |
| | **SURFACTANTS** | **(07 Hours)** |
| | Classification, Factors affecting surfactant behaviour, Phase behaviour:- Micellar phase, CMC and packing parameter, Mixed surfactant systems, Langmuir trough, Industrial applications. | |
| | **POLYMERS** | **(07 Hours)** |
| | Definition, Classification, Methods of polymerization and Mechanical properties. Polymer solutions: - Ideal chain, radius of gyration, excluded volume and solvent effects, Concentration effects, Entropic chain, Polyelectrolytes, Hydrogels. Glassy and melt phases, Liquid crystal polymers. Experimental methods: - Scattering, FTIR, Raman Spectroscopy, NMR. | |
| | **COLLOIDS** | **(07 Hours)** |

| | | |
|---|---|---|
| | Classification and characteristics, Brownian motion: - Einstein theory and Smoluchowski equation. Forces in colloidal systems: - van der Waals, Electrostatic, Depletion forces, Steric repulsion. DLVO theory, Colloidal aggregation, Colloidal crystals, Granular materials, Foams.Experimental methods: - Dynamic light scattering and rheology. | |
| | **SOFT BIOLOGICAL MATERIALS** | **(07 Hours)** |
| | Structure and composition of cell, Cell membrane: - Lipid phase behaviour, Lipid domains and raft hypothesis, Elasticity and curvature of the lipid membrane. Protein: - Filaments, cytoskeleton, persistence length, microtubules, nucleic acids. Experimental methods: - Membrane behaviour using atomic force microscopy, fluorescence microscopy, transmission electron microscopy, and x-ray spectroscopy | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Hirst, L.S., Fundamentals of Soft Matter Science, 2nd Edition, CRC Press 2019. |
| 2 | Zhou, L., Introduction to Soft Matter Physics", World Scientific, 2019 |
| 3 | Jones, R.A.L., Soft Condensed Matter, Oxford University Press, 2004. |
| 4 | Ghosh, P., Colloid and Interface Science, PHI Learning Private Limited, India, 2009. |
| 5 | Hiemenz, P.C., & Rajagopalan, R., Principles of Colloid and Surface Chemistry, 3rd Edition, CRC Press, 2017. |
| 6 | Israelachvili J.N., Intermolecular and Surface Forces, 3rd Edition., Academic Press, New York, 2011. |

| B. Tech. IV (Chemical Engineering)<br>GREEN TECHNOLOGY<br>CH457<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| **1. Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** | |
|---|---|
| CO1 | To explain smart energy, green infrastructure and non-renewable energy challenges. |
| CO2 | To analyse models that simulate sustainable and renewable green technology systems. |
| CO3 | To explain history, global environmental & economic impacts of green technology. |
| CO4 | To explain the usage of microorganism for the bioremediation. |
| CO5 | To develop nanoparticles by various biological methods |
| CO6 | To propose the green techniques for the production of renewable. |

| **2.** | **Syllabus** | |
|---|---|---|
| | **GREEN TECHNOLOGY** | **(10 Hours)** |
| | Definition, factors affecting green technologies, co/green technologies for addressing the problems of Water, Energy, Health, Agriculture, phyto-remediation, ecological sanitation, renewable energy technologies, industrial ecology, agro ecology and other appropriate green technologies, reuse, recovery, recycle, raw material substitution, cleaner production, wealth from waste, Some case studies. | |
| | **CLEAN TECHNOLOGY** | **(13 Hours)** |
| | Biotechnology and Microbiology for Degradation – Aerobic and Anaerobic pathway of wastewater degradation, Biogas technology, Microbial and biochemical aspects i,e., microbial fuel cell, forward osmosis, Osmotic microbial fuel cell for industrial waste water treatment. Operating parameters for biogas production | |
| | **GREEN NANOMATERIALS** | **(12 Hours)** |
| | Greener Synthetic Methods for Functionalized Metal Nan particles, Greener Preparations of Semiconductor and Inorganic Oxide Nano particles, green synthesis of Metal nanoparticles, Nanoparticle characterization methods. | |
| | **BIO-POLYMER AND GREEN HYDROGEL FOR WASTEWATER** | **(10 Hours)** |
| | Green materials: biomaterials, biopolymers, bioplastics, and composites. Natural polymer, hydrogel and its application in wastewater treatment, Shell and core hydrogel and core and shell hydrogel. | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Heinloth K., Energy Technologies: Renewable Energy, Springer-Verlag Berlin Heidelberg 2006. |
| 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. |
| 3 | Poole C., and Owens F., Introduction to Nanotechnology, John-Wiley, New Jersey, 2003. |
| 4 | Clark J., Macquarrie D., Handbook of Green Chemistry and Technology Blackwell Series, 2002,UK. |
| 5 | Ristinen, Robert Kraushaar, Jack J.A Kraushaar, Jack P. Ristinen, Robert A.,Energy and the Environment, 2nd Edition, John Wiley, 2006. 2. B. R Wilson & W J Jones, Energy, Ecology and the Environment, Academic PressInc, 2005. 3. Sarkar S, Fuels and combustion, 2nd ed., University Press, 2009. |

| B.Tech. IV (Chemical Engineering)<br>MICROFLUIDICS AND NANOFLUIDICS<br>CH458<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Understand the concept of process intensification and hydrodynamics in the micro scale devices |
| CO2 | Employ key transport equations to describe the fluid flow in microchannels |
| CO3 | Describe the effect of micromixing on the reactor performance |
| CO4 | Design of single, multiphase, and integrated micro-reactors |
| CO5 | Evaluate the impact of various technologies on mixing, heat transfer and mass transfer in micro devices. |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION AND OVERVIEW** | **(05 Hours)** |
| | Process intensification, Introduction to Microfluidics and Nanofluidics: Application and Examples | |
| | **FLUID DYNAMICS IN MICROCHANNELS** | **(05 Hours)** |
| | Transport Phenomena and major applications of Micro/Nanofluidics, Governing Equations for Fluid Flow: Derivation and Perspectives | |
| | **MICROSCALE FLOW VISUALIZATION** | **(05 Hours)** |
| | Fundamentals, Visualization of flow Fields in Micro- and Minichanels | |
| | **MIXING IN MICROSYSTEMS** | **(05 Hours)** |
| | Mixing Principles and Features of Microsystems, Experimental Mixing Characterization, Comparison of Performances of Micromixers | |
| | **HEAT TRANSFER IN MICRO/NANOFLUIDICS** | **(10 Hours)** |
| | Continuum Assumption, Heat Transfer in Homogeneous Microfluidic Systems, Pronounced Effects in Microchannel Heat Transfer, Conventional Heat Transfer Correlations for Macroscale Tubes and Channels | |
| | **MICRO-STRUCTURED DEVICES** | **(10 Hours)** |
| | Parallel flow of two immiscible phases, Droplet manipulation, Slug flow; Microreactor Systems Design and Scale-Up | |
| | **CASE STUDIES OF MICRO/NANOFLUIDICS** | **(05 Hours)** |
| | Case studies on mixing, heat transfer, and mass transfer in micro/nanodevices | |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | Hessel, V., A. Renken, J.C. Schouten and J.-I. Yoshida (eds.). Micro Process Engineering-A Comprehensive Handbook. 2009. Wiley-VCH. |
| 2 | Poux, M., P. Cognet and C. Gourdon. Green Process Engineering from Concepts to Industrial Applications. 2015. CRC Press. |
| 3 | Boodhoo, K. and A. Harvey. Process Intensification for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing. 2013. John Wiley & Sons Inc. |
| 4 | Kashid, M., A. Renken and L. Kiwi-Minsker. Microstructured Devices for Chemical Processing. 2015. Wiley-VCH. |
| 5 | Hessel, V., Kralisch, D. and N. Kockmann. Novel Process Windows, 2015. Wiley. |
| 6 | Poux, M., P. Cognet and C. Gourdon. Green Process Engineering. 2015. CRC Press. |

| B. Tech. IV (Chemical Engineering)<br>MULTIPHASE FLOW<br>CH459<br>Elective | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Understand multiphase flow and its principles |
| CO2 | Analyzing the theoretical principles for potential applications of multiphase flow |
| CO3 | Integrating interfacial transport phenomena in the multiphase flow systems |
| CO4 | Illustrating the multiphase flow in process industries |
| CO5 | Solving multiphase flow problems |
| CO6 | Assessing the physical understandings of the multiphase flow through interdisciplinary studies |

| 2. | Syllabus | |
|---|---|---|
| | **INTRODUCTION AND OVERVIEW** | **(05 Hours)** |
| | Gas/liquid, liquid/liquid and liquid/solid particle flow systems. Multiphase flows in pipes, flow regime maps, pressure drop | |
| | **GENERAL CONSERVATION LAWS** | **(05 Hours)** |
| | Equation of motion for a small spherical particle, Stokes flow around a spherical particle, interfacial flow and constitutive relations. | |
| | **ONE DIMENSIONAL STEADY SEPARATED FLOW** | **(05 Hours)** |
| | One dimensional steady separated flow model; Phases are considered together but their velocities differ; Phases are considered separately, flow with phase change. | |
| | **SOLID-LIQUID AND GAS-SOLID FLOW** | **(05 Hours)** |
| | Hydrodynamics of solid-liquid and gas-solid flow; Particle Dynamics: Inertial effects, Two Fluid Models, Turbulence modulation by particles. | |
| | **THREE PHASE FLOW** | **(05 Hours)** |
| | Introduction to three phase flow | |
| | **MEASUREMENT TECHNIQUES** | **(05 Hours)** |
| | Measurement techniques for multiphase flow, Flow regime identification, pressure drop, void fraction and flow rate measurement. | |

| | | |
|---|---|---|
| | **FLOW IN MICROCHANNELS** | **(07 Hours)** |
| | Flow in mini channels/microchannels, their principles and applications. Bubble dynamics, Droplet deformation and breakup, Droplet collisions and coalescence. | |
| | **CASE STUDIES-APPLICATION AREAS** | **(08 Hours)** |
| | Case studies of the multiphase flow. Modeling and simulations using CFD software's | |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | Yadigaroglu G., and Hewitt Geoffrey F., "Introduction to Multiphase Flow", Springer International Publishing, 2018 |
| 2 | Brennen, C.E. "Fundamentals of Multiphase Flow", Cambridge University Press, New York, 2005. |
| 3 | Crowe, C.T. "Multiphase Flow Handbook". Taylor & Francis, Boca Raton, Fl. 2006. |
| 4 | V. P. Carey, Liquid-Vapor Phase-Change Phenomena, 2nd ed., Taylor & Francis, New York, 2008. |
| 5 | Michaelides E. E., Crowe C. T., Schwarzkopf J. D.", Multiphase Flow Handbook", CRC Press, 2016. |
| 6 | Fries D. M., "Multiphase Flow in Microchannels: Hydrodynamics and Implementation in Process Engineering", ETH, 2008 |

| B.Tech. IV (Chemical Engineering)<br>**CATALYST SCIENCE AND TECHNOLOGY**<br>**CH460**<br>**Elective** | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | **Course Outcomes (COs):**<br>**At the end of the course, the students will be able to** |
|---|---|
| CO1 | Describe concepts and significance related to heterogeneous and homogeneous catalysts |
| CO2 | Explain steps and methods in catalyst preparation |
| CO3 | Describe and apply selected catalyst characterization methods (identify anayltical tools for specific catalytic applications) |
| CO4 | Explain why and how catalysts deactivate and how catalyst deactivation can be postponed or prevented |
| CO5 | Outline dis-/advantages of supported and full-catalysts with respect to their application |
| CO6 | Explain industrial catalytic processes |

| 2. | **Syllabus** | |
|---|---|---|
| | **INTRODUCTION TO CATALYSIS** | **(02 Hours)** |
| | Significance of catalysis, Heterogeneous Catalysis: Examples, Case Histories and Current Trends. | |
| | **SOLID CATALYSIS** | **(06 Hours)** |
| | Types of catalysts, Preparation methods of Solid Heterogeneous Catalysts, Catalyst supports, Activation. | |
| | **CATALYSTS CHARACTERIZATION METHODS** | **(08 Hours)** |
| | Adsorption methods, Physicochemical Properties, Spectroscopic Methods. | |
| | **CATALYST PERFORMANCE** | **(04 Hours)** |
| | Testing of catalysts, activity and selectivity studies. | |
| | **EFFECT OF TRANSPORT PROCESSES** | **(04 Hours)** |
| | External transport processes, internal transport processes for reaction and diifusion in porous catalysts. | |
| | **MECHANISM OF CATALYTIC REACTIONS** | **(04 Hours)** |
| | Rates of adsorption, desorption, surface reactions, rate determining steps. | |

| | | |
|---|---|---|
| | **KINETIC MODELLING AND PARAMETER ESTIMATIONS.** | **(04 Hours)** |
| | Kinetic study and parametric evaluation. | |
| | **CATALYSTS DEACTIVATION** | **(02 Hours)** |
| | Promoters, inhibitors, catalyst deactivations, kinetics of catalyst deactivations. | |
| | **INDUSTRIAL CATALYSIS APPLICATION** | **(06 Hours)** |
| | Green Chemistry, Biomass to biofuels and chemicals, $CO_2$ utilization etc. | |
| | **NEW DEVELOPMENT IN SOLID CATALYSIS** | **(02 Hours)** |
| | Monolith catalysts, Nanocatalysts, etc. | |
| | **INTRODUCTION TO HOMOGENEOUS CATALYSIS** | **(03 Hours)** |
| | **(Total Contact Time: 45 Hours)** | |

| **3.** | **Books Recommended** |
|---|---|
| 1 | J. M. Thomas and W. J. Thomas, "Principles and Practice of Heterogeneous Catalysis", Wiley-VCH. ISBN: 978-3-527-31458-4 February 2015 |
| 2 | C. H. Bartholomew and R. J. Farrauto "Fundamentals of Industrial catalytic Processes", Wiley-VCH. ISBN: 978-0-471-73007-1 August 2010 |
| 3 | Julian Ross: Heterogeneous Catalysis - Fundamentals and Applications, © Elsevier 2012. |
| 4 | S. Lowell, Joan E. Shields, Martin A. Thomas, Matthias Thommes. Characterization of Porous Solids and Powders: Surface Area, Pore Size and Density. 2004, Springer Science, New York |
| 5 | Fogler H.S., "Elements of Chemical Reaction Engineering", 4th Edition, Prentice Hall, NJ, 2006 |
| 6 | Articles from Peer Reviewed Journals |

| B.Tech. IV (Chemical Engineering)<br>**ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS**<br>**CH461**<br>**Elective** | Scheme | L | T | P | Credit |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 03 |

| 1. | Course Outcomes (COs):<br>At the end of the course, the students will be able to |
|---|---|
| CO1 | Describe intermolecular forces and relate to macroscopic thermodynamic properties. |
| CO2 | Differentiate between ideal and non-ideal thermodynamic behaviour in both pure substances and mixtures. |
| CO3 | Explain phase equilibria for multicomponent systems. |
| CO4 | Estimate the thermodynamics properties of mixtures and solutions. |
| CO5 | Evaluate and apply different methods/assumptions for performing phase equilibrium calculations, |
| CO6 | Explain multi-reaction equilibria and solve problems. |

| 2. | Syllabus | |
|---|---|---|
| | **REVIEW OF CLASSICAL THERMODYNAMICS** | **(03 Hours)** |
| | **PROPERTIES OF PURE FLUIDS** | **(04 Hours)** |
| | Thermo Properties from Volumetric Data, Equations of State, Generalized correlations. | |
| | **INTERMOLECULAR INTERACTIONS AND CORRESPONDING STATE THEORY** | **(05 Hours)** |
| | Origin of interactions (Permanent, induced and instantaneous dipoles), Intermolecular forces and potential energy functions, Corresponding states theory | |
| | **THERMODYNAMIC PROPERTIES OF MIXTURES** | **(15 Hours)** |
| | Mixtures, partial molar properties, Chemical potential, Gibbs Duhems equations, Property changes on mixing, Fugacity in gas mixtures-Virial and Cubic EOS, corresponding states, fugacities in liquid mixures, fugacities in liquid mixures(electrolyte solution) Excess Functions in Liquid Mixtures, Models for Excess Gibbs energy | |
| | **PHASE EQUILIBRIA** | **(08 Hours)** |
| | Multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Solubility of gases in liquids, solubility of solids in liquids. | |
| | **CHEMICAL EQUILIBRIUM** | **(08 Hours)** |
| | Combined phase and Reaction equilibrium | |
| | **INTRODUCTION TO MOLECULAR SIMULATION** | **(02 Hours)** |
| | **(Total Contact Time: 45 Hours)** | |

| 3. | **Books Recommended** |
|---|---|
| 1 | J.M. Prausnitz, R.M. Lichtenthaler and E.G. Azevedo, Molecular Thermodynamics of Fluid-Phase Equilibria,3rd edition, Prentice Hall Inc., New Jersey,1999. |
| 2 | J.M. Smith. H.C. Van Ness and M.M.Abott, Introduction to Chemical Engineering Thermodynamics, 8th edition, McGraw Hill International edition, 2018. |
| 3 | S. I. Sandler, Chemical, Biochemical, and Engineering Thermodynamics, 5th Edition, John Wiley & Sons, Inc.,2017. ISBN: 978-1-119-32128-6 |
| 4 | B. E. Poling, J. M., Prausnitz, J. P. O'Connell, The Properties of Gases and Liquids, 5th edition, McGraw Hill, 2001. |
| 5 | J.W. Tester and M. Modell, Thermodynamics and Its Applications, 3rd ed., Prentice Hall, NJ, 1997. |

# DEPARTMENT OF CHEMICAL ENGINEERING
# VOCATIONAL TRAINING / PROFESSIONAL EXPERIENCE
# (MANDATORY FOR EXIT; AND OPTIONAL FOR OTHERS)

## VOCATIONAL TRAINING (Semester I)

**UNCERTAINTY ANALYSIS IN EXPERIMENTAL RESEARCH**
**CH V01 Contact Hours: 50**

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

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

| | |
|---|---|
| CO1 | Appreciate the need of statistical analysis of experimental data and uncertainty analysis |
| CO2 | Generate experimental data for statistical analysis |
| CO3 | Select a suitable instrument/equipment for experiment |
| CO4 | Apply statistical analysis of experimental data and uncertainty analysis in real world problems |
| CO5 | Develop a correlation for uncertainty analysis |

**2. Syllabus:**

- **INTRODUCTION (04 Hours)**

Need of uncertainty analysis, Impact of uncertainty on result, Understanding instrument terminology, Practice problems

- **STATISTICAL ANALYSIS OF EXPERIMENTAL DATA (16 Hours)**

Basic terminology, Rejection criteria of a reading, Practice problems, Use of Excel in analysis, Generation of data and perform the analysis

- **UNCERTAINTY ANALYSIS (20 Hours)**

Basic terminology, Various types of analysis, Correlation, Practice problems, Use of Excel in analysis, Generation of data and perform the analysis

- **USE OF SOFTWARE IN STATISTICAL ANALYSIS AND UNCERTAINTY ANALYSIS (10 Hours)**

**(Total: 50 hours)**

Conditions:

- Minimum 25 students to run the program
- Registration fee Rs. 4000/- per student

Faculty members involved:

- Dr. Meghal A. Desai
- Dr. Sanjay R. Patel

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester I)**

**EXPERIMENTAL RESEARCH IN PHYTOCHEMICAL EXTRACTION (Part I)**
**CH V01 Contact Hours: 200**

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

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

CO1 Appreciate the importance of phytochemicals in varied fields
CO2 Conduct literature survey
CO3 Summarize the information provided in the literature
CO4 Analyze the information provided in the literature
CO5 Develop a critical thinking with respect to the theme

**2. Syllabus:**

- **LITERATURE SURVEY (200 Hours)**

Introduction to phytochemicals, Types of phytochemicals, Introduction to extraction, Various extraction methods and their applications, Utilization of novel and conventional methods in phytochemical extraction, Collection of various research articles in the field of phytochemical extraction, Summary and analysis of research articles, Preparation of a report based on critical thinking

Conditions:

- Minimum 3 students to run the program
- Registration fee: Rs. 500/- per student

Faculty members involved:

- Dr. Meghal A. Desai
- Dr. Jigisha K. Parikh

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester I)**

**EXPERIMENTAL RESEARCH ON LIQUID MEMBRANES**
**CH V01 Contact Hours: 200**

**1. Course Outcomes (COs):**
At the end of the course, students will be able to:

CO1 Understand the types and working principle of liquid membranes
CO2 Conduct literature survey
CO3 Summarize and analyse the information provided in the literature
CO4 Develop a critical thinking with respect to the theme
CO5 Perform the experimental research on liquid membranes

**2. Syllabus:**

- **LITERATURE SURVEY (100 Hours)**

Introduction to Liquid membranes, Types of Liquid membranes, Introduction to liquid-liquid extraction, various applications of different types of liquid membranes, factors affecting the performance of various types of liquid membranes in various applications, Collection of various research articles in the field of liquid membranes, Summary and analysis of research articles based on various methods of design of experiments for the process optimization, Preparation of a report based on critical thinking.

- **MINI PROJECT (80 Hours)**
- **CONTINUOUS EVALUATION (20 Hours)**

**(Total: 200 hours)**

Conditions:

- Minimum 3 students to run the program
- Registration fee: Rs. 5000/- per student

Faculty members involved:

- Dr. Smita Gupta

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester I)**

**INTRODUCTION TO NANOMATERIALS FOR SUSTAINABLE SYSTEMS**
**CH V01 Contact Hours: 200**

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

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

CO1 Appreciate the need of nanomaterials
CO2 Conduct literature survey
CO3 Summarize the information provided in the literature
CO4 Analyze the information provided in the literature
CO5 Develop a critical thinking with respect to the theme

**2. Syllabus:**

Introduction to nanomaterials, Appreciate the need of nanomaterials, nanomaterials for sustainablesystems, Conduct literature survey, Types of nanomaterials, Collection of various research articles in the field, Various novel materials and their applications, Nanomaterialsand their applications in energy systems and environmental systems, Nanomaterialsand characterization techniques, applications, Preparation of a report based on critical thinking

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- No Registration fee
- Interdisciplinary nature and students from Chemical Engineering, Physics, Chemistry, Electronics Engineering, Electronics Engineering, Mechanical Engineering, Civil Engineering, background can enrol.

Faculty members involved:

- Dr. Jignasa V.Gohel
- Dr. Vineet Rathore
- Dr. Manish Rathod
- Dr. Jyoti Meghnani
- Dr. Kalpana Maheria

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester II)**

**EXPERIMENTAL RESEARCH IN PHYTOCHEMICAL EXTRACTION (Part II)**
**CH V02 Contact Hours: 200**

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

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

CO1 Conduct experiment using conventional methods
CO2 Analyse the sample using sophisticated instruments
CO3 Apply parametric study in experiments
CO4 Apply statistical method of analysis in experiments

**2. Syllabus:**

- **Experimental design and analysis** **(200 Hours)**

Introduction to distillation (Hydro- and Steam- Distillation), Experiments employing various factors affecting responses (yield, phenolic contents and anti-oxidant activities), Utilization of DoE for experiments, Analysis of samples using sophisticated instruments, Preparation of a report based on experiment and analysis

Conditions:

- Minimum 3 students to run the program
- Registration fee: Rs. 1000/- per student

Faculty members involved:

- Dr. Meghal A. Desai
- Dr. Jigisha K. Parikh

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester II)**

**EXPERIMENTAL RESEARCH IN SOLAR CELL TECHNOLOGY (Part I)**
**CH V02 Contact Hours: 200**

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

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

CO1 Appreciate the importance of solar cells in varied fields
CO2 Conduct literature survey
CO3 Summarize the information provided in the literature
CO4 Analyze the information provided in the literature
CO5 Develop a critical thinking with respect to the theme

**2. Syllabus:**

Introduction to solar cells, Types of solar cells, Introduction to next generation solar cells, Various novel materials and their applications in solar cells, Nanomaterialsand their applications in solar cells, Collection of various research articles in the field of next generation solar cells, Summary and analysis of research articles, Preparation of a report based on critical thinking

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- No Registration fee
- Interdisciplinary nature and students from Chemical Engineering, Physics, Chemistry, Electronics Engineering, Electronics Engineering, Mechanical Engineering, Civil Engineering, background can enrol.

Faculty members involved:

- Dr. Jignasa V. Gohel
- Dr. A. K.Panchal
- Dr. Vipul Kheraj
- Dr. Kalpana Maheria
- Dr. Vivek Garg

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester III)**

**INTRODUCTION TO SAMPLING AND CHARACTERIZATION TECHNIQUES AND SIGNIFICANCE**
**CH V03 Contact Hours: 200**

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

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

CO1 Explain the types of Samplings of waste and significance
CO2 Sample the Solid, liquid and gases products
CO3 Understand the characterization tools for samples
CO4 Implement of statistical tools for data analysis
CO5 Implement the report writing methodology.

**2. Syllabus:**

- **INTRODUCTION AND SCENERIO OF SAMPLING AND CHARACTERIZATION TOOLS (25 Hours)**

General information of sampling, scope, safety, procedural precautions, quality control precautions, auxiliary information and data collection, records, investigation derived waste, characterization tools and significance, etc

- **SIGNIFICANCE OF SAMPLING AND METHODOLOGY (25 Hours)**

Waste sampling- background, waste unit types: open unit, closed unit, waste sampling equipment, ancillary equipment for waste sampling, waste sampling procedures, waste piles, surface impoundments, drums, tanks, Types of samplings, methodology, storage, precautions, preservation, norms, labelling, etc.

- **PRACTICAL ASPECTS OF SAMPLING AND DATA COLLECTION (25 Hours)**

Practical aspects for sampling and data collection, live sampling strategies for solid/liquid/and gases waste materials, waste sample handle procedures, procedural precautions

- **STATISTICAL TOOLS FOR DATA COLLECTION AND INTERPRATATION (50 Hours)**

Importance of data, significance of data, segregation of data and utilization of statistical tools for making data useful. Uncertainty analysis of collected data, documentation errors of data collected at field, hazardous waste sampling, sorting of waste

- **CHARACTERIZATION TOOLS AND INSTRUMENTS KNOWLEDGE (25 Hours)**

Significance of characterization tools, basic understanding of various instruments for the characterization of various solid/liquid/gases samples, practical aspects of the instruments, etc

- **REPORT WRITING AND STRATEGIES (50 Hours)**

Significance of report writing, methodology, tools and designing, references nomenclature, tables and figure understanding and preparation, submission of report.Report types and common mistakes during writing

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering, Chemistry background can enrol.

Faculty members involved:

- Dr. Alka A. Mungray
- Dr. Arvind Kumar Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

## VOCATIONAL TRAINING (Semester III)

### INTRODUCTION TO FUEL CELL TECHNOLOGY

**CH V03** **Contact Hours: 200**

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

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

| | |
|---|---|
| CO1 | Explain the types of Fuel cells and their application, scope and future |
| CO2 | Calculate the thermodynamic properties and behaviour of the fuel cell |
| CO3 | Calculate the reaction kinetics |
| CO4 | Classify the various types of fuel cell |
| CO5 | Identify the various components of the fuel cell |

**2. Syllabus:**

- **INTRODUCTION** **(20 Hours)**

Introduction to fuel cell, A simple fuel cell, fuel cell advantages, fuel cell disadvantages, fuel cell types basic fuel cell operation, fuel cell performance characterization and modelling, fuel cell technology, fuel cells and the environment, Energy demand and supply and accordingly need of fuel cells, history, overview of fuel cells, classification, workings, need, challenges, basic chemistry and thermodynamics, efficiencies, and future of fuel cells.

- **FUEL CELL THERMODYNAMICS** **(30 Hours)**

Thermodynamics review, Heat potential of a fuel: enthalpy of reaction, Work potential of a fuel: Gibbs free energy, Predicting eversible voltage of a fuel cell under non-Standard-state conditions, fuel cell efficiency, Thermal and Mass balances in fuel cells, Thermodynamics of reversible fuel cells

- **FUEL CELL REACTION KINETICS** **(25 Hours)**

Introduction to electrode kinetics, activation energy of charge transfers reactions, activation energy determines reactionrate, net rate of a reaction calculation, rate of reaction at equilibrium:exchange current density, potential of a reaction at equilibrium: Galvanipotential, potential and rate: Butler–Volmer equation, exchange currents andelectrocatalysis: Improvingkinetic performance, simplified activationkinetics: Tafel equation.

- **FUEL CELL CHARGE TRANSPORT** **(25 Hours)**

Charges move in response to forces, charge transport results in a voltage loss, characteristics of fuel cell charge transport resistance, physical meaning of conductivity, and review of fuel cell electrolyte classes.

- **FUEL CELL MASS TRANSPORT** **(20 Hours)**

Transport in electrode versus flow structure, transport in electrode: diffusive transport, transport in flow Structures: convective transport.

- **OVERVIEW OF FUEL CELL TYPES** **(20 Hours)**

Introduction, phosphoric acid fuel cell, polymer electrolyte membrane fuel cell, alkaline fuel cell, molten carbonate fuel cell, solid-oxide fuel cell and other fuel cells

- **CLLASIFICATION OF FUEL CELL** **(30 Hours)**

Types of fuel cells, Hydrogen fuel cell, Proton exchange fuel cell, alkaline fuel cell, Bio fuel cells. Feed composition, source and availability, effects of impurities, potentials, comparison, limitations, advantages and examples of real life applications.

- **COMPONENTS OF FUEL CELLS** **(30 Hours)**

Design aspects of fuel cells, Electrodes for anode and cathodes, their characteristics, kinetics of electrodes, electrochemistry involved, membranes and their performances, circuiting, performance assessment tools and parameters, characterization techniques, various resistances and their assessment and minimization.

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering and Chemistry background can enrol.

Faculty members involved:

- Dr. Arvind Kumar Mungray
- Dr. Alka A. Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester IV)**

**INTRODUCTION OF GOVERNMENT REGULATIONS & TREATMENT OF WASTE FOR ENERGY**
**CH V04 Contact Hours: 200**

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

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

CO1 Explain the details of Government regulations and their significance
CO2 Explain the history and various clauses of Govt. laws and regulations
CO3 Understand of the Basics of treatment of waste
CO4 Analyze the Conventional and advanced treatment schemes
CO5 Implement the report writing methodology.

**2. Syllabus:**

- **INTRODUCTION AND SCENERIO OF VARIOUS GOVERNMNET LAWS AND REGULATIONS AND TREATMENT SCHEMES (25 Hours)**

What is sampling and its significance, characterization tools and significance, etc. Hazardous Waste Management Rules are notified to ensure safe handling, generation, processing, treatment, package, storage, transportation, use reprocessing, collection, conversion, and offering for sale, destruction and disposal of Hazardous Waste.

- **SIGNIFICANCE OF LAWS AND REGULATIONS, THEIR ORIGIN AND IMPLEMENTATION (25 Hours)**

Environment protection act, Hazardous Waste, Bio-Medical Waste,Solid Waste,Plastic Waste, Extended Producer's Responsibility, construction and Demolition Waste, Battery, duties of waste generators and authorities, solid waste management, e-waste management

- **ROLES OF VARIOUS POLLUTION CONTROL BOARDS (25 Hours)**

Role of Central Pollution control board, Ministry of urban development, Stale level pollution control boards, Practical aspects for sampling and data collection, live sampling strategies for solid/liquid/and gases waste materials

- **TYPES OF TREATMENT SCHEMES FOR WASTE (50 Hours)**

Segregation of waste at Source, Pre- treatment of Laboratory and Highly infectious waste, Collection and Storage of segregated waste in colour coded bags/containers/bins, Intra-mural transportation from generation site to central storage area, Storage at central facility, Treatment of Waste, Final Disposal through Central Bio- Medical Waste Treatment Facility.

- **ADVANCED OXIDATION PROCESSES FOR WASTE MANAGEMENT (25 Hours)**

Waste management for domestic and industrial sectors through various advanced oxidation processes, limitations, significance, limitations, characterization, case studies, etc.

- **REPORT WRITING AND STRATEGIES (50 Hours)**

Significance of report writing, methodology, tools and designing, Batteries (management and handling) rules, references nomenclature, tables and figure understanding and preparation, submission of report.

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering and Chemistry background can enrol.

Faculty members involved:

- Dr. Alka A. Mungray
- Dr. Arvind Kumar Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester IV)**

**DESIGN AND MODELLING OF FUEL CELLS**
**CH V04 Contact Hours: 200**

**1. Course Outcomes (COs):**
At the end of the course, students will be able to:
CO1 Calculate the current density, voltage losses and other parameters of the fuel cell
CO2 Calculate various conditioning parameters of the fuel cell
CO3 Develop the working model using the suitable simulation tools
CO4 Design the cost analysis and life cycle analysis of the various fuel cells
CO5 Perform the various fuel cell related calculations

**2. Syllabus:**

- **INTRODUCTION (20 Hours)**

Basic understandings of various techniques like types of voltage losses, polarization curve, fuel cellefficiency, exchange currents, current density, power density, potential andthermodynamics of fuel cell, Tafel equation, Cyclic Voltammetry, Electrochemical Impedance spectroscopy, Columbic efficiency. Fuel cell subsystem, thermal managementsubsystem, fuel delivery/processing subsystem, power electronics subsystem,case study of fuel cell system design: stationary combined heat and power systems

- **POWER CONDITIONING (30 Hours)**

Fuel cell power conversion for supplying dedicated load, fuel cell power conversion for supplying backup power, fuel cell power conversion for load connected at parallel, power conditioning for the automotive fuel cells

- **FUEL PROCESSING SUBSYSTEM DESIGN (30 Hours)**

Fuel reforming overview, water gasshift reactors, carbon monoxide clean-up, reformer and processor efficiencylosses, reactor design for fuel reformers and processors. Modelling tools available for the fuel cells.

- **HYDROGEN FUEL CELL (30 Hours)**

Details and fundamentals of Hydrogen fuel cell, need, efficiencies, availability of Hydrogen from natural resources, fossil fuels, etc., production routes of Hydrogen, Hydrogen storage, compression, Performance parameters, Power management system, Stacking and series and parallel electrical circuiting. Hydrogen plant safety issues, Cost calculation and economics, commercial and future applications of Hydrogen fuel cells, life cycle assessment.

- **BIO FUEL CELLS (30 Hours)**

History of biofuel cells and their need, types like microbial fuel cells, Microbial desalination cell, Microbial synthesis cell, microbial electrolysis cell, Osmotic microbial fuel cell, enzymatic fuel cell, etc. Their working, components, mechanism and principle, limitations, assessment. Potential generation and limitations.

- **LIFE CYCLE ASSESSMENT AND SIMULATION TOOLS (30 Hours)**

Assessment tools and characterization. Scale up applications and cost economics, Sustainable development and close loop concept. GaBi software and other life cycle analysis software

- **FUEL CELL CALCULATIONS** **(30 Hours)**

Fuel cell calculations, fuel processing calculation, power conditioners, system issues, efficiency calculations, thermos-dynamic consideration, cost calculations, automotive design calculations

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering and Chemistry background can enrol.

Faculty members involved:

- Dr. Arvind Kumar Mungray
- Dr. Alka A. Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester V)**

**INTRODUCTION OF MEMBRANES FOR WASTE TO ENERGY CONCEPT**
**CH V05 Contact Hours: 200**

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

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

CO1 Explain the details of Separation methods and their significance
CO2 Explain the history of membranes and their upgradations
CO3 Explain the fundamentals of membranes for waste treatment
CO4 Analyze the advancement of membranes and Cost effectivity
CO5 Implement of report writing methodology.

**2. Syllabus:**

- **INTRODUCTION AND SCENERIO OF VARIOUS SEPERATION REQUIREMENT FOR TREATMENT (25 Hours)**

Waste to hydrogen production, Two-dimensional materials for gas separation membrane, Mass transfer mechanism of 2D materials-based membrane in gas separation, Fabrication of 2D material-based membranes, Construction of gas separation membrane with advanced 2D materials

- **POLYMERS AND THEIR SIGNIFICANCE TOWARDS SEPARATIONS (25 Hours)**

Covalent-organic frameworks (COFs), Basics of polymers, types, various processes, requirement for membrane preparation, biopolymers, environmental aspects, etc Metal-organic frameworks (MOFs)

- **SIGNIFICANCE OF MEMBRANES NAD THEIR DEVELOPMENT (50 Hours)**

Basics of separation processes, membranes, fundamentals, functions synthesis, fabrication and their utilizations in waste treatment, fuel cells, fabrication tools, types and structures, strength, characterization tools and calculation of various flues, fouling and its mitigation, advancement in membrane development, cost analysis, biodegradable membranes

- **CHARACTERIZATION TOOLS FOR MEMBRANES (25 Hours)**

Carbon-based 2D materials, Significance and methodology of characterization tools for membrane characterization, instruments and their mechanisms and development, nanoparticle tools

- **HANDS-ON MEMBRANE FABRICATION IN LABORATORY IN FUEL CELLS AND CHARACTERIZATION (50 Hours)**

Preparation of various polymeric and ceramic membranes, tools for preparation, characterization, applications in fuel cells, efficiencies, characterization, and assessment, use of nanotechnology for the membrane efficiency improvement.

- **REPORT WRITING AND STRATEGIES (25 Hours)**

Comparison of 2D materials in membrane technology used in waste-to-hydrogen process, Significance of report writing, methodology, tools and designing, references nomenclature, tables and figure understanding and preparation, submission of report.
Challenges:Immaturity and setbacks, Scalability and reproducibility, Membrane processes, Future potential

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering, Chemistry background can enrol.

Faculty members involved:

- Dr. Alka A. Mungray
- Dr. Arvind Kumar Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester V)**

**NOVEL METHODS FOR EFFICIENT FUEL CELLS**
**CH V05 — Contact Hours: 200**

**1. Course Outcomes (COs):**
At the end of the course, students will be able to:

| | |
|---|---|
| CO1 | Explain the recent advances in the fuel cell technology |
| CO2 | Identify the efficient membranes for the fuel cell |
| CO3 | Analyse the effect of working parameters on various fuel cells |
| CO4 | Develop the nanotechnology based efficient fuel cell system |
| CO5 | Modify the membrane for better efficiency and process intensification. |

**2. Syllabus:**

- **INTRODUCTION (20 Hours)**

Fuel cell technology, Use of membrane technology, nanotechnology, nanofluids, nanocomposites, recent advances in the application of membrane technology and nanotechnology for fuel cells, sophisticated instruments used for the synthesis.

- **MEMBRANES FOR FUEL CELLS (30 Hours)**

Proton exchange membrane, Cation and anion exchange membrane, emulsion liquid membranes, supported liquid membranes, ceramic membranes, etc., their scope, application, mechanism of ion transfer, membrane development, fabrication tools, types and structures, strength, characterization tools and calculation of various flues, fouling and its mitigation, advancement in membrane development, cost analysis, biodegradable membranes.

- **ALKALINE FUEL CELL (30 Hours)**

Various novel fuel cells, Cell components, effect of pressure, effect of temperature, effect of impurity, effect of current density, effect of cell life

- **PHOSPHORIC ACID FUEL CELL (30 Hours)**

Cell components, effect of pressure, effect of temperature, effect of reactant gas composition and utilization, effect of impurity, effect of current density, effect of cell life,

- **MOLTEN CARBONATE FUEL CELL (30 Hours)**

Cell components, effect of pressure, effect of temperature, effect of reactant gas composition and utilization, effect of impurity, effect of current density, effect of cell life, Internal reforming

- **NANOTECHNOLOGY APPLICATIONS IN FUEL CELL (30 Hours)**

Nanofluids interferometer, Nanofluids Heat conductivity, Nano-emulsion &Micro-emulsion preparation & stability, Nanoparticle, its need and scope in fuel cell efficiency increment and for the removal of their limitations, electrode modifications, by changing their properties like conductivity, porosity, fouling, life etc.,

- **MODIFICATION IN MEMBRANE (30 Hours)**

Membrane modification. Utilization of nanoparticles as catalysts. Achievement of required temperature by using nanofluids, suitable solvent, assessment parameters, integration of solar with fuel cells.

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering, Chemistry background can enrol.

Faculty members involved:

- Dr. Arvind Kumar Mungray
- Dr. Alka A. Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**
**VOCATIONAL TRAINING (For Semester VI)**

**HANDS-ON TRAINING FUEL CELL DEVELOPMENT**
**CH V06 Contact Hours: 200**

**1. Course Outcomes (COs):**
At the end of the course, students will be able to:

| | |
|---|---|
| CO1 | Explain various fuel cell types, batteries and circuits, capacitors |
| CO2 | Develop various fuel cell models, novel simulation strategies for the fuel cell |
| CO3 | Develop the various fuel cell systems |
| CO4 | Analyse various experimental parameters with sophisticated instrumentations |
| CO5 | Optimise the system and cost optimisation of the process. |

**2. Syllabus:**

- **INTRODUCTION TO FUEL CELL & BATTERIES AND CIRCUITS (30 Hours)**

Various types of fuel cells, Types of batteries, chargeable and non-chargeable, capacitors, super-capacitors, stacking potentials, MPPT, power management system, various electrical circuits, DC to AC and AC to DC circuits, booster pumps, etc. for real life assessment.

- **DEVELOPMENT OF MODELS FOR THE FUEL CELLS (70 Hours)**

Use of various simulation tools for the fuel cell development, Preparation of working models and their assessment, develop novel simulation strategies.

- **HANDS ON TRAINING OF FUEL CELL SYNTHESIS (70 Hours)**

Lab training sessions, design and construction of various fuel cells, characterization, assessment of performance parameters, fabrication and preparation of various electrodes, nanoparticles, membranes, power management circuits, and stacking with various series and parallel electrical and hydrodynamic circuits.

- **HAND ON EXPERIENCE OF ANALYSIS INSTRUMENTATION (30 Hours)**

Hand on training of characterization equipment like DLS, UV, GC for the analysis of the various parameters required for the efficient fuel cell system

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering, Chemistry background can enrol.

Faculty members involved:

- Dr. Arvind Kumar Mungray
- Dr. Alka A. Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

## VOCATIONAL TRAINING (Semester VI)

### HANDS ON EXPERIENCE OF WASTE TO ENERGY CONCEPT

**CH V06 Contact Hours: 200**

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

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

- CO1 Explain the types of Waste and their potentials towards energy generation, scope and future
- CO2 Identify the challenges towards Waste to Energy Schemes and their probable solutions
- CO3 Assess the various Physio-Chemical, Biological, Thermochemical, Advance Oxidation Processes, nanomaterials, for Waste to Energy Conversion
- CO4 Design novel reactors and their processes for various waste
- CO5 Implement the report writing methodology

**2. Syllabus:**

- **INTRODUCTION AND SCENERIO OF WASTE TO ENERGY CONVERSION (10 Hours)**

Quantity of waste, type of waste, issues, quality, Need, assessment, environmental guidelines, environmental problems, sustainable development, sustainable development goals, waste to energy concept, requirement, options, types, future, limitations, probable solutions, cost economics, close loop concept various start-ups.

- **UNDERSTATING OF VARIOUS PHYSICAL CHEMICAL, BIOLOGICAL TREATMENT PROCESSES (30 Hours)**

Basics and fundamentals of Physicochemical based treatment systems as primary treatment, assessment their efficiencies, type of reactors or systems required, their need and optimization**,** Basic understandings of various biological processes, reactors, limitations, and novel aspects, anaerobic and aerobic mechanism and reactors and accordingly calculations, Biodiesel synthesis, Bioglycerol to value added product, Biodisel blend and engine performance, Biogas and upgrading of biogas to biomethane: power-to-gas with ex-situ biomethanation, bottling of biogas, Bioelectrochemical systems, their configurations, research, Electrolysis; Biomethanation at thermophilic conditions; Microbial electrochemical systems; Mass balances in biological reactors, Oxygen mass transfer in biological aerobic reactors, assessment of biological reactors, biofuel cells, batteries and power management systems. batteries, capacitors, super-capacitors, stacking potentials, power management system for storage of energy and supply

- **THERMO-CHEMICAL PROCESSES (30 Hours)**

Biodisel blend property, Biomass, Classification of waste/biomass as fuel, thermo-chemical conversion, Direct combustion, biomass gasification, pyrolysis and liquefaction, biochemical conversion, digestion, types of biogas plants, alcohol productionfrom biomass, bio diesel production, Urban waste to energy conversion, Biomass energy programme in India, Hydrothermal processes, hydrothermal carbonization, liquefaction, gasification, optimization, production of bio-char/hydro-char, process water, HHV values, assessment and characterization and characterization tools.

- **CHARACTERIZATION TOOLS FOR EFFICIENCY ASSESSMENT (30 Hours)**

Various tools, characterization techniques, models, etc for finding the reactor efficiencies, etc

- **HANDS-ON HANDS ON TRAINING AND MODEL PREPARATION (80 Hours)**

Lab training sessions, design and construction of various reactors, characterization, assessment of performance parameters, fabrication and preparation/synthesis of various membranes, nanoparticles/nanofluids, power management circuits, making biochar and process water from various substrate, preparation of working models and their assessment.

- **POWER MANAGEMENT SYSTEMS AND REPORT WRITING AND STRATEGIES (20 Hours)**

Designing power management tools for storage of energy, Significance of report writing, methodology, tools and designing, references nomenclature, tables and figure understanding and preparation, submission of report.

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering, Chemistry background can enrol.

Faculty members involved:

- Dr. Alka A. Mungray
- Dr. Arvind Kumar Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester VII)**

**VARIOUS BUSINESS MODELS TOWARDS WASTE TO ENERGY CONCEPT**
**CH V07 Contact Hours: 200**

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

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

CO1 Explain the need of various business models for waste to energy concept
CO2 Assessment of Environmental audits and its significance
CO3 Identification of the challenges towards start up models for Waste to Energy Schemes and their probable solutions
CO4 Designing a novel start- up model for any waste to energy concept
CO5 Implementation of report writing methodology.

**2. Syllabus:**

- **INTRODUCTION AND SCENERIO OF BUSINESS MODELS (10 Hours)**

Need of waste to resources models, business opportunities, scenarios, etc. Production of bio-ethanol, Substrate suitability of bio-ethanol, cost of production, uses of bio-ethanol, bio-gas production through anaerobic digestion, history of anaerobic digestion, principles of anaerobic digestion process, factors affecting the anaerobic digestion process, landfill biogas, leachate, co-digestion.

- **BASICS OF START-UP AND STRATEGIES (40 Hours)**

Need, definitions, regulations, team, role, assessment, etc. importance of bio-ethanol in the transportation sector, ethanol production processes, material source for bio-ethanol production, process for bio-ethanol production, factors affecting the lignocellulose biomass conversion into bio-ethanol

- **VARIOUS GOVERNMENTAL AND PRIVATE SCHEMES TOWARDS START-UP (20 Hours)**

Assessment of various governmental and private schemes, schemes available at skill India, make in India, Start-up India, and funding opportunities provided by private companies.

- **UNDERSTATING ENVIRONMENTAL AUDITS, REQUIREMENT, METHODOLOGY, ASSESSMENT (30Hours)**

Environmental protection laws, methodologies developed for the entrepreneurs, documentation processes, common mistakes made during the application process, what is environmental audits, its need, governmental regulations, etc

- **REGISTRATION POLICIES AND VARIOUS REGULATIONS OF START-UP, MAKING A MODEL START-UP BUSINESS MODEL (80 Hours)**

Case studies and preparation of any start up model for any waste in laboratory, scale up challenges, model development

- **REPORT WRITING AND STRATEGIES (20 Hours)**

Significance of report writing, methodology, tools and designing, references nomenclature, tables and figure understanding and preparation, submission of report.

**(Total: 200 hours)**

Conditions:

- Minimum 2 students to run the program
- Registration fee Rs. 500/- per student
- Interdisciplinary nature and students from Chemical Engineering, Civil Engineering, Chemistry background can enrol.

Faculty members involved:

- Dr. Alka A. Mungray
- Dr. Arvind Kumar Mungray
- Dr. M. Chakraborty
- Dr. Parag Thakur

**Department of Chemical Engineering**
**Vocational Training / Professional Experience**
**(Mandatory for Exit; and Optional for others)**

**VOCATIONAL TRAINING (Semester VII)**

**SCALE-UP STUDY OF FUEL CELLS**
**CH V07 Contact Hours: 200**

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

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

CO1 Explain the types of Fuel cells and electroactive biofilm and electron transfer
CO2 Explain the bio-electro remediation
CO3 Explain the scale up method and strategies used for the system
CO4 Identify and solve the challenges faced during the commercialization of fuel cell
CO5 Develop the models using artificial intelligence

**2. Syllabus:**

- **INTRODUCTION (30 Hours)**

Introduction to microbial electrochemical systems, classification of microbial fuel cell, microbial electrolysis cells, microbial solar cells, microbial electro-synthesis cells, microbial desalination cells, operational and electro-chemical limitations of microbial fuel cell, techno-economic viability, pilot scale to industrial scale of microbial fuel cell.

- **ELECTROACTIVE BIOFILM AND ELECTRON TRANSFER (30 Hours)**

Electro-active micro-organism, formation of electro-active biofilms, electron transfer mechanism, effect of design, operational and biological parameters on electro-activity of electro-active biofilms, role of electro-active biofilms in governing the performance of microbial electro-chemical system, strategies for the development of electroactive biofilms. Electron transfer in the electro-active biofilms

- **BIO-ELECTROREMEDIATION OF WASTES USING BIO-ELECTRO-CHEMICAL SYSTEM (25 Hours)**

Introduction, Drawbacks of conventional bioremediation, Phytoremediation, BES for ground water remediation, practical obstacles in ground water remediation, In situ bio-electro-remediation: Ideal step, Bio-electro-remediation: future perspectives, designing and fabrication of single chambered microbial fuel cell, natural fibre-reinforced polymer, substrates used in MFCs.

- **SCALE UP OF MES (25 Hours)**

Introduction, designing of reactor to scale up, electrode modification in scaling up of MES, Membrane separators in MES, scale up: issues and strategies, stacking of BES, Voltage reversal and prevention, pilot scale BESs for hydrogen/methane production, Scaled up BESs for bio-remediation

- **COMMERCIAL ASPECT OF SCALE UP (30 Hours)**

Role of different materials in development of MFC, strategies for development of MFC stacking, modes of operation, parameters affecting the scale up, engineering design parameters of of MFC scale-up, reactor architecture, electrodes, membranes, process parameters like organic loading rate, buffers, nitrogen purging and aeration, criteria for scale up: electrode surface area, electrode spacing, stacked MFCs, hydrodynamics, mass transfer and reaction kinetics, market segmentation

- **CHALLENGES FOR SCALE UP** **(30 Hours)**

Operating conditions and anodic constrains, catholyte and cathodic conditions, electrode materials, proton exchange membrane, oxygen reduction reaction catalysts, design parameters and configuration, commercialization of microbial fuel cell, economi assessment, life cycle assessment social impact

- **USE OF ARTIFICIAL INTELLIGENCE FOR THE BIO-ELECTROCHEMICAL SYSTEMS** **(30 Hours)**

AI methods for the prediction of electricity/power generation in MFCs, AI methods for detection of substrates/chemicals in MFC based bio-sensors, AI methods for predicting the hydrogen production in MECs, AI based control strategy for MDCs

**(Total: 200 hours)**

<u>Conditions:</u>

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