**M.TECH.**

**(CHEMICAL ENGINEERING)**

**(Effective from the admitted batch of 2019-20)**

**Scheme and Syllabi**

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**DEPARTMENT OF CHEMICAL ENGINEERING**

**AU COLLEGE OF ENGINEERING (A)**

**ANDHRA UNIVERSITY**

**VISAKHAPATNAM**

DEPARTMENT OF CHEMICAL ENGINEERING

AU COLLEGE OF ENGINEERING (A)

ANDHRA UNIVERSITY

VISAKHAPATNAM

 **SCHEME OF INSTRUCTION & EXAMINATION**

**I/II M.TECH. (CHEMICAL ENGINEERING) FIRST SEMESTER**

**(WITH EFFECT FROM 2019-20 ADMITTED BATCH ONWARDS)**

**UNDER CHOICE BASED CREDIT SYSTEM**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Code No.** | **Course** | **Credits** | **Theory** | **Tutorial** | **Lab** | **Total** | **Sessional marks** | **Exam marks** | **Total marks** |
| CHEM 1.1.1 | Process Modeling and Simulation | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM1.1.2 | Process Dynamics and Control | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM 1.1.3 | ChemicalReaction Engineering | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM 1.1.4 | Transport Phenomena | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM 1.1.5 | Elective-I | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CHEM1.1.6 | Elective-II | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CHEM 1.1.7 | Elective lab | 2 | -- | -- | 3 | 3 | 50 | 50\* | 100 |
| CHEM 1.1.8 | Seminar | 2 | -- | -- | 3 | 3 | 100 | -- | 100 |
|  | TOTAL | 28 | 20 | 4 | 6 | 30 | 330 | 470 | 800 |

\*Only internal evaluation.

**Elective-I :** 1.Petroleum Refinery Engineering-I

 2. Process Dynamics and control-I

 3. Electrochemical Engineering-I

**Elective-II** : 1. Corrosion Engineering-I

 2. Energy Engineering-I

 3. Reaction Engineering-I

DEPARTMENT OF CHEMICAL ENGINEERING

AU COLLEGE OF ENGINEERING (A)

ANDHRA UNIVERSITY

VISAKHAPATNAM

 **SCHEME OF INSTRUCTION & EXAMINATION**

**1/2 M.TECH (CHEMICAL ENGINEERING) SECOND SEMESTER**

**(WITH EFFECT FROM 2019-20 ADMITTED BATCH ONWARDS)**

**UNDER CHOICE BASED CREDIT SYSTEM**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Code No.** | **Course** | **Credits** | **Theory** | **Tutorial** | **Lab** | **Total** | **Sessional marks** | **Exam marks** | **Total marks** |
| CHEM 1.2.1 | Computer Aided Design | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM1.2.2 | Advanced Engineering Maths and Statistics | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM 1.2.3 | Advanced Mass Transfer | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM 1.2.4 | Pollution Control | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CHEM 1.2.5 | Elective-III | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CHEM1.2.6 | Elective-IV | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CHEM 1.2.7 | Elective lab | 2 | -- | -- | 3 | 3 | 50 | 50 | 100 |
| CHEM 1.2.8 | Seminar | 2 | -- | -- | 3 | 3 | 100 | -- | 100 |
|  | TOTAL | 28 | 20 | 4 | 6 | 30 | 330 | 470 | 800 |

**Elective-III :** 1. Petroleum Refinery Engineering-II

 2. Process Dynamics and control-II

 3. Electrochemical Engineering-II

**Elective-IV** : 1. Corrosion Engineering-II

 2. Energy Engineering-II

 3. Reaction Engineering-II

DEPARTMENT OF CHEMICAL ENGINEERING

AU COLLEGE OF ENGINEERING (A)

ANDHRA UNIVERSITY

VISAKHAPATNAM

 **SCHEME OF INSTRUCTION & EXAMINATION**

**2/2 M.TECH (CHEMICAL ENGG) FIRST & SECOND SEMESTER**

(WITH EFFECT FROM 2019-20 ADMITTED BATCH ONWARDS)

**UNDER CHOICE BASED CREDIT SYSTEM**

**PROJECT WORK:**

CHEM-2.1.1 - FIRST SEMESTER: CREDITS:10, MARKS:100

CHEM-2.2.1- SECOND SEMESTER: CREDITS:14, MARKS:100

* Project guide will be allotted at the beginning of first semester and the student has to give presentation on his/her project work at the end of first semester and grading will be awarded as A,B,C or F.
* At the end of second semester final viva-voce examination will be conducted and grading will be

 awarded as A,B,C or F.

**SYLLABUS**

**M.TECH. I SEMESTER**

**CHEM-1.1.1: Process Modeling and Simulation**

**(Common for MPE, CACE & IPCE )**

 **Objective:**

 Deals with writing various process models based on basic physical process. It also deals with solving the various models by means of numerical methods by computer simulation. By studying this course, one can simulate various chemical processes by computer simulation.

**Outcome:**

1. Understand the writing of a model of a process based on basic physical processes like mass, momentum and energy balances.
2. Able to develop a model equation for Tanks, Isothermal and Non-Isothermal Systems

1. Able to understand the models for binary distillation column, batch reactors, etc.
2. Able to solve the model equations by numerical methods.

**Syllabus:**

Principles of formulation - Continuity equations – Energy equation – Equation of motion – Equations of state – Transport equations – Chemical Kinetics – Algebraic and Integral / differential equations, Explicit and Implicit equations –Numerical Integration,Feed forward and feed backward control.

Basic modeling for tank system, mixing vessel – Simultaneous mass and energy balances – Models for boiling, batch distillation, and partial condenser.

Models for Reactor – Model for heterogeneous catalysis – Models for pumping system – Model for heat exchanger.

Operational blocks in simulation- Simulation Programming – Simulation examples of three CSTR’s in series, gravity flow tank, binary distillation column, non–isothermal CSTR.

Implicit function convergence ,Internal–halving convergence, Newton–Raphson method, False position convergence, Explicit convergence methods, Numerical Integration, Euler Integration, Runge - Kutta (fourth order) method.

**Textbooks:**

1. Process Modeling, Simulation and Control for Chemical Engineers by Luyben, W.L., McGraw Hill Books Co.
2. Mathematical Modeling in Chemical Engineering by Roger, G.E. Franks – John Wiley Sons Inc.

**Reference Book:**

 Mathematical Methods in Chemical Engineering by V.G. Jenson and G.V. Jefferys, Academic Press – 2nd Edition.

**CHEM-1.1.2: Process Dynamics & Control**

**(Common for MPE, CACE & IPCE )**

**Objectives** :

  The main purpose of teaching Process Dynamics & Control for first year postgraduate students is to take the student from basic mathematics to a variety of design applications in a clear, concise manner. This course is focused on the use of the digital computer in complex problem solving and in process control instrumentation. For chemical engineering problem solving students need more advanced mathematical preparation like partial differential equations, linear algebra and Fourier series all are introduced in this course.

**Outcome:**

* Able to know the sampled data control systems consists of sampling and advanced mathematical model Z- transforms.
* Able to describe the process in which the flow of the signals is interrupted periodically like in chromatograph.
* Able to calculate the open loop response of a sampled data system and can develop a pulse transfer function that is the counterpart of the transfer function for continuous systems.
* Able to know the sophisticated instruments used for the analysis of water and air pollutants, The student should have knowledge to design the equipment used for the abatement of these pollutants.
* In a position to modernize the solid waste management and the student must be in a position to get awareness on accidents that are occurring in industries during handling, storage, and manufacturing of chemicals, remedial measures to arrest the accidents immediately.

**Syllabus:**

Review of time domain, Laplace domain and frequency domain dynamics of process and control system.

 Sampled data control system – sampling and Z–Transforms , open loop and closed loop response, Stability.

 State space methods – representation of physical systems – transfer function matrix – Multivariable systems – Analysis and control.

 Non linear control –examples of non linear systems – Methods of phase plane analysis.

Control of heat exchangers, distillation columns and Chemical Reactors.

**Textbooks:**

1. Process system Analysis and control, 2nd edition, Donald R Coughanower and Koppel.
2. Automatic process Control by Peter Harriot.
3. Process Modeling, Simulation and control for Chemical Engineers by W.L. Luyben.

**CHEM-1.1.3: Chemical Réaction Engineering**

**(Common for MPE, CACE & IPCE )**

**Objectives:**

* To focus on the thermal characteristics of various reactions and the design aspects of non isothermal and adiabatic reactors
* To focus on Heterogeneous data analysis and design
* To focus on CVD reactors
* To study the design aspects of heterogeneous catalytic systems
* To impart the knowledge on mass transfer with reaction in process catalysts

**Outcome:**

* Enables the students to understand the design aspects of non isothermal and adiabatic reactors
* Enables the students to on heterogeneous data analysis and design aspects of heterogeneous catalytic systems
* Able to derive the rate laws for CVD
* Able to develop the rate laws for heterogeneous fluid solid catalyzed reactions under rate limiting situations.

**Syllabus:**

Review of Fundamentals Rate laws and stiochiometry, reactions with phase change (Scope: Chapter 3 of Fogler) Least squares Analysis of rate data: differential reactors: Laboratory reactors (Scope: sections 5.4 to 5.6 of Fogler) Multiple reactions (Scope: Chapter 9 of Fogler).

Isothermal reactor design (Scope: Chapter 4 of Fogler) Batch reactor, PFR, CSTR design. Pressure drop in reactors, Reversible reactions, unsteady state operation of reactors, Simultaneous reaction and separation

Catalysis and catalytic reactors (Scope: Chapter 6 of Fogler) Steps in catalytic reaction: derivation of rate laws, design for gas-solid reactions, heterogeneous data analysis and design; Chemical vapour deposition, catalyst reactivation, moving bed reactions.

 Diffusion and reaction in process catalysts (Scope: Chapter 11 of Fogler).

 Diffusion and reaction in spherical catalyst.

Internal effectiveness factor, falsified kinetics; estimation of diffusion and reaction limited regimes. Mass transfer and reaction in packed bed. Determination of limiting situations from reaction data, CVD reactors.

Non-isothermal reactor design (Scope: Chapter 8 of Fogler), Energy Balance, equilibrium conversion under adiabatic conditions unsteady state operation, multiple steady states.

**Textbook:**

Fogler. H.S: Elements for Chemical Reaction Engineering 2nd Edition, Prentice Hall, New Delhi, 1992.

**Reference:**

 Smith J.M: ‘Chemical Engineering Kinetics’ 3rd Edition, McGraw Hill, 1981.

**CHEM-1.1.4: Transport Phenomena**

**(Common for MPE, CACE & IPCE )**

***Objectives:***

* To be able to analyze various transport processes with understanding of solution approximation methods and their limitations.

***Outcomes:***

* Ability to understand the chemical and physical transport processes and their mechanism.
* Ability to do heat, mass and momentum transfer analysis.
* Ability to analyze industrial problems along with relevant approximations and boundary conditions.
* Ability to develop steady and time dependent solutions along with their limitations.

**Syllabus:**

Unit 1: Momentum Transport

* 1. The Equations of change for isothermal systems.
	2. Velocity distributions with more than one independent variable.
	3. Velocity distributions in turbulent flow.
	4. Inter phase transport in isothermal systems.

 Unit 2: Energy Transport

* 1. The Equations of change for non – isothermal systems.
	2. Temperature distributions with more than one independent variable.
	3. Temperature distributions in turbulent flow
	4. Interphase transport in nonisothermal systems.

 Unit 3: Mass Transport

* 1. The Equations of Change for multicomponent systems.
	2. Concentration distribution with more than one independent variable.
	3. Concentration distribution in turbulent flow.

**Textbook:**

“Transport phenomena” R. Byron Bird, Warren E. Stewart and E.N. Light foot, Wiley & Sons, Inc., New York.

**Reference Books:**

1.”Fundamentals of Momentum, Heat and Mass Transfer” James R. Welty, Charles E. Wicks and Robert E. Wilson, John Wiley & Sons, Inc., New York.

2. “Boundary – Layer Theory”, Dr.H.Sehlichting, McGraw – Hill Book Company, New York.

**CHEM-1.1.5: Elective – I**

**CHEM- 1.1.5 A - Elective-I (Petroleum Refinery Engineering-I)**

**Objective:**

To introduce the basics of refinery engineering subject for petroleum specialization students to gain knowledge of the overall refinery operations, refinery products and its test methods. To learn various primary and secondary cracking process available to produce normal and value added products. Further, to learn the treatment process available to remove the impurities in the crude and finished products and its test methods for quality check.

**Out come:**

Student gains very basic knowledge which every petroleum specialization student should know to work in the refinery field. Student will learn the importance of quality check and different methods available for quality check. Student learns about various treatment processes available to increase the quality of the product. Student is able to gain complete knowledge on the process available including operating conditions, reaction kinetics, catalyst, products, etc. This knowledge is very helpful for the student to have primary and basic knowledge of the process in advance before delivering the duty as process engineer.

***Syllabus:***

***Origin and formation of petroleum***: Reserves and deposits of the world - Indialn petroleum industry - Composition of crudes.

***Refinery products specifications and test methods***: Evaluation of crudes. Crudes Pretreatment dehydration and desalting. Physical properties of petroleum oils and products.

Introduction to processing- Refinery distillation - processes - catalytic cracking, Reforming Hydro cracking , and hydro treating, hydrosulfurization.

***Chemical treatments & Extraction Processes*** *:* Alkylation, polymerization Lube oil processing.

***De-waxing*** *:*

Asphalt and air blown asphalt.

Treatment of products, additines, blending of gasoline, treatment of gasoline, Kerosene etc.,

***Heat transfer equipment in Refinery*** - Heat exchangers and pipe still heaters.

Design of atmospheric distillation tower and Vacuum distillation tower, catalytic cracking units.

**Text Books :**

1. Petroleum Refinery Engineering - Nelson.
2. Refinery distillation - Watkins.

**CHEM- 1.1.5 B - Elective-I (Process Dynamics and Control-I)**

**Objectives:**

The student is equipped with the analytical tools that are required in the actual design and analysis of distillation control systems. Further this subject provides a unified treatment of steady-state and control aspects of distillation operations.

**Outcome:**

1. The student know different techniques to formulate and solve binary and multicomponent distillation problems along with case studies
2. Knowing of those variables that affect the composition of the products
3. Dynamic mathematical tools used in controller tuning and process-identification techniques would be known.
4. Design and application of advanced control concepts to distillation would be thoroughly understood.

**Syllabus:**

 Unit 1 : Overview of steady state distillation concepts.

 Unit 2 : Distillation control concept - Controlled variables in distillation - Basis for distillation control strategies - Dynamic Modelling & Simulation.

 Unit 3 : Process identification - Frequency response and Controller tuning - Pairing and interaction in distillation.

 Unit 4 : Feed forward control - Cascade and parallel cascade control - Dead time compensation.

 Unit 5 : Inferential control and model algorithmic control.

**Textbook :**

Distillation Dynamic and Control - Pradeep B., Deshpande, ISA, Tata McGraw Hill Co. Ltd.

**Reference**:

Design of Distillation Column Control Systems -Luyben and Shunta ISA. Tata McGraw Hill Co.

# **CHEM- 1.1.5 C - Elective-I (Electrochemical Engineering-I)**

**OBJECTIVES:**

* To enable the basic principles of electrochemistry, electrochemical devices, electro active materials used in such devices, and case studies of batteries.

* To enable the clean energy needs and demands especially in the electrochemical power generation sector; and to become educators, practicing engineers, and national leaders in electrochemical energy conversion and storage.
* To enable the integrated skills in fundamentals of electrochemistry (e.g.; chemistry, physics, mathematics, thermodynamics, and chemical kinetics) and electrochemical engineering applications (batteries, solar, flow and fuel cells, electrochemical synthesis and corrosion) to ensure successful career opportunities and growth within electrochemical power generation industries and academia.
* To enable the students in energy related programs such as clean power generation and future green technologies.

 **OUTCOMES:**

* The student would know how to solve the problems relating to the production, storage, distribution and utilization of electrochemical energy and the associated environmental issues. And he would know integration of electrochemical principles and materials science for application in modern electrochemical devices.
* The student would know design and conduct experiments, acquire data, analyze, interpret data, solve practical and complex problems on a variety of electrochemical devices such as batteries, solar cells, flow and fuel cells and integrate the professional, ethical, social and environmental factors in electrochemical engineering and understand the impact of these factors on global energy issues.

**Syllabus:**

**Introduction:**

Unit I : Basic Concept: Mechanism of Electrolysis, Laws of Electrolysis, Curent and Voltage Efficiency - Electrolytic dissociation, Coulometers, Ionic conduction. Electrolytic conductivity, Absolute ionic velocities, ionic mobilities, Transference Nos. Modern Ionic Theory, Ionic activity Degree of dissociation. Ionic Atmosphere Time of relaxation and relaxation effect, Electrophoretic effect - Debye - Huckel Onsager equation of conductance (Derivation is not required) and its validity.

Unit II: Thermodynamics I: Chemical Potential and Free Energy changes. Cell and Electrode potentials. Thermodynamics of Electrode potentials - Nernst Equation. Equilibrium Constant, Arbitrary Zero of potential, EMF series and their limitations Activity Coefficient of and their evaluation, Liquid Junction potentials, Concentration Cells - Reference Electrodes.

 Unit III : Thermodynamics II : Electrode Kinetics, Role of Interface, Electric Double Layer and its capacitance - Irreversible Electrode processes - Irreversibility, Tates of Electrode Processes. Electrode Kinetics Model, Cathodic Hydrogen evolution, Depolarisation - Overpotential, Tafel Equation, Ohmic or resistance Over potential, Concentration overpotential, Oxygen Evolution reaction and Decompostion potential, Ionic Transport by Migration, Diffusion and Convection - Mass transfer.

Unit IV : Kenetics of Corrosion Processes and Evans Diagrams : Electrokinetic phenomenon - Straming potential, zeta potential and Electro - Osmosis, Electrophoresis, Dorn Effect.

Measurements and Systems Analysis : Conductivity measurements - Conductometric analysis - Titrations, Measurements of pH, potential - potentiometric titrations, Polarography Electrogravimetry, Coulometry. Current Distribution in a cell. Rotating Disc Electrode, Rotating Cylinder electrode, Rough Surface Electrode Limiting Current Technique.

Unit-V: Potential relations in corrosion cells potentials, pH diagrams in corrosion.

Corrosion theory : Manifestation of corrosion, bases of electrochemical corrosion, amount and intensity of corrosion, Eight forms of corrosion : Uniform attack, Galavanic corrosion, crevice corrosion,Pitting, inter granular corrosion. Selective leaching, stress corrosion cracking. Conditions leading to pitting attack., environmental factors, hydrogen damage. Corrosion inhibition and prevention : Domestic water supplies, recirculating water systems, corrosion inhibitors, Inhibitors for acid pickling, vapor phase inhibitors. Coatings and paits: Phosphating, Protective metal coatings; cathodic protection and corrosion of buried structures.

**Textbooks:**

1. An Introduction to Electrochemistry by Samuel Glasstone, D. Van Nostrand Company Inc princeton, Affiliated East-West press Pvt. Ltd.
2. Electrochemistry - Principles and Applications by Edmund C. Fotter Oliver Hume Press Ltd., London.

**Reference Books:**

1. Electrochemical Engineering, Principles, by Geofferey Prentice, The Johns Hopkins University, Prentice Hall, Englewood Cliffs, New Jersy, 07632.
2. Electrochemistry - Bookris and A.K.Reddy.
3. Electrochemical Engineering by C.L.Mantell.
4. Principles of Electrochemical Engineering by L.W.Shemilt.
5. Chemical Engineering Development Centre, Indian Institute of Technology, Madras 600 036.
6. Fontanna and Grene ‘Corrosion Engineering’.

**CHEM-1.1.6: Elective –II**

**CHEM-1.1.6 A - Elective-II (Corrosion Engineering-I)**

**The main objectives are to provide:**

1. Basic aspects of electrochemistry relevant to corrosion phenomena,
2. Importance and forms of corrosion.
3. Knowledge on corrosion rate expressions and measurement techniques.
4. Knowledge on factors influencing corrosion of iron and steel exposed to atmospheric, soil and aqueous medium.
5. Basic knowledge on remedial measures for corrosion.

**Outcome:**

1. Acquires knowledge on basic principles of electrochemistry, importance of corrosion, corrosion tendency and electrode potentials.
2. Able to identify the nature of corrosion and form in which it attacks(Uniform attack, Galvanic Corrosion, Crevice Corrosion, Pitting, Intergranular Corrosion, Selective Leaching, Erosion Corrosion and Stress Corrosion. Hydrogen damage .
3. By acquiring knowledge on polarization and its influence on corrosion rates will be able to measure corrosion rates and analyze.
4. Acquires knowledge on mechanism and propose viable remedial measures.

**Syllabus:**

Basic Concepts and Outlines of Electrochemistry: Fundamentals of Electrochemical reactions, Faraday’s Laws Electrolytic and ionic conductance, ionic mobility’s, Transport Nos. Galvanic Cell and Electrolytic cells.

Definition and importance of corrosion, Dry cell, analogy, Corrosion Cells, Types of Corrosion Cells- a) Dissimilar electrode cells b) Concentration cells such as a salt concentration cells, differential aeration cells c) differential Temperature cells. Corrosion Rate Expresions - mdd, ipy, cpy, mpy, etc.

Corrosion Tendency and Electrode Potentials: Free Energy changes, Development of Nernst Equation for calculation of Half-cell potentials, Hydrogen electrode, Spontaneity of a reaction, Reversible cells and potentials – convention of Sign and calculations of EMF from standard Equilibrium potentials., EMF Series and Galvanic series, Reference Half Cells – Calomel, Silver-Silver Chloride and Saturated Copper-Copper Sulphate Half Cells. Pourbaix Diagram for Iron, Aluminum and magnesium, limitations of pourbaix diagrams.

Polarization and Corrosion Rates: Polarization and a Polarized Cell, Causes of Polarization – Concentration Polarization, Activation Polarization and IR drop. Hydrogen Over potentials, combined polarization and Mixed potential theory. Tafel Slopes and Tafel Equation. Graphical method of expressing Corrosion Reactions (Polarization diagrams/Evans diagrams), Derivation of Stern-Geary Equation, Influence of Polarization on Corrosion rates.

Passivity: Characteristics of Passivation, Flade potential, behavior of passivators, transpasivity, Theories on Passivity.

Forms of Corrosion: Uniform attack, Galvanic Corrosion, Crevice Corrosion, Pitting, Intergranular Corrosion, Selective Leaching, Erosion Corrosion and Stress Corrosion. Hydrogen damage. Factors influencing, mechanisms and prevention techniques for all forms of corrosion. Calculation of Corrosion rates using weight lost method and Polarization data. Electrochemical Impedance Spectroscopy.

Effect of Dissolved Oxygen (Air saturated Water, High Partial Pressure of Oxygen and Anaerobic bacteria), Temperature, pH, Galvanic coupling, velocity, dissolved salts concentration. Wet and dry corrosion.

**Textbooks :**

1. Corrosion and Corrosion Control by Herbert, H. Uhlig John Wiley and Sons Inc., New York.
2. Corrosion Engineering by Mars F Fontana, McGraw Hill.
3. An Introduction to Electrochemistry by Samuel Glass stone, Affiliated East West

Press Pvt. Ltd.,

**Reference Books :**

1. Corrrosion Volumes 1 & 2 by L.L. Shrier, Newnes - Butter-worths, London.

**CHEM- 1.1.6 B - Elective-II (Energy Engineering-I)**

**Objectives:**

To lean overview of solar radiation and it’s potential for collection to meet the energy needs of mankind and potential for solar energy option. To learn measuring techniques of solar radiation and its compilation.

To learn various design and operational aspects of solar energy collection and storage.

To learn the design and operation of solar energy appliances like liquid flat plate collectors, Solar Air Heaters, Thermal energy storage, Thermal energy storage, Solar Pond, Solar thermal power generation.

To learn theory and application of Photovoltaic cells

**Outcome:**

The student learns collection and design of various kinds of equipment operated on solar energy. The student learns principles and practice of Photo voltaic cells.

**Syllabus:**

**The Solar Energy option**

Thermal conversion – collection and storage Thermal applications – photovoltaic conversion – wind energy – Energy from Bio – mass – ocean thermal energy conversion.

**Solar Radiation**

Solar Radiation outside the earths – atmosphere Solar radiation at the Earth’s surface – Instruments for measuring Solar Radiation – Solar Radiation data – Solar Radiation Geometry Empirical equations for predicting the availability of Solar Radiation – Solar radiation on tilted surface.

**Liquid flat – Plate Collectors**

Components of liquid flat plate – various types of collectors – Performance Analysis – Transmissivity – Absorptivity product – Overall loss coefficients and heat Transfer correlations – Collector efficiency heat removal factors – effect of various parameters on performance. Transient Analysis – Testing procedures.

**Solar Air Heaters**

Various types of solar Heaters – Performance Analysis of a conventional Air Heater – Testing procedures – Concentrating collectors – various types of concentrating collectors cylindrical and parabolic collectors – General receiver collectors.

**Thermal energy storage**

Sensible heat storage – Latent heat storage – Thermochemical storage

**Solar Pond**

Description – Performance analysis – Experimental studies – Operational problems.

**Solar Air Conditioning and Refrigeration**

Heat pump cycle – Coefficient of performance of the heat pumps – solar air-conditioning with absorption – Refrigeration system (Ammonia water and lithium bromide – water systems).

**Solar thermal power generation**

Thermal and direct electricity generation – Major sub-stations of a solar thermal power plant, Examples of installed systems – Concentration ratio. Temperature and efficiency concepts – Solar farm and tower – Economics.

**Photovoltaic Energy Conversion**

Photovoltaic Energy Conversion Fundamentals – band theory of solids – Physical processes in a solar cell – Solar cell with light incidence – Solar cell module – Silicon Solar Cells – Copper Sulphate / Cadmium sulphide Solar Cells.(Banasal et at.,chapters 9;Taylor, chapters 6, pages 256-298.

**Text Books:**

1. Solar Energy: Principles of thermal collection and storage by S.P. Sukhatme, Tata McGraw Hill, New Delhi 1984 (Chapters 2 to 8)
2. Renewable energy sources and conversion technology by N. K. Bansal, M. Kleemann, Michael Mcliss, 1990 (Chapters 2 – 9).

**CHEM- 1.1.6 C - Elective-II (Reaction Engineering-I)**

**Unit I** : (Scope : J.M. Smith : Chapter 7): Heterogeneous Processes, catalysis, and absorption: Global Rates of Reaction - Types of Heterogeneous Reactions - The nature of catalytic Reactions - The Mechanism of catalytic Reactions - Surface Chemistry and Absorption - Absorption Isotherms - Rates of Absorption.

**Unit II** ( Scope : J. M. Smith: Chapter 8 : Solid Catalysts: Determination of surface area - Void Volume and solid density - Fore volume distribution - Theories of Heterogeneous Catalysis - Classification of catalysts - Catalyst Preparation - Promoters and Inhibitors Catalyst Deactivation (Poisoning).

**Unit III:** (Scope: J.M. Smith : Chapter 9): Rate equations for fluid - Solid Catalytic Reactions: Rates of adsorption, Desorption, Surface Reaction - Rate equations in terms of Fluid phase concentrations at the catalyst surface - Qualitative analysis of rate equation - Quantitative inter pretation of Kinetic data - Redox Rate equations.

**Unit IV:** ( Scope : Octave Levenspiel : Chapter 15) : Deactivating Catalysts : Mechanism of Catalyst Deactivation - The ratre of equation - The rate of equation from experiment - Batch - solids: Determining the rate for Independent Deactivation Batch - solids : Determining the rate of parellel, series or side - by - side Deactivation - Flowing solids experimental Reactors - Finding the Mechanism of Decay from experiment Design.

**Unit V**: ( Scope : J. M. Smith : Chapter 10) : External transport Processes in Heterogeneous Reactions: Fixed bed reactors - The effect of physical processes on observed rate of reaction - Mass and Heat transfer coefficients (fluid particle) in packed beds - Quantitative treatment of external transport effects - Stable operating conditions - Effect of external transport Processes on selectivity.

 Fluidised bed reactors - Particle - fluid Mass and Heat transfer Slurry Reactors - Mass transfer coefficients: Gas bubble to liquid (K1) - Mass transfer coefficients: Liquid to particle

(Kc) - The effect of mass - transfer on observed rates Trickle - Bed reactors - mass transfer coefficients: Gas to liquid (K1 ag) - Liquid to particle (kc ac) - Calculation of global rate.

**Text Books:**

1. Smith. J.M., “ Chemical Engineering Kinetics”, McGraw Hill book Company, New Delhi (Third Edition) 1981.
2. Octave Levenspiel, “ Chemical Reaction Engineering” , Wiley Eastern Limited - Second Edition - 1972.

**Reference Books** :

1. Thomas, J.M. And Thomas, W.J. “ Introduction to the Principles of Heterogeneous Catalysis”. Academic Press Inc., New York 1967.
2. Carbnerry, James, J., “ Chemical and Catalytjic Reaction - Engineering”, McGraw - Hill, Engineering Series.

**II SEMESTER**

**CHEM –1.2.1: COMPUTER–AIDED DESIGN**

**(Common for Chemical Engineering, CACE & IPCE )**

**The objectives of this course are to provide the student with:**

* a basic understanding of the fundamentals of executive program, executive program aided simulation, unit computations, information flow diagram, encoding of information flow diagram, simulation of a simple plant, applications of simulation
* knowledge to write algorithm and programs for various fluid flow problems, pressure drop in two phase flow, pipeline network calculations
* knowledge to write algorithm and programs for rating and design calculations heat exchanger, condenser, reboiler, flash calculations, distillation column, gas absorption column, crosscurrent and counter current extraction, analysis of data in a reactor, extent of reaction, ideal reactors, semibatch reactor, packed bed reactor and fluidized bed reactor

**Outcome:**

* Enables students to learn the basics of computer aided design, executive program aided simulation and its applications
* Students will be able to write/develop unit computations (programs) for fluid flow, mass transfer, heat transfer and reaction engineering problems

**Syllabus:**

Unit I

Introduction on simulation and importance of simulation for chemical process industries Introduction to computer aided design- executive program. coding of chemical process flow chart. Information flow diagram, unit computations, developing a description of information flow diagram, information flow diagram to numerical form, planning calculations, finding recycles, planning calculations for recycle set.

Unit II

Mass transfer operations: introduction, distillation- simple binary distillation, Multicomponent flash calculations, multi component stage wise calculations, Gas absorption- absorption and stripping in plate columns, absorption in packed columns, Liquid extraction- single stage contact, cross current extraction, counter current extraction

Unit III

Flow of fluids in pipes: Introduction, flow of Newtonian fluid in a pipe- incompressible fluid flow, sizing of pipes, Pressure drop in compressible fluid flow, flow of non Newtonian fluids- Bingham plastic fluid, Power law fluid, generalized Reynolds number, Sizing of pipes for non Newtonian fluid How, Pipe network calculations, two phase flow systems- gas liquid flow, solid liquid flow, gas solid flow.

Unit IV

Heat transfer: Introduction, shell and tube exchangers without phase change- tube side heat transfer coefficients, shell side heat transfer coefficients, pressure drop in shell and tube heat exchanger, condensers, reboilers

Unit V

Chemical reaction Engineering: Introduction, extent of reaction, chemical reaction equilibrium- independence of reactions, calculation of chemical equilibrium, Analysis of rate data - Integral method, differential method, nonelementary reactions, temperature dependence of rate constant, Ideal reactors- batch reactor, continuous stirred tank reactor, plug flow reactor, semi batch reactor, Temperature effects in homogeneous reactors- ideal batch reactor, CSTR, PFR, Heterogeneous system- analysis of rate data, fixed bed reactor, catalyst deactivation.

**Prescribed book:**

1. Chemical Process calculations by Raghu Raman, Elsevier applied science publishers,

 London-New York

2, Simulation of sulphuric acid plant by Crowe

3. Product and process design principles- synthesis, analysis and evaluation by Warren

 Sieder, J.D. Sieder, Daniel R. Lewin

**CHEM-1.2.2 – ADVANCED ENGINEERING MATHEMATICS & STATISTICS**

**Objective:**

The main objective is to make the students get familiar with the Advanced Numerical Methods and Statistical techniques by learning them. The student should be able to learn how to get the Numerical solutions of Boundary value problems as these arise in several engineering studies, such as in Hydrodynamics, Quantum mechanics, applied elasticity, Heat and Mass transfer etc. The student should be able to study about Probability and Statistics; which provides a mathematical frame work for different assertions and is essential in every decision making process.

**Outcome:**

The Students come out with the good knowledge of Advanced Numerical Methods and Statistical Techniques and they will be able to implement these techniques whenever required in their further studies.

**SYLLABUS:**

1. **Finite Difference Methods of Solving Boundary value problems Associated with partial Differential Equations:** Introduction, Finite difference scheme for Laplace’s equation, Finite difference methods for the parabolic type of partial differential equations, Forward difference method, Crank-Nicholson implicit method, Stability analysis, backward difference equation for parabolic equations, finite difference explicit scheme for the wave equation. An implicit scheme for the linear wave equation, method of characteristics for solving hyperbolic partial differential equations.
2. **Boundary value problems in ordinary differential equations:** Reduction to an intial value problems, Finite difference method, The shooting method, Multiple integration.
3. **Statistics and probability:** Concept of random variable – distribution and density functions conditional distribution and density functions, Functions of one and two random variables, Many random variables, Concept of Stochastic Processes.

**Textbooks:**

1. Computer Programming and Numerical Analysis by N.Datta Published by Universities Press(India) Private Limited, 3-5-819, Hyderabad – 500029 for Section I & II.
2. Probability by Seymour Lipschutz: Schaum’s outline series for Section III.
3. Introductory Methods of Numerical Analysis by S.S.Sastry.

**CHEM- 1.2.3 - ADVANCED MASS TRANSFER**

***Objectives:***

* To develop skills in the process design of mass transfer operations
* To understand problems involving mass transfer using the principles of material and energy balances.

***Outcomes:***

* Ability to design process equipment for various mass transfer operations.
* Ability to use equations of change for multi-component systems.
* Ability to solve problems of mass transfer in laminar and turbulent regimes.
* Ability to solve problems of interphase transport in non-isothermal systems.

**Syllabus:**

**Chapter 1: Flux Definition**

* Mass and molar transport by convection
* Summary of mass and molar fluxes
* Fick’s law

**Chapter 2:** Differential Equations of Mass transfer

* Differential equation for mass transfer
* Boundary conditions

**Chapter 3:** Molecular diffusivities

* Diffusivities in gases
* Diffusivities in liquids

**Chapter 4:** Molecular diffusion

* Steady state molecular diffusion
* Steady-State Equimolal counter diffusion in gases
* Steady state Equimolal unidirectional diffusion in gases
* Molar diffusion in liquids
* Diffusion through a stagnant gas film
* Diffusion with a moving interface
* Diffusion through a Nonisothermal Spherical film
* Diffusion with a Heterogeneous Chemical reaction
* Diffusion with a slow Heterogeneous Chemical reaction
* Diffusion with a homogeneous Chemical reaction
* Unsteady state diffusion in a sphere
* Unsteady state diffusion in a slab
* Unsteady state diffusion in a Cylinder

**Chapter 5: Mass Transfer coefficients**

* Individual Mass transfer coefficients
* Overall Mass Transfer coefficients
* Mechanism of Mass transfer
* The two-film theory
* The penetration theory
* The theory of penetration with Random surface renewal

**Chapter 6:** Mass transfer in Laminar Flow

* Mass transfer in the laminar boundary layer on a flat plate (Integral Solution)
* Mass transfer in laminar Natural convection on a vertical plate
* Mass transfer in a falling liquid film in a laminar flow
* Mass transfer between a gas phase and a falling liquid film ( gas absorption)
* Mass transfer between an inclined plate and a falling liquid film ( Solid dissolution)
* Gas absorption with rapid reaction

**Chapter 7:** Mass Transfer in turbulent flow

* Mass transfer in the turbulent boundary layer on a flat plate
* Mass transfer in turbulent Natural convectionon a vertical plate
* Mass transfer between inclined plate and a falling liquid film in turbulent flow
* Anologies between momentum, heat and mass transfer
* Reynolds analogy
* Prandtl analogy
* Von Karman analogy
* Analogies in terms of j factor

**Text Books:**

1. A H P Skelland, Diffusional Mass transfer, John Wiley and Sons (1974)

**Reference Books:**

1. R B Bird, W E Steward and E N Lightfoot, Transport Phenomena, 2nd Ed., John Wiley and Sons (2002)
2. J R Welty, C E Wicks, R E Wilson and G. Rorrer, Fundamentals of Momentum, Heat and Mass transfer, 4th Ed., John Wiley and Sons (2001)

**CHEM-1.2.4: POLLUTION CONTROL**

**Objectives:**

* Focus on classification of air pollutants, water pollutants and solid waste –causes, effects and control methods, need of environmental Legislation.

**Outcome:**

* Enables the students to adopt the preventive measures for the control of air pollutants, waste water treatment methods, and solid waste management methods in domestic, municipal waste.
* Enables the students to understand the control measures of pollutants emitted from different industries like Paper and pulp, fertilizer, sugar and alcohol, petrochemical and petroleum refinery, pharmaceutical and metal finishing industries.

**Syllabus:**

Kinds of ecology, environment and ecofactors, types of ecosystems, sulphur cycles, phosphorous cycle, Nitrogen cycle and hydrological cycle

Sources for water, Air and solid pollution, Analysis and effects of the pollutants in air, in water, Solids(particulate matter, SOx, NOx, Cox, CHx).

Limits of pollutants, Environmental Legislation.

Control aspects of various pollutants Air (Particulate matter, SOx, NOx, COx, CHx, Noise) water (primary, secondary and territory treatment techniques) Solids (recycling, incineration,bio-conversion).

Case studies of Industries: Paper and pulp, petrochemical, Fertilizer, Pharmaceuticals, tannery, sugar and alcohol industries, metal finishing industries.

**Text books:-**

1. S.P.Mahajan., Pollution control in process Industries, Tata McGraw hill publishing company.
2. Arcadio P. Sincero and Georgia Sincero., Environmental Engineering
3. Environmental Pollution Control., by C.S.Rao, wiely eastern ltd.

**CHEM-1.2.5 - Elective-III**

**CHEM-1.2.5 A – ELECTIVE-III (Petroleum Refinery Engg-II)**

**Objective:**

To know about various production processes for the manufacture of C1 to Aromatic Compounds.

To know the design aspects to be taken into consideration for the designing of various equipments used in the process.

**Outcome**:

1. Able to understand the processes and mechanisms of various production processes of C1 to Aromatic compounds.

2. Able to understand the design aspects of various equipment used in the production processes.

**Syllabus**:

Raw materials for petrochemicals - Refinery process and petrochemical feed stocks - pyrolysis for petrochemical feed stocks - separation of individual hydrocarbons by fractionation.

Petrochemicals from C1, C2 , C3 & C4  fractions. Petrochemicals from aromatic feed stocks.

*Design of petrochemical equipment:* Pyrolysis furnace, Pyrolysis reactor (Ethane Cracking or propene cracking).

Super fractionator ( Ethyane - Ethylene, Propene - Propylene, Ethyle Benzene - styrene)

Fixed bed reactor ( Ethyle Benzene - Styrene)

Multiphase reactor ( Oxo synthesis).

***Text Books :***

1. Ethylene & its derivations - S.A. Miller
2. Propylene and its derivations - E.G. Hancock.
3. Benzene, Toluene, Xylene and their Derivations. E.G. Hancock.

**CHEM-1.2.5 B – ELECTIVE-III (Process dynamics and control-II)**

 **Objectives** :

  The main purpose of teaching Process Dynamics and Control as elective-II for M. tech second year postgraduate students is to make them to understand the unity in outlook that has been lacking in the field of chemical reactor design. The stability viewpoint does in a sense in diverse areas like stirred tank reactor, plug flow reactor. The course in common emerge as qualitative description of the behavior of the respective models, for the stability viewpoint deals with certain structural aspects present in both problems.

**Outcome:**

* The student should be able to know a brief introduction about the most common chemical reactor models. The subject of steady state multiplicity in stirred tank reactors and develops uniqueness criteria for various cases that may be of interest for design.
* The student should be able to know the interpretation of terms such as steady and stable. The student should have knowledge to explore the implications of the stability concept in dealing with finite disturbances of practical magnitude.
* The student should be in a position to analyze from ordinary differential equation models to partial differential equation models.
* The student should be in a position to understand the steady state multiplicity, local stability, and regional stability are treated for distributed systems.

**Syllabus:**

**Unit I :** Mathematical modeling of reactors - Mass and energy balance equations for CSTR,PFTR, TRAM, TRRM, catalyst particle - multiphase models.

Lumped parameter model - steady state multiplicity of a CSTR- Van Herden diagram - criteria for uniqueness of steady state for isothermal and temperature dependent reactors and multiphase systems - design consideration.

**Unit II :** Geometry of dynamics for a lumped parameter model - stable and unstable steady states - phase plane for the CSTR and eigen values - linear second order system and eigen vector - Liapunov stability criterion and Liapunov functions - fundamental linearization theorem - local stability and steady state operating curves for a temperature - dependent reactor.

**Unit III :** Region of asymptotic stability and v-function in x-space - Krasovskil’s theorem and V-function in f-space.

##### Unit IV : Steady states in distributed parameter systems - uncoupling the energy and mass balances for TRAM model - Steady state models of a PFTR and parametric sensitivity - Steady state multiplicity of a TRAM and catalyst particle model - uniqueness criteria for fixed bed reactors.

**Unit V** : Local stability of distributed parameter systems - the techniques of linearization of nonlinear differential equations and uncoupling of certain transient conservation equations - applications of these techniques to the cases of catalyst particle and TRAM.

 Methods of solution of transient mass and energy balance quations applied to catalyst particle model and TRAM - Galerkin method - Collocation method.

**Text Book:**

 Stability of Chemical Reactors by Daniel D. Perlmutter, John Weily and Sons Inc. (New York, (1976).

**CHEM-1.2.5 C- ELECTIVE-III (Electro Chemical Engineering-II)**

**The main objectives are to provide:**

1. Knowledge on Electroplating, Electroforming, electro refining, electro wining.
2. Knowledge on Electrolysis and Manufacturing process.
3. Knowledge on primary & secondary batteries and fuel

**Outcome:**

1. Acquires knowledge on electrochemical ore beneficiation techniques, electroplating, electro refining and electro winning.
2. Able to work in commercial and industrial manufacturing units using electrolysis.
3. Familiarize with batteries and components like separators, binder, electrolyte, and additives used in batteries.
4. Familiarize with the characterization methods of batteries, e.g. charge/discharge cycles, overpotential, battery capacity, state of charge, state of health, impedance.
5. Familiarize with the Fuel cells.

**Syllabus:**

**Part –A**

Electroplating, Electroforming and Electrophoresis

Electrorefining of metals - Copper, Silver, Gold, Nickel, Lead and Cobalt.

Electrowinning of metals - Copper, Zinc, Cadmium, Chromium and Manganese.

Electrolysis of Alkali Halides and Sulfates - Chlorine and Caustic, Potassium halides, Hydrochloric acid, Fluorine and sodium sulfate.

Manufacture of Hydrogen and Oxygen. Electrolytic Reduction and Oxidation - Persalts, Cuprous oxide, Mercuric oxide, Manganese dioxide and Perchlorates.

Electrolysis of fused Salts - Aluminum, Magnesium, Sodium, Beryllium and Zirconium.

**Part –B**

Batteries: Classification of cells and batteries, theoretical cell voltage, capacity, energy, electrochemical principles and reactions

Primary batteries: Zinc carbon batteries(Leclanche and Zinc chloride cell system), Magnesium and Aluminum batteries, Alkaline manganese dioxide batteries, Lithium batteries.

Secondary batteries: Lead acid batteries, nickel cadmium batteries, nickel metal hydride batteries, lithium ion batteries, rechargeable zinc, alkaline, manganese dioxide batteries

Fuel cells: Molten carbonate fuel cell(MCFC), phosphoric acid fuel cell(PAFC), Solid oxide fuel cell (SOFC), proton exchange membrane fuel cell(PEMFC).

**Textbooks:**

1. Electrochemical Engineering by Mantell, C.L. McGraw–Hill
2. Electrochemistry Principles and Applications Edmund Potter, Cleaver–Hume Press Ltd.
3. Handbook of batteries by David linden and Thomas B Reddy, McGraw –Hill

**CHEM-1.2.6- ELECTIVE-IV**

**CHEM-1.2.6 A-ELECTIVE-IV (Corrosion Engineering-II)**

**Objectives:**

* To enable the principles of corrosion, common corrosion forms, uniform, galvanic, pitting, inter granular, crevice, dezincification, stress corrosion, corrosion fatigue, hydrogen embrittlement corrosion control methods, and material selection to reduce corrosion cost.
* To enable the ability to understand electrochemical fundamentals
* To enable the ability to understand corrosion preventing methods

**Outcome:**

* The student would know application of weight loss method
* The student would know application of cathodic protection, anodic ptotection
* At the end of this course, the student would know effective surface preparation of specimen can be done
* After completion of this course, the student would understand the causes and the mechanisms of various types of corrosion, including uniform corrosion, galvanic corrosion, crevice corrosion, pitting corrosion, intergranular corrosion.
* The student would know application of Corrosion Processes and Evans Diagrams and application of electroplating, coatings and importance of inhibitors.

**Syllabus:**

Corrosion in selective environments: Marine, Acids (Sulfuric acid, Hydrochloric acid, Nitirc acid, Phosphoric acid) Biological and industrial gases (SO2H2S).

 Corrosion Testing - Purposes, Materials and specimen. Surface preparation, Measuring and weighing , Exposure Techniques - duration, Planned - Interval Tests, Aeration, cleaning specimens after exposure, Temperature, Standard expression for corrosion rates - Galvanic Corrosion, Erosion Corrosion, crevice Corrosion, Intergranular corrosion, test for stainless steels, warren test pitting, stress corrosion, Paint tests, Sea Water tests, Presenting and summarizing data - Nomo graph for corrosion rates and interpretation of results.

 Cathodic and anodic protection, surface preparation for coatings and chemical conversions: Degreasing, Descaling , Polishing - Anodized coating : anodizing oxidizing, chromate coating, phosphate coatings - Metallic coatings : Hot dipping, cementation, vapor deposition of metallic coating; Sprayed coatings: flame spraying plasma spraying, Galvanizing - Electroplating : Nickel & chromium coatings, chromizing.- Organic coatings : paints, enamels, lacquers, resin mixtures.

Linings, laminates, reinforced plastic, fibre glass - Corrosion inhibitors: mechanism of inhibition, recirculating of water of water systems

Measurement and testing of preventive coatings ; Thickness and Resistance tests for anodized, Painted, electroplated surfaces using polarization resistance, Linear polarization, curve fit analysis and Electrochemical impedance spectroscopy.

**Reference books :**

1. Mars GFontana - Corrosion Engineering

2. Burns, R.M., Bradley, W.W., ‘protective coatings for Metals.’ Chapters 2 to 18.

**Reference Books :**

Corrrosion Volumes 1 & 2 by L.L. Shrier, Newnes - Butter-worths, London.

**CHEM- 1.2.6 B - Elective-IV (Energy Engineering-II)**

**Objectives:**

The student is provided with the fundamentals of some renewable energy processes. Basic information to comprehend the various non-conventional energy systems would be gained by the student.

**Outcome:**

1. Methods to be adopted to utilize biomass as an important energy source.
2. Application of thermodynamics to convert ocean energy.
3. Possible mechanism to drawn energy from wind and other natural sources
4. Fuel cells as sources of energy.
5. New technologies to produce energy such as thermionics, thermoelectricity etc.

**Syllabus:**

**Non – Conventional & New Energy Systems and Energy Conservation Technology**

**Systems based on bio mass**

Physical and Bio mass – Definition – potential thermo – chemical methods of Bio - Conversion – Gasification – Liquefaction – Pyrolysis.

Bio-gas technology – Historical review and development in India Different designs of bio-gas jplants – Selection of a model and size – Installation – Gas collection and distribution – operation and maintenance – Properties and uses of bio-gas – Utilization of manure – National Projects for Bio – gas development – safety.(Bansal et at,chapters 10 and 11; Khandelwal and Mahdi, Chapters 3,4,5,6,7,8,9,10: Chawla,chapters 2,3,4,5,6,7 & 8).

**Fuel Cells**

Hydrogen – Oxygen Fuel Cells – carbonaceous Fuel Cells – Molten Alkali Carbonate Cells – Electrode Reactions and kinetics. (Fuel Cells by Young).

**Energy Wind, Tidal and OTEC**

Potential in India – Origin of wind and general circulation systems of Earth – Wind direction – Wind measurement – Wind energy converters – Historical development – Power coefficient – Aerodynamic construction of a rotor blade Rotors – Wind electric generators in India – Economics of wind farm – Fundamentals and concepts of Wave energy – Ocean thermal – energy conversion (OTEC). (Bansal et at., Chapters 12,13 & 14).

**Hydrogen Energy, Methanol & Ethanol**

Hydrogen from fossil fuels from Electrolysis – Developments of various electrolytic cells – High pressure cells – Solid electrolytic systems – Hydrogen powered IC engines – Storage system – Handling and Transmission.(Journals on Hydrogen energy).

Methanol and Ethanol as Automobile fuels – Comparison with Gasoline and Diesel oil. (Journals on Hydrocarbon on processing).

**Energy Conservation Technologies:**

Principles of Energy Conservation – Optimum Energy Conservation – Industrial Energy Conservation modeling – waste heat recovery and utilization.

**Prescribed Books:**

1. Renewable Energy Sources and Conversion Technology, N.K.Bansal, Manfred Klieemann,Michael Meliss, tataMcGraw Hill, 1990.
2. Bio Gas Technology, A practical hand book Vol 1, K.C.Khandelwal and S.S.Maholi, TataMcGraw Hill, 1986.
3. Advances in Bio Gas Technology: O.P.Chawla,publications and Information Division, Indian council of Agricultural Research,New Delhi, 1986.
4. Alternative Energy Sources: R.H .Taylor, Adam Hilger Ltd.,Brister.
5. Fuel cells, Vols.I & II: Reinhold publishing Crop.,New York.
6. International journal of hydrogen Energy, Vol.5, No. I, 1980 pages 1- 84: No.2, pages 119-129; pages 151-203; No.5. Pages 527 – 534 & 539 – 553; No.6, Pages 611 – 625.
7. Hydro Carbon Processing Vol. 58, May 1979 pages 127 – 138:Vol. 59, Feb. 1980, pages 72–75.
8. Handbook of Industrial Energy Conservation, David Hu, S., Van Nostrand Reinhold Company pages 73 – 133, 149-199, 297-327.

**CHEM- 1.2.6 C - Elective-IV (Reaction Engineering-II)**

**Syllabus:**

## UNIT - I

Laboratory Reactors - Interpretation of Experimental Data - Interpretation of Laboratory Kinetics Data - Homogeneous and Heterogeneous Laboratory Reactors. Calculation of Global Rate - The structure of Reactor Design.

*(Scope: Chapter 12 of J.M Smith 3rd Edition)*

## UNIT - II

 Design of Heterogeneous Catalytic Reactors Isothermal and Adiabatic Fixed Bed Reactors Non-isothermal, Non-adiabatic Fixed Bed Reactors.

*(Scope: Chapters 13.1 - 13.9 of J.M Smith 3rd Edition)*

## UNIT - III

Design of fluidized bed Reactors - Two -Phase Fluidized Bed model - Operating characteristics - Slurry Reactors - Trickle - Bed Reactors - Optimization.

*(Scope: Chapter 13.10 - 13.13 of J.M Smith 3rd Edition.)*

## UNIT - IV

 Fluid - Solid Noncatalytic Reactions - Design concepts - Single Particle Behavior - Reactor Models.

*(Scope: Chapter 14 of J.M Smith 3rd Edition)*

## UNIT - V

 Short notes from the portions of all the above four units. Four bits are to be answered out of 7 bits (Not more than 2 bits to be given from any one Unit).

**Text Book:** Chemical Engineering Kinetics by J.M Smith, McGraw - Hill Book

 Company , 1980, 3rd Edition.