**M.TECH.**

**(COMPUTER AIDED CHEMICAL ENGINEERING)**

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

**Scheme and Syllabi**

****

**DEPARTMENT OF CHEMICAL ENGINEERING**

**AU COLLEGE OF ENGINEERING (A)**

**ANDHRA UNIVERSITY**

**VISAKHAPATNAM**

**DEPT OF CHEMICAL :: A.U.COLLEGE OF ENGINEERING(A)**

 **SCHEME OF INSTRUCTION & EXAMINATION**

**1/2 M.TECH(CACE) 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** |
| CACE 1.1.1 | Modellling & Simulation | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE1.1.2 | Process Dynamics & Control | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE 1.1.3 | Chemical Reaction Engg | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE 1.1.4 | Transport Phenomena | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE 1.1.5 | Elective-I | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CACE1.1.6 | Elective-II | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CACE 1.1.7 | Computational lab | 2 | -- | -- | 3 | 3 | 50 | 50\* | 100 |
| CACE 1.1.8 | Seminar | 2 | -- | -- | 3 | 3 | 100 | -- | 100 |
|  | TOTAL | 28 | 20 | 4 | 6 | 30 | 330 | 470 | 800 |

\*Only internal evaluation.

Elective-I: 1.Computational Fluid Flow &Heat Transfer

 2.Distillation Design & Control

 3.Process Flow sheeting

Elective-II: 1. Corrosion Engineering-I

 2. Energy Engineering-I

 3. Reaction Engineering-I

**DEPT OF CHEMICAL ENGG :: A.U.COLLEGE OF ENGINEERING(A)**

 **SCHEME OF INSTRUCTION & EXAMINATION**

**1/2 M.TECH(CACE) 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** |
| CACE 1.2.1 | Computer Aided Design | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE1.2.2 | Computational Methods  | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE 1.2.3 | Separation Processes | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE 1.2.4 | Optimization | 4 | 3 | 1 | -- | 4 | 30 | 70 | 100 |
| CACE 1.2.5 | Elective-III | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CACE1.2.6 | Elective-IV | 4 | 4 | -- | -- | 4 | 30 | 70 | 100 |
| CACE 1.2.7 | Computational lab | 2 | -- | -- | 3 | 3 | 50 | 50\* | 100 |
| CACE 1.2.8 | Seminar | 2 | -- | -- | 3 | 3 | 100 | -- | 100 |
|  | TOTAL | 28 | 20 | 4 | 6 | 30 | 330 | 470 | 800 |

Elective-III: 1.Nanotechnology

 2.Bioinformatics

 3.Neural Networks

Elective-IV: 1. Corrosion Engineering-II

 2. Energy Engineering-II

 3. Reaction Engineering-II

**DEPT OF CHEMICAL ENGG :: A.U.COLLEGE OF ENGINEERING(A)**

 **SCHEME OF INSTRUCTION & EXAMINATION**

**2/2 M.TECH (CACE) 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**

**CACE-1.1.1: PROCESS MODELING AND SIMULATION**

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

**Objective:**

 Process Modeling and Simulation is a important subject of study for Post Graduate Chemical Engineers . It deals with writing various process models based on basic physical process. It also deals with solving the various models by means of various numerical methods by computer simulation. By studying this course ,one can simulate various chemical process 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. Develop a model equation for Tanks, Isothermal and Non-Isothermal Systems
3. Understand the models for Binary Distillation Column, Batch Reactors etc.
4. Solve the model equations by Numerical methods like Euler and Runge –Kutta etc.

**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.

**CACE-1.1.2: PROCESS DYNAMICS & CONTROL**

**(Common for MPE, CHEMICAL & 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.

**CACE-1.1.3: CHEMICAL REACTION ENGINEERING**

**(Common for MPE, CHEMICAL & 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.

**CACE-1.1.4: TRANSPORT PHENOMENA**

**(Common for MPE, CHEMICAL & 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.

**CACE- 1.1.5 A - Elective-I (Computational Fluid flow and Heat transfer)**

**Objective:**

The main purpose of teaching ”COMPUTATIONAL FLUID FLOW AND HEAT TRANFER” for the first year M.TECH students is to introduce the basics of FLUID FLOW, HEAT TRANSFER and TRANSPORT PHENOMENA combined subjects for CACE specialization students to gain fair knowledge of overall fluid flows, fluid dynamics and the importance of heat transfer .

**Out come:**

Student gains fair knowledge which every CACE specialization student should know to derive the derivations and problems which are related to fluid flow, transport phenomena and heat transfer as well as chemical engineering problems. Student will learn the importance solving the problems. Student is able to gain the complete knowledge on the subject. This knowledge is very helpful for the students how the heat transfer is taking place in a different materials for industrial applications and designing new Chemical Industries .

**Syllabus:**

1. Types of partial differential equations - parabolic, elliptic and hyperbolic equations - boundary layer equations for laminar and turbulent flows - Crank-Nicolson and ADI methods to solve heat transfer problems.
2. External laminar flow: Flow of an incompressible fluid over an isothermal flat plate by (a) similarity method, and (b) implicit finite difference method.
3. Internal laminar flow: equations and solution for the problem of fully developed flow through a pipe and heat transfer - fully developed flow in a duct or channel and heat transfer - plane duct with a developing temperature field - pipe flow with developing velocity and temperature fields - pipe flow with developing velocity and temperature fields.
4. Introduction to turbulent flow: Governing equations - turbulence models - mixing length model - K- model.
5. External turbulent flow: Flow over a flat plate - solution by analogy between momentum and heat transfer - - numerical solution of the boundary layer equations by finite difference method.
6. Internal turbulent flow: Analogy solution for fully developed pipe flow.
7. Solution of laminar incompressible flow problems by vorticity-stream function formulation - flow in a rectangular cavity - application to cylindrical coordinates - flow over a sphere.
8. MAC and SIMPLE algorithms: Solution of Unsteady state Navier-Stokes equations for incompressible flows - staggered Grid - MAC (Marker and Cell) method - implementation of boundary conditions - solution of energy balance equation - SIMPLE formulation - discretization of one-dimensional convection-diffusion equation - formulation of flow problem - upwind differencing - pressure correction - TDMA and Thomas algorithm.

Text Books:

1. Introduction to convection heat transfer analysis, Patrick H. Oosthuizen and David Naylor, McGraw-Hill Inc., New York (1999). (For topics 1 to 6)
2. Computational fluid flow and heat transfer, Second Edition, K. Muralidharan and T.Sundararajan (Editors), Narosa Publishing House, New Delhi (2003). (For topics 1, 7 and 8)

Reference Books:

1. An Introduction to computational fluid dynamics: The finite volume method, H.K. Versteeg, W. Malalasekra, Prentice Hall (1995).
2. Computational fluid dynamics – the basics with applications, John D. Anderson, Jr., McGraw-Hill International Editions, New York (1995)

**CACE-1.1.5B: Elective – I**

**CACE-1.1.5 B: DISTILLATION DESGIN & CONTROL**

**Syllabus:**

*(Design and control of Distillation columns will be emphasized using ASPEN in this subject.)*

1. Review of vapor-liquid equilibrium. Analysis of distillation columns: degrees of freedom, McCabe-Thiele method, approximate multicomponent methods, analysis of ternary systems.
2. Setting up a steady-state simulation: configuring a new simulation, specifying chemical components and physical properties, specifying stream properties and equipment parameters, running the simulation, finding the optimum tray and minimum conditions, column sizing.
3. Distillation economic optimization: heuristic optimization, economic basis, operating optimization.
4. Steady-state calculation for control structure selection: summary of methods, binary Propane/Isobutane system, ternary BTX system, multicomponent hydrocarbon system, ternary azeotropic system.
5. Converting from steady-state to dynamic simulation: equipment sizing, exporting to ASPEN dynamics, installing basic controllers, performance evaluation, comparison with economic optimum design.
6. Reactive Distillation: types reactive distillation systems, TAME process basics, TAME Reaction Kinetics and VLE, plant control structure.
7. Control of Petroleum Fractionators: petroleum fractions, characterization of crude oil, steady-state design of pipestill, control of pipestill.

Text book:

W.L. Luyben, **Distillation Design and Control using Aspen Simulation**, John Wiley,2006.

Reference books:

1. M.F. Doherty and M.F.Malone, Conceptual Design of Distillation Systems, Mcgraw-Hill, 2001.
2. P.B. Deshapande, Distillation Dynamics and Control, Instrumentation Systems Publishers, 1985.
3. H.Z. Kister, Distillation Design, Mcgraw-Hill, 1992.
4. M. Van Winkle, Distillation , Mcgraw-Hill, 1967.

**CACE-1.1.5C: Elective – I**

**CACE-1.1.5 C: PROCESS FLOWSHEETING**

**Syllabus:**

1. Steady state and dynamic flow sheeting and the design process, the total design project, Flow sheeting on the computer: motivation for the development, developing a simulation model, approaches to flow sheeting systems
2. Solving linear and nonlinear algebraic equations: solving one equation in one unknown, solution methods for linear equations, general approaches to solving sets of nonlinear equations, sloving sets of sparse nonlinear equations
3. Physical property service facilities: The data cycle, computerized physical property systems, physical property calculations; Degrees of freedom in a flow sheet: degrees of freedom, independent stream variables, degrees of freedom for a unit, degrees of freedom for a flowsheet
4. The sequential modular approach to flowsheeting: The solution of an example flowsheeting problem, other features, convergence of tear variables. Partitioning and tearing of a flowsheet.
5. Flowsheeting by equation solving methods based on tearing
6. Simulation by linear methods
7. Simulation by quasi linear methods

Text book:

A.W. Westerberg, H.P. Hutchison, R.L. Motard, and P. Winter , **Process Flowsheeting**, Cambridge University press, 1979

Reference books:

1. Leesley, M.E., Computer aided process plant design, Gulf Publishing, Huston, 1982
2. R.Turton, R.C.Bailie, W.B.Whiting and J.A.Shaeiwitz, Analysis, Synthesis and Design of Chemcal Processes, Prentice Hall, 1998.
3. W. D. Seider, J.D. Seader, and D.RLewin, Product and Process Design Principles: Synthesis, Analysis and Evaluation, 2nd edition, 2003, John Wiley & Sons(Asia) Pte. Ltd.

**CACE-1.1.6: Elective –II**

**CACE-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:**

**CHEM-1.1.6: Elective –II**

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

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.

**CACE- 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).

**CACE- 1.1.6 C – Elective-II (Reaction Engineering-I)**

**Syllabus:**

**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 arallel, series or side – by – side Deactivation – Flowing solids experimental Reactors – Finding the Mechanism of Decay from experiment Design.

**UnitV**: ( 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**

**CACE-1.2.1-COMPUTER AIDED DESIGN**

{Common for Chemical and 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

**CACE-1.2.2- COMPUTATIONAL METHODS**

**Objective:**

The main purpose of teaching ”COMPUTATIONAL METHODS” for the first year M.TECH students is to introduce the basics of computational techniques subject for CACE specialization students to gain fair knowledge of overall computational techniques. To learn various computational methods which are available to solve the chemical engineering problems which are related to computer aided chemical engineering applications.

**Out come:**

Student gains fair knowledge which every CACE specialization student should know to solve the problems. Student will learn the importance of solving the problems. Student is able to gain the complete knowledge on the subject. This knowledge is very helpful for the student to solve the different types of problems in Chemical Industry with different computational methods.

**Syllabus:**

**1. Linear and Non-linear Algebric Systems:**

Elimination methods for solving linear systems, matrix inversions, factorization, norm and rank; Solutions of nonlinear algebric equations, iterative methods, methods of Newton, Secant, Bracketing and Bisection, Newton's methods for multiple non-linear equations, Jacobian, Quasi-Newton methods.

**2. Matrix Eigen Value Analysis:**

Orthogonal matrices, eigen values and vectors of real matrix, eigen values and properties of linear systems, estimating eigen values, eigen vector matrix decomposition and basis sets, numerical calculation eigen values and vectors, extremal eigen values, QR method, Single Values Decomposition, eigen problems in quantum mechanics, computing the roots of polynomial.

**3. Initial Value Problems:**

Initial Value Problems of ordinary differential equations, polynomial interpolation, Newton Cotes integration, Gaussian quadrature, multi­ dimensional integrals, dynamic stability, accuracy and stability of single step methods, stiff stability of BDF methods, simplistic methods for classical mechanics, differential-algebraic equation systems, parametric continuation.

**4. Boundary Value Problems (BVPs)**

BVPs from conservation principles, real space versus function space methods, finite difference methods for 2-D BVP, extension of finite difference method, chemical reaction and diffusion in spherical catalysts pillet, conversion/diffusion equation, modeling a tubular reactor with dispersion, numerical issues for discretized PDEs with more than tow spatial dimensions, finite differences in complex geometries, finite volume method, finite element method (FVM).

**Text book:**

K.J.Beers, Numerical Methods for Chemical Engineering, Cambridge University Press, 2006.

**Reference books:**

1. B.A. Finlayson, Introduction to Chemical Engineering Computing, John Wiley, 2006
2. A.Constantinides and N.Mostoufi, Numerical Methods for Chemical Engineers with MATLAB Applications, Prentice Hall, 1999.
3. A.Varma and M.Morbidelli, Mathematical Methods in Chemical Engineering, Oxford University Press 1997
4. M.B.Cutlip and M.Shachasm, Problem Solving in Chemical Engineering with

 Numerical Methods, Prentice Hall, 1999

1. OT.Haanna and IO.C.Sandall, Computational Methods in Chemical Engineering,

 Prentice Hall, 1995

1. J.H.Mathews and K.D.Fink, Numerical Methods using MATLAB, 4th ed.,Prentice-Hall India Private

Limited, 2005

**CACE – 1.2.3- SEPARATION PROCESSES**

**OBJECTIVES:**

* To enable the physical and thermodynamic principles of mass transfer with an emphasis on how these principles affect the design of equipment and result in specific requirements for quality and capacity.
* To enable the students to know the design of a distillation column, design of a absorber and calculations involved in liquid liquid extraction.
* To enable the Model and solve problems related to flash distillation, liquid-liquid extraction, batch distillation, cascades, simple and complex binary distillation systems and absorption in packed towers
* To enable the Types and characteristics of membranes. Separation of gases. Separation of liquids. Osmosis. Reverse osmosis. Dialysis, Electro-dialysis. Pervaporation. Ultra filtration. Industrial applications

**OUTCOMES:**

* The student would know Design of design absorber and stripper, distillation column and extraction and the student would build and develop quantitative models of how these separation processes work and how to apply these in new applications
* The student would understand equilibrium and rate governed multistage separation processes and also characterization of membranes and separation processes such as reverse osmosis, dialysis, ultra filtration and electro dialysis.

**Syllabus:**

**Unit: -I**

**Introduction: Classification of reparation processes; Equilibrium** – Based reparations General properties operation and complexities of reparations that involve mass rap rating agents and energy repeating agents. Review of vapor liquid and energy separating agents. Review of vapor liquid equilibrium and other equilibrium. Thermodynamic consistency test for VLE date phase rule and degrees of freedom estimations. Eqmilirinor ratio concept and its estimation from Defroster’s charts; Bubble and Dew-Point calculations, Flash calculation estimation of state of the mixture

**Unit-II**

Binary separation process: Common approach for process design estimation of feed location, product qualities and theoretical stages of equilibrium based reparations: single stage-single component and Multistage single component reparation processes involving absorption stripping liquid -liquid immiscible extraction adsorption and distillation Kermes-brown equation and its limitation process designee (estimation of feed location, product qualities and theoretical stages) of multistage multiple feeds and side stream process.

**Unit III**

Multi component separation process: Multi component Distillation Introduction. Key components; Estimation of minimum theoretical stages (Fizzles equation0 Distribution as non-key components in airhead and bottom products at total refuse; Determination of minimum refuse ratio (under wood’s method), Approximate calculation for multi component, multistage distillation estimation of actual refuse ratio and theoretical stages) kirks-Bridge equation) distribution of no-key components at actual refuse.

**Unit-IV**

Capacity and efficiency of contacting devices energy requirements of reparation process case studies in the reelection of separation process

**Unit –V**

Membrane separation process principled, characteristics and clarification of membrane reparation process, membrane materials, structure preparation of techniques, membrane modules, Membrane characterization pose size, pore distribution. Factors affecting retentively, Concentration polarization, gel polarization, fouling, eleaqing and refrigeration of membranes. Mechanisms of separation processes membrane, deme membranes and liquid membranes science and Technology of micro filtration reverse osmosis ultra filtration, Nan filtration dialysis and electro dialysis perspiration, liquid membrane permeation, gas permeation membrane reactor: polymeric, ceramic metal and Bio membranes

# **Textbook: Separation Process Principles, 2nd Edition**

[J. D. Seader](http://as.wiley.com/WileyCDA/Section/id-302477.html?query=J.+D.+Seader), [Ernest J. Henley](http://as.wiley.com/WileyCDA/Section/id-302477.html?query=Ernest+J.+Henley), John Willey & Sons,2nd Edition 2006.

**TEXT / REFERENCE BOOKS:**

1. R.E. Treybal, Mass Transfer operation, 3rd edition MC Graw – Hill 1980
2. G.J. Geankoplis, Transport Process and separation process Principles, 4th equation, pretice Hall of India, 2007
3. P.H. Mankat, Equilibrum Stays Separation, Elsewies publication, 1988.

**CACE – 1.2.4: OPTIMIZATION**

**OBJECTIVE:**

Optimization of Chemical Process is an important of subject for Post Graduate Chemical Engineers. It deals with various optimization techniques in reducing cost of production ,energy consumption, maximum throughput and minimum labour cost etc. On studying the course one can understand how to write a model of the process optimize the process using the model

**OUTCOME:**

 After successfully completing the course the student be able to

 1.Understand the definition of Optimization and how to write an Objective function

 2. Understand various types of Objective functions like Concave and Convex functions and its properties

 3. Study the Optimization of uni and multi dimensional search problems

 4. Solve the Optimization problems by Linear and Non-Linear Programming methods

***Syllabus:***

1. **Basic Concepts of Optimization:** Introduction to Process Optimization; Continuity of Functions; Unimodal versus Multimodal Functions; Convex and Concave Functions; Convex Region; Necessary and Sufficient Conditions for an Extremum of Unconstrained Function; Interpretation of the Objective Function in Terms its Quadratic Approximation.
2. **Optimization of unconstrained Functions - One-dimensional Search:** Numerical Methods for Optimizing a Function of One Variable; Scanning and Bracketing Procedures; Newton, Quasi-Newton and Secant Methods of Unidimensional Search – Newton’s Method, Quasi-Newton Method, Secant Method.
3. **Region Elimination Methods** - Polynomial Approximation Methods - Quadratic Interpolation, Cubic Interpolation; How the One-Dimensional Search is Applied in a Multidimensional Problem; Evaluation of Unidimensional Search Methods.
4. **Unconstrained Multivariable Optimization:** Direct Methods - Random Search, Grid Search, Univariate Search, Simplex Method, Conjugate Search Directions, Powell’s Method; Indirect Methods First Order - Gradient Method and Conjugate Gradient Method. Indirect Method Second Order – Newton’s method
5. **Linear Programming and its Applications:** Basic Concepts in Linear Programming; Degenerate LP’s – Graphical Solution; Natural Occurrence of Linear Constraints; The Simplex Method of Solving Linear Programming Problems
6. **Nonlinear Programming with Constraints:** Lagrange multiplier method, necessary and sufficient conditions for a local minimum, generalized reduced-gradient method, random search methods, and comparative evaluation of different methods.
7. **Global Optimization:** Overview of Genetic Algorithm, Simulated Annealing and other global optimization methods, Heuristic Search methods.

(*Problems dealing with the applications of optimization techniques for various chemical engineering operations using optimization software packages will be given as assignments to the students and will be evaluated by internal assessment)*

***Texts Book:***

T.F.Edgar, D.M.Himmelblau and L.S.Lasdon, **Optimization of Chemical Processes, 2nd Edition,** McGraw-Hill , 2001.

***Reference Books:***

1. P.Venkataraman, Applied Optimization with MATLAB, John Wiley, 2002
2. Ravindran , A., Ragsdell, K.M., and Reklaitis, G.V., Engineering Optimization - Methods and Applications, Wiley, 2nd ed., 2006.
3. WH.Ray and J.Szekely, Process Optimization with Applications in Metallurgy and Chemical Engineering, John Wiley, 1973.
4. K. Deb, Optimization for Engineering Design, Prentice Hall of India Private Limited, New Delhi, 2003
5. S.S.Rao, Engineering Optimization, 3rd Edition, Wiley**, 1996.**

**CACE-1.2.5 A. ELECTIVE –III( Nanotechnology)**

**Objectives:**

 Nanotechnology may be treated as **Green technology**. It is one of the most advanced technologies now-a-days. It leads to have revolutionary changes in the fields of medical, Bio-medical, and fabrication of materials. Technologists are able to prepare ageless materials with the help of nano-techniques. Main objectives of the subject nanotechnology are :

1. To define green technology properly
2. To expose the students with new techniques of the nanotechnology.
3. To make them to learn the importance of quantum technology
4. To learn the procedure ageless materials to avoid wear-tear.
5. To learn the importance of nano –robots, machines
6. To know about the latest microscopes such as SEM, TEM
7. To know the importance of nanotechnology in the dawn of optical instruments

**Outcome:**

1. Application of nanotechnology in the development of energy
2. Application of nanotechnology in the development of solar panels, Fuel cells
3. Knew the importance of atoms manipulation
4. Knew that the applications of nanoparticles in the development of DVD, LEDs etc.
5. Biomedical applications in terms of preparing artificial, drug delivery, encapsulation, addition to that pharmaceuticals.

**Syllabus:**

1. Introduction tonanotechnology, molecular and atomic size, surface and dimensional spaces.

Molecular nanotechnology: atoms by inference, electron microscopes, nanomanipulator, nanotweezers, atom manipulation, nanodots, nanolithography.

1. Nanopowders and nanomaterials: preparation, plasma arcing, chemical vapor deposition, sol-gels, electrodeposition, Ball milling, applications.

Carbon nanotubes: types, formation, assemblies, purification, properties and uses.

1. Molecular mimics: Catenanes and rotaxanes, various molecular switches, synthesis of rotaxanes and catenanes, molecular computers, chemical rotors, prodders, flippers, atom shuttles, actuators, contacts.
2. Nanobiometrics: Lipids as nano-bricks and mortar, self – assembled monolayers,

 proteins, 3-D structures arising from amines acids, nanoscale motors, Biological

 Computing, ion channels as sensors, Information in DNA structure, using DNA to

 build nano-cubes, hinges, smart glue, wire template.

1. Optics, photomics and solar energy: Properties of light and nanotechnology, Interaction

of light and nanotechnology, Nanoholes and photons, Imaging, New low cost energy efficient windows and solar absorbers based on nanoparticles, Photonic crystals, surface wave guides and control of light paths.

1. Nanoelectrons: birth of electrons, semiconductors, transistor, integrated circuits, the tools of micro and nanofabrication, quantum electronic devices, quantum information and quantum computers, experimental implementations of quantum computers.
2. Future applications: microelectomechanical systems, nano-robots , ageless materials, invisible mending of atomic dislocations inside damaged materials, nanomechanics and nanoelasticity, nanoparticle coatings, nanoelectronic and magnetic devices and new computing systems, optoelectronic devices, environmental applications.
3. Molecular Dynamics, Simulation and Optimization of Nanosystems: Integration of Newton equation of motion, simulation of systems in contact with a heat bath, simulation methods based on accuracy and computational time, use of local and global optimization methods. (Scope: Chapters 5&6, Ali Mansoori\*: Principles of Nanotechnology)

 (*This last section is not open for external assessment, but students are assessed*

 *internally by means of assignments and home work problems).*

Text-book:

1. M.Wilson, K.Kannangara, G. Smith, M. Simmons and B. Ragues, **Nanotechnology**, Overseas press ( India) Private Ltd; New Delhi, 2005.

Reference books:

1. G. Ali Mansoori\*, **Principles of Nanotechnology**, World Scientific Publishing Company, 2005.
2. G. Timp, Nanotechnology, Springer-Verlag, Network, 1999.
3. P. Poole and F.J. Owens, Introduction to Nanotechnology, John Wiley, 2003.
4. D.Ratner and M.Ratner, Nanotechnology: A Gentle Introduction, Pearson Education,2003.
5. B. Bhusan, Handbook of Nanotechnology, Springer, 2004

**CACE-1.2.5 B-ELECIVE-III( BIOINFORMATICS)**

**Syllabus:**

1. Introduction, Molecular Biology and Bioinformatics, Biological database: Primary, Secondary and Structural data bases, tools for web search, data retrieval tools.
2. Genome analysis and gene mapping: sequence assembly problem, genetic mapping and linkage analysis, genome sequencing, sequence assembly tools, Human genome project.
3. Alignment of pairs of sequences, scoring matrices, multiple sequences, phylogenetic analysis, Tree evaluation, automated tools for phylogenetic analysis, working with FASTA and BLAST.
4. Gene identification and prediction: Basis for gene prediction, pattern recognition, gene prediction methods, working with DNA, Micro arrays, Micro array analysis.
5. Protein classification and structure visualization: structure – based protein classification, protein structure databases, visualization databases and tools, protein structure alignment, tools for plotting protein-ligand interaction.
6. Protein structure prediction: Analysis and prediction of primary structure and secondary structure, motifs, profiles, patterns and fingerprints search, Ab Initio approach, 2-D structure prediction, protein function prediction from DNA sequence.
7. Proteomics: Tools and techniques in proteomics, protein – protein interactions, gene family identification methods.

 Computational Methods for pathways and systems Biology: Analysis of pathways,

 metabolic network properties, metabolic control analysis, simulation of cellar

 activities.

Text-book:

S.C..Rastogi, N.Mendiratta and P.Rastogic, **Bioinformatics**, Prentice- Hall of India Pvt.Ltd, New Delhi, 2004

Reference books:

1. T.K.Attwood and D.J. Parry-Smith, Introduction to Bioinformatics, Pearson Education Asia, Delhi, 2002
2. A.M. Lesk, Introduction to Bioinformatics, Oxford University press, New Delhi, 2004.

**CACE 1.2.5 C-ELECTIVE – III (Neural Networks)**

**Syllabus:**

 *Theory*

1. Introduction to the theory of Artificial Neural networks, unsupervised learning.
2. Back propagation and its variations; General approximation for feed-forward neural networks
3. Radial basis neural networks and generalized regression neural networks

 *Applications*

1. Application of neural networks in process dynamics, process modeling of fault detection using neural networks.
2. Modeling chemical process using multi resolution representation neural networks
3. Neural networks based control strategies for a continuous polymerization reactor
4. Statistical and neural methods in classification and modeling.

Text-book

A.B.Bulsari, **Neural Networks for Chemical Engineers**, Elsevier, 1995.

Reference books

1. I.M. Mujtaba and M.A. Hussain, Application of Neural Networks and other learning technologies in Process Engineering, World Scientific Publishing Company, 2006
2. D.R. Baughman, Y.A. Liu, Neural Networks in Bioprocessing and Chemical Engineering, Academic Press, 1995.
3. S.N. Sivanandam, S.Sumathi and S.N. Deepa, Introduction to Neural Networks using MATLAB-6, Tata McGraw-Hill , New Delhi, 2006

**CACE-1.2.6-ELECTIVE-IV**

**CACE-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.

**CACE- 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.

**CACE- 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.