PROGRAM EDUCATIONAL OBJECTIVES (PEOs):
The students of M.Tech Chemical Engineering will
1. Be employed as chemical engineers in industry, government, and private sectors and will be working toward the development of sustainable technologies for various industries.
2. Pursue higher studies, become a consultant and may start up own business.
3. Exhibit professional, ethical codes of conduct, perform service to the society and to the engineering profession through membership and participation in professional societies.
4. To enrich students with experience in learning and applying tools (e.g., computer skills) to solve theoretical and open-ended chemical engineering problems.
5. Provide students with opportunities to design systems, components, and chemical processes to meet specific needs and constraints through experiential learning.

PROGRAMME OUTCOMES (POs):
On successful completion of the programme
1. Each graduate will have the ability to work as a member of multidisciplinary teams, and have an understanding of team leadership.
2. Each graduate will have the ability to identify, formulate and solve chemical engineering problems using modern engineering tools necessary for engineering practice.
3. Student will be able to successfully apply advanced concepts of chemical engineering to the analysis, design and development of chemical reactors.
4. Students will be able to analyze and interpret data of experiments.
5. Will develop an ability to apply a multi-disciplinary approach to conceive, plan, design, and implement solutions to chemical engineering problems in the field of energy and sustainability.
6. Will have the ability to express ideas and positions clearly and concisely, both orally and in writing
7. Will know the importance of safety and environmental aspects in the design and operation of process engineering systems.
8. Will have the ability to accomplish basic design and optimization of process components and systems.
9. Will have a complete working knowledge on advanced material and energy balances applied to chemical processes.

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|        |      | Fluid Phase Equilibria | | | | | | | | | ✔️
|        |      | Professional Elective I | | | | | | | | | |
|        |      | Professional Elective II | | | | | | | | | |
|        |      | Computational Programme in Chemical Engineering Laboratory | | | | | | | | | ✔️
| YEAR II | SEM II | Chemical Process Design | | | | | | | | | ✔️
|        |      | Advanced Process Control | | | | | | | | | ✔️
|        |      | Advanced Separation Processes | | | | | | | | | ✔️
|        |      | Multicomponent Distillation | | | | | | | | | ✔️
|        |      | Professional Elective III | | | | | | | | | |
|        |      | Professional Elective IV | | | | | | | | | |
|        |      | Seminar | | | | | | | | | ✔️
|        | SEM III | Process Modeling and Simulation | | | | | | | | | ✔️
|        |      | Professional Elective-V | | | | | | | | | |
|        |      | Professional Elective-VI | | | | | | | | | |
|        |      | Internship | | | | | | | | | ✔️
|        |      | Project Work Phase I | | | | | | | | | ✔️
|        | SEM IV | Project Work Phase II | | | | | | | | | ✔️

2
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### List of Professional Electives (PE)

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### Professional Core(PC)

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### Employability Enhancement Courses(EEC)

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OBJECTIVES:

- The course will develop numerical methods aided by technology to solve algebraic, transcendental and differential equations and to apply finite element methods for solving the boundary value problems in differential equations. The course will further develop problem solving skills and understanding of the application of various methods in solving engineering problems. This will also serve as a precursor for future research.

UNIT I ALGEBRAIC EQUATIONS


UNIT II ORDINARY DIFFERENTIAL EQUATIONS


UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATIONS


UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS

Laplace and Poisson’s equations in a rectangular region: Five point finite difference schemes, Leibmann’s iterative methods, Dirichlet’s and Neumann conditions – Laplace equation in polar coordinates: Finite difference schemes – Approximation of derivatives near a curved boundary while using a square mesh.

UNIT V FINITE ELEMENT METHOD


TOTAL: 60+15=75 PERIODS

OUTCOMES:

After completing this course, students should demonstrate competency in the following skills:

- Solve an algebraic or transcendental equation, linear system of equations and differential equations using an appropriate numerical method.
- Solving the initial boundary value problems and boundary value problems using finite difference and finite element methods.
Selection of appropriate numerical methods to solve various types of problems in engineering and science in consideration with the minimum number of mathematical operations involved, accuracy requirements and available computational resources.

REFERENCES:

CX5101 ADVANCED TRANSPORT PHENOMENA

OBJECTIVES:
• To enable the students to understand different types of fluids, their flow characteristics and different mathematical models applied to actual situations, Mechanism of fluids in motion under different conditions.

UNIT I BASIC CONCEPTS

UNIT II APPLICATIONS OF DIFFERENTIAL EQUATIONS OF CHANGE
Applications in laminar and turbulent transport in compressible and incompressible fluids. Boundary layer theory.

UNIT III APPLICATIONS OF INTEGRAL EQUATIONS OF CHANGE
Macroscopic balance for isothermal and nonisothermal systems and their applications in Momentum, Heat and Mass transport problems.

UNIT IV INTERPHASE AND MULTIPHASE MOMENTUM TRANSFER

UNIT V INTERPHASE TRANSPORT IN NON-ISOTHERMAL SYSTEMS
Heat Transfer coefficient, Forced convection in tubes, around submerged objects, Heat Transfer by free convection, film type and dropwise condensation and equations for heat transfer, Heat transfer in boiling liquids. Mass Transfer co-efficient in single and multiple phases at low and high mass transfer rates, Film theory, Penetration theory, Boundary layer theory, Macroscopic balance to solve steady and Unsteady state problems.

TOTAL: 60 PERIODS
OUTCOME:

- Students would gain the knowledge of fundamental connections between the conservation laws in heat, mass, and momentum in terms of vector and tensor fluxes. The students would be able to understand the mechanism of fluids in motion under different conditions.

REFERENCES


CX5102 FLUID PHASE EQUILIBRIA L T P C

3 0 0 3

OBJECTIVE:

- To impart knowledge on equilibrium and transport properties of fluids, solids, and interfaces, physical/phase and chemical equilibria; fundamental thermodynamic relations; and stability.

UNIT I BASIC CONCEPTS

Energy and first Law; Reversibility and second Law; Review of Basic Postulates, equilibrium criteria, Legendre Transformation and Maxwell’s relations

UNIT II STABILITY AND PHASE TRANSITION

Stability of thermodynamic systems, first order phase transitions and critical phenomenon, phase rule, single component phase diagrams, thermodynamic properties from volumetric and thermal data

UNIT III MULTICOMPONENT MIXTURES

Partial molar properties, fugacities in gas and liquid mixtures, activity coefficients, Ideal and Non-ideal solutions, Gibbs-Duhem equation, Wilson, NRTL, and UNIQUAC equations, UNIFAC method

UNIT IV PHASE EQUILIBRIUM

VLE - Equations of state, corresponding states, Henry’s Law, lattice theory, criticality, high pressure VLE. Other phase equilibriums- SLE/LLE/VLLE.

UNIT V CHEMICAL EQUILIBRIUM

Homogeneous gas and liquid phase reactions, heterogeneous reactions – phase and chemical equilibrium

TOTAL: 45 PERIODS

OUTCOME:

- Students would have gained knowledge on equilibrium and nonequilibrium thermophysical properties of fluids, solids and interfaces.
10

REFERENCES

2. Rao., Y.V.C., Chemical Engineering Thermodynamics, University Press, Hyderabad,2005

CX5151

CATALYTIC REACTION ENGINEERING

L T P C

3 2 0 4

OBJECTIVE:

- To impart knowledge on different types of chemical reactors, the design of chemical reactors under isothermal and non-isothermal conditions

UNIT I

CATALYST AND ITS CHARACTERIZATION

15

General definition of catalysts, Design for catalysts – Primary constituents, secondary constituents; Catalyst supports. Methods of determining catalysts activity – static methods, Study of structure pore radii; Mercury porosimetry, determination of true and apparent densities of catalysts; Structural study of electron microscopy, determination of mechanical strength of catalysts-static methods, dynamic methods; Methods of thermal analysis.

UNIT II

KINETICS OF HETEROGENEOUS CATALYTIC REACTIONS

12


UNIT III

TRANSPORT PROCESSES WITH REACTIONS CATALYZED BY SOLIDS

16


UNIT IV

CATALYST DEACTIVATION

11


UNIT V

THE MODELING OF CHEMICAL REACTORS.

21


TOTAL : 75 PERIODS
OUTCOME:

- Students would have gained knowledge on the selection of the reactor for the reaction and its design.

REFERENCES


CX5111 COMPUTATIONAL PROGRAMMING CHEMICAL ENGINEERING LABORATORY

OBJECTIVES

- Students will solve chemical engineering problems from core courses using C and MATLAB programming and also using computational tools like Excel and Aspen.

Programming in C
C programs will be written to solve problems from core courses of chemical engineering.

Excel Software
The computational, plotting and programming abilities in Excel will be used to solve different chemical engineering problems.

Programming in MATLAB
Chemical engineering problems will be solved using the powerful computational and graphical capability of MATLAB.

Evaluation
This lab course will have two or three online assessment tests and an online end semester examination in the Process Simulation Laboratory and assignments in all the above units.

TOTAL : 60 PERIODS

List of experiments.

1. Roots of nonlinear equations iterative methods:
   - Bisection method
   - False position method
   - Newton Raphson method
   - Secant method
2. Direct solution for set of linear equations:
   - Gauss Elimination Method
   - Gauss-Jordan method
   - Matrix inversion method
   - Triangular Factorization (L.U.Decomposition method)
3. Iterative solution for set of linear equations:
   - Jacobi’s method
   - Gauss Seidel method

4. Regression analysis:
   - Fitting Linear equation
   - Fitting Transdental equations
   - Fitting a polynomial function

5. Numerical integration:
   - Trapezoidal rule
   - Simpson’s 1/3 Rule
   - Simpson’s 3/8 th rule

6. Numerical solution of ordinary differential equations:
   - Taylor series method
   - Euler’s method
   - Runge-Kutta method

7. Predictor and corrector methods:
   - Milne-Simpson method
   - Adam Bash forth method

8. Rating of shell and tube heat exchanger.


10. Simulation of Recycle Processes.

11. Simulation of PFR and CSTR.

LIST OF EQUIPMENTS FOR A BATCH OF 18 STUDENTS:
   - Stand alone desktops/server with respective simulation softwares 18 Nos.
   - Softwares
     - C compiler
     - MATLAB Single user license
     - Open source office
     - Open source chemical engineering simulation software.

OUTCOMES
   - Able to solve chemical engineering problems using C and MATLAB programming and Excel software.
   - Analyse and estimate the physical properties of data bank and non data bank components; calculate bubble and dew points and generate T-xy and P-xy diagram by simulating flash drum using Process Simulator.

REFERENCES

CX5201 CHEMICAL PROCESS DESIGN 3 0 0 3

OBJECTIVE:
   - To learn about the selection, design of unit operations and unit processes for process industries.
UNIT I  INTRODUCTION  9
The Hierarchy of Chemical process Design- Overall process Design, approaches to design.

UNIT II  CHOICE OF REACTORS AND SEPARATOR  9
Reaction path, reactor performance, practical reactors, Separation of Heterogeneous mixtures, homogeneous fluid mixtures.

UNIT III  SYNTHESIS OF REACTION – SEPARATION SYSTEMS  9
Process recycle, Batch processes, process yield

UNIT IV  DISTILLATION SEQUENCING  9
Using simple columns, using columns with more than two products, Distillation Sequencing Using thermal coupling.

UNIT V  HEAT EXCHANGER NETWORK & UTILITIES – ENERGY TARGETS  9
Heat recovery pinch, The Problem table Algorithm, Utilities Selection, Energy targets capital& total Cost targets -Number of Heat Exchanger Units, Area Targets, Number of Shells Targets, Capital Cost Targets, Total Cost Targets.

TOTAL : 45 PERIODS

OUTCOME:

- The students will be in a position to choose and design of equipments.

REFERENCES

CX5202  ADVANCED SEPARATION PROCESSES  L T P C
3 0 0 3

OBJECTIVE:

- To learn about the different separation processes available.
- To make the students understand the fundamental concepts behind the various separation processes.

UNIT I  GENERAL  12
Review of conventional processes, recent advances in separation techniques based on size, surface properties, ionic properties and other special characteristics of substances. process concept, theory and equipment used in cross flow filtration, cross flow electrofiltration, dual functional filter, surface based solid-liquid separations involving a second liquid, sirofloc filter.

UNIT II  MEMBRANE SEPARATIONS  8
Types and choice of membranes, plate and frame, tubular, spiral wound and hollow fibre membrane reactors and their relative merits, commercial, pilot plant and laboratory membranepermeators involving dialysis, reverse osmosis, nanofiltration, ultrafiltration, microfiltration and Donnan dialysis, economics of membrane operations, ceramic membranes.
UNIT III  SEPARATION BY ADSORPTION TECHNIQUES  8
Mechanism, types and choice of adsorbents, normal adsorption techniques, affinity chromatography and immuno chromatography, types of equipment and commercial processes, recent advances and process economics

UNIT IV  IONIC SEPARATIONS  8
Controlling factors, Applications, Types of equipment employed for electrophoresis, dielectrophoresis, Ion Exchange chromatography and electrodialysis, Commercial processes

UNIT V  OTHER TECHNIQUES  9
Separations involving lyophilization, pervaporation and permeation techniques for solids, liquids and gases, industrial viability and examples, zone melting, additive crystallization, other separation processes, supercritical fluid extraction, oil spill management, industrial effluent treatment by modern techniques.

TOTAL : 45 PERIODS

OUTCOME:
- The students will understand the importance of separation processes and its applications.
- The students will be in a position to select the best separation process for a given problem.

REFERENCES

CX5251  ADVANCED PROCESS CONTROL  L T P C
3 0 0 3

OBJECTIVES
- To introduce dynamic response of open and closed loop systems, control loop components and stability of control systems along with instrumentation.

UNIT I  ADVANCED CONTROL STRATEGIES  9
Feed forward, cascade, dead time compensation, split range, selective and override control; automatic tuning and gain scheduling

UNIT II  INTERNAL MODEL CONTROL  9
Model based control – IMC structure – development and design; IMC based PID control, MPC

UNIT III  MULTIVARIABLE CONTROL  9
Control loop interaction – general pairing problem, relative gain array and application, sensitivity. Multivariable control – zeros and performance limitations, directional sensitivity and operability, decoupling
UNIT IV DISCRETE SYSTEMS

UNIT V DIGITAL FEEDBACK CONTROLLERS
Design of digital feedback controllers, digital approximation of classical, effect of sampling, Case study of Industrial Instrumentation and Control system, DCS, PLC, shutdown system.

TOTAL: 45 PERIODS

OUTCOMES
• Students get knowledge on control strategies of process variables and digital feedback controllers for automatic process control.

REFERENCES

CX5252 MULTICOMPONENT DISTILLATION

OBJECTIVE:
• To provide comprehensive knowledge on multicomponent distillation principle, thermodynamic property evaluation and design.

UNIT I THERMODYNAMIC PRINCIPLES

UNIT II THERMODYNAMIC PROPERTY EVALUATION
Fundamental principles involved in the separation of multi component mixtures – Determination of bubble-point and Dew Point Temperatures for multi component mixtures – equilibrium flash distillation calculations for multi component mixtures – separation of multi component mixtures at total reflux.

UNIT III MINIMUM REFLUX RATIO FOR MCD SYSTEM

UNIT IV VARIOUS METHODS OF MCD COLUMN DESIGN
Theta method of convergence – Kb method and the constant composition method -Application of the Theta method to complex columns and to system of columns – Lewis Matheson method – Stage and reflux requirements – Short cut methods and Simplified graphical procedures.
UNIT V VARIOUS TYPES OF MCD COLUMNS

Design of sieve, bubble cap, valve trays and structured packing columns for multi component distillation – computation of plate efficiencies.

TOTAL : 45 PERIODS

OUTCOME:
- The students will understand the importance of multicomponent distillation, fundamental concepts and its applications.

REFERENCES

CX5211 SEMINAR

OBJECTIVE:
- To provide exposure to the recent developments.
- To improve the students presentation skills.

OUTCOME:
- The students will get better employability and communication skills.
Students are expected to present two seminars along with report on any recent topic in Environmental Science and Technology

CX5391 PROCESS MODELING AND SIMULATION

OBJECTIVE:
- To understand the basics of model construction.
- To learn about solving model equations and validation of the models.

UNIT I INTRODUCTION
Introduction to modeling and simulation, classification of mathematical models, conservation equations and auxiliary relations.

UNIT II STEADY STATE LUMPED SYSTEMS
Degree of freedom analysis, single and network of process units, systems yielding linear and non-linear algebraic equations, flowsheeting – sequential modular and equation oriented approach, tearing, partitioning and precedence ordering, solution of linear and non-linear algebraic equations.

UNIT III UNSTEADY STATE LUMPED SYSTEMS
Analysis of liquid level tank, gravity flow tank, jacketed stirred tank heater, reactors, flash and distillation column, solution of ODE initial value problems, matrix differential equations, simulation of closed loop systems.
UNIT IV  STEADY STATE DISTRIBUTED SYSTEM  9+6
Analysis of compressible flow, heat exchanger, packed columns, plug flow reactor, solution of ODE boundary value problems.

UNIT V  UNSTEADY STATE DISTRIBUTED SYSTEM  9+6

TOTAL : 75 PERIODS

OUTCOME:
- Understanding the fundamental of modeling and simulation, system analysis and evaluation.

REFERENCES

CX5312  PROJECT WORK (PHASE I)  L T P C
0 0 12 6

OBJECTIVE:
- To apply the principles learned from various courses to solve real time problem.

Students have to do a research-based project in the department or in an industry and submit a report at the end of Phase I

CX5411  PROJECT WORK (PHASE II)  L T P C
0 0 24 12

OBJECTIVE:
- To apply the principles learned from various courses to solve real time problem.

OUTCOME:
The students will get confidence to solve challenging problems.
Phase II of Project Work is a continuation of Phase I of Project. Students submit a report at the end of Phase II.

CX5071  MULTIPHASE FLOW  L T P C
3 0 0 3

OBJECTIVE:
- To understand the concepts of multiphase flow and particle interaction.
UNIT I   CHARACTERISTICS OF MULTIPHASE FLOWS  9
Significance of multiphase flows, important non-dimensional numbers, parameters of characterization, particle size measurement, size distribution and moments, size distribution models

UNIT II   PARTICLE FLUID INTERACTION  9

UNIT III   MODELING OF MULTIPHASE FLOWS  9
Flow patterns - identification and classification - flow pattern maps and transition - momentum and energy balance - homogeneous and separated flow models - correlations for use with homogeneous and separated flow models - void fraction and slip ratio correlations - influence of pressure gradient - empirical treatment of two phase flow - drift flux model - correlations for bubble, slug and annular flows

UNIT IV   CONSERVATION EQUATIONS  9
Averaging procedures - time, volume, and ensemble averaging, quasi-one-dimensional flow, two-fluid volume-averaged equations of motion, turbulence and two-way coupling.

UNIT V   MULTIPHASE SYSTEMS  9
Flow regime and hydrodynamic characteristics of packed bed, fluidized bed, pneumatic conveying, bubble column, trickle beds; Conventional and novel measurement techniques for multiphase systems including CARPT, Laser Doppler anemometry, Particle Image Velocimetry.

OUTCOME:

- The students will understand the importance and analysis of multiphase flow.

REFERENCES

OBJECTIVE:
- Students gain knowledge on fundamentals of fluidization engineering, hydrodynamics, heat and mass transfer effects.

UNIT I  INTRODUCTION
The Fluidized state, Nature of hydrodynamic suspension, particle forces, species of Fluidization, Regimization of the fluidized state, operating models for fluidization systems, Applications of fluidization systems.

UNIT II  HYDRODYNAMICS OF FLUIDIZATION SYSTEMS

UNIT III  SOLID MIXING AND SEGREGATION
Phase juxtapositions operation shifts, Reversal points, Degree of segregation, Mixing Segregation equilibrium, Generalised fluidization of poly disperse systems, liquid phase Mixing and gas phase mixing.

UNIT IV  HEAT AND MASS TRANSFER IN FLUIDIZATION SYSTEMS
Mass transfer – Gas Liquid mass transfer, Liquid Solid mass transfer and wall to bed mass transfer, Heat transfer – column wall – to – bed heat transfer, Immersed vertical cylinder to bed heat transfer, Immersed horizontal cylinder to bed heat transfer.

UNIT V  MISCELLANEOUS SYSTEMS
Conical Fluidized bed, Moving bed, Slurry bubble columns, Turbulent bed contactor, Two phase and Three phase inverse fluidized bed, Draft tube systems, Semifluidized bed systems, Annular systems, Typical applications, Geldart’s classification for power assessment, Powder characterization and modeling by bed collapsing.

TOTAL : 45 PERIODS

OUTCOME:
- The students will understand the importance of fluidization engineering, solid mixing and its applications.

REFERENCES
UNIT I  FUNDAMENTALS OF PIPING ENGINEERING  
Definitions, Piping Components their introduction, applications. Piping MOC, Budget Codes and Standards, Fabrication and Installations of piping.

UNIT II  PIPE HYDRAULICS AND SIZING  
Pipe sizing based on velocity and pressure drop consideration cost, least annual cost approach, pipe drawing basics, development of piping general arrangement drawing, dimensions and drawing of piping.

UNIT III  PLOT PLAN  
Development of plot plan for different types of fluid storage, equipment layout, process piping layout, utility piping layout. Stress analysis -Different types of stresses and its impact on piping, methods of calculation, dynamic analysis, flexibility analysis.

UNIT IV  PIPING SUPPORT  
Different types of support based on requirement and its calculation.

UNIT V  INSTRUMENTATION  
Final Control Elements; measuring devices, instrumentation symbols introduction to process flow diagram (PFD) and piping & instrumentation diagram (P&ID)

TOTAL : 45 PERIODS

OUTCOME:
- Be familiar with standards, selection, support and instrumentation.

REFERENCES

ES5071  ENVIRONMENTAL RISK ASSESSMENT  
L T P C 3 0 0 3

OBJECTIVE
- Develop a basic understanding of environmental health and risk assessment and its role within the risk management process.
- To learn about different risk assessment formats and their use in environmental health studies
- To learn about the different models for environmental risk assessment studies.

UNIT I  
Risk analysis introduction, quantitative risk assessment, rapid risk analysis –comprehensive risk analysis – identification, evaluation and control of risk

UNIT II  
Risk assessment – introduction and available methodologies, Risk assessment steps, Hazard identification, Hazard assessment (consequence analysis), probabilistic hazard assessment (Fault tree analysis)
UNIT III
Overall risk contours for different failure scenarios – disaster management plan – emergency planning – onsite and offsite emergency planning, risk management ISO 14000, EMS models – case studies – marketing terminal, gas processing complex.

UNIT IV
Safety measures design in process operations. Accidents modeling – release modeling, toxic release and dispersion modeling, fire and explosion modeling.

UNIT V
Past accident analysis: Flux borough – Mexico – Bhopal analysis. Government policies to manage environmental risk

TOTAL : 45 PERIODS

OUTCOMES:
- Students will gain the knowledge and understanding of the methods and processes employed in environmental health and risk assessment.
- They will use different tools to aid the risk assessment analysis.
- They will gain the knowledge on environmental laws and regulations to develop guidelines, procedures and processes for health and safety issues.
- They will use epidemiological data and to analyze the various methods of risk assessment.

REFERENCES

CX5074 COMPUTATIONAL FLUID DYNAMICS

OBJECTIVE
- Be able to demonstrate competence in setting up computational fluid dynamics models for some industrially important applications. This technical competence in building and conducting CFD simulations is a skill which enhances employability.

UNIT I CONSERVATION LAWS AND TURBULENCE MODELS
Governing equations of fluid flow and heat transfer – mass conservation, momentum and energy equation, differential and integral forms, conservation and non-conservation form. Characteristics of turbulent flows, time averaged Navier Strokes equations, turbulence models-one and two equation, Reynolds stress, LES and DNS

UNIT II FINITE DIFFERENCE APPROXIMATION
Mathematical behaviour of PDE, finite difference operators, basic aspects of discretization by FDM, explicit and implicit methods, error and stability analysis
UNIT III    FINITE VOLUME METHOD
Diffusion problems – explicit and implicit time integration; Convection-diffusion problems – properties of discretisation schemes, central, upwind, hybrid, QUICK schemes; Solution of discretised equations.

UNIT IV    FLOW FIELD COMPUTATION
Pressure velocity coupling, staggered grid, SIMPLE algorithm, PISO algorithm for steady and unsteady flows

UNIT V    GRID GENERATION
Physical aspects, simple and multiple connected regions, grid generation by PDE solution, grid generation by algebraic mapping.

TOTAL: 45 PERIODS

OUTCOME:
• Students will be in a position to analyse the flow behavior in various systems.

REFERENCES

CX5075    SOLVENT EXTRACTION
L T P C
3 0 0 3

OBJECTIVES
• Student develop a sound knowledge on equilibrium in liquid-liquid system, HETS, NETS, HTU, NTU, dispersion and coalescence in extractors and design of extraction column.

UNIT I    EQUILIBRIUM IN LIQUID-LIQUID SYSTEM
Binary and ternary liquid equilibria, Tie-lines, Critical solution temperature, Tie line correlations ,Contour/prism diagrams, Binary / Ternary prediction methods of activity coefficient, Theory and Prediction of diffusivity in liquids, Theory of inter phase mass transport, Estimation and prediction of mass transport coefficient

UNIT II    DIFFERENTIAL / STAGE-WISE EQUILIBRIUM CONTACT OPERATIONS
Equilibrium stage-wise contact, Single and multiple contacts with co-current and counter current flow of phases for immiscible and partially miscible solvent phases , Calculation methods, Fractional extraction with reflux of raffinate and extract. Differential contact, HETS, NETS, HTU,
NTU concepts and Estimation of these parameters, Mass transfer efficiency, Axial mixing and Residence time distribution in extractors and their estimation.

**UNIT III     DISPERSION AND COALESCENCE IN EXTRACTORS**  
Characteristics of dispersion involving single and multiple nozzle distributors, Drop size and formation and coalescence, Mean drop size at dispersion and their settling velocities/relative characteristics velocities. Effect of drop oscillation ,wobbling and Internal circulation, Effect of surface active agents, Prediction of drop size and characteristics velocity in spray , packed and mechanically agitated contactors as in RDC, pulsed columns, solute transfer effects on drop dynamics.

**UNIT IV     DESIGN OF LIQUID EXTRACTION COLUMNS**  
Design of extractor height and diameter, Prediction of flow capacities in terms of flooding rates, Regime of operating envelops, Hydrodynamic design variables such as hold up, characteristic velocities, pressure drop, Effect of direction of solute transfer on these variables and their prediction methods, Correction of mass transfer data, Axial mixing correction for column height, Interfacial area estimations, using slow, fast and instantaneous reactions and their application with models for mass transfer coefficients.

**OUTCOME:**  
- The students will understand the fundamentals and importance of extraction processes in process industries.

**REFERENCES**

**OBJECTIVES**
- To impart knowledge on corrosion in petroleum refining.

**UNIT I     TYPES OF CORROSION AND TESTING METHODS**  
Basic principles of corrosion and its control – Forms of corrosion, uniform, Galvanic, Crevis, pitting, selective leaching, erosion, stress-corrosion, cracking – Cavitation phenomena & their effects – Corrosion testing – Field testing – Electrochemical techniques for measurement of corrosion rates, corrosion detection and components examination – Accelerated salt-spray testing.

**UNIT II     CORROSION PROTECTION METHODS**  
Corrosion inhibitors, electroplated coatings, conversion coatings, anodizing, hot dipping, spray metal coatings, zinc coating by alloying, electrophoretic coatings and electro painting, powder coating, electrical methods of corrosion protection, composite materials in corrosion minimization – Cathodic and Anodic protections.
UNIT III        CORROSION IN SPECIFIC ENVIRONMENTS
Corrosion damage to concrete in industrial and marine environments and its protection; biological corrosion, halogen corrosion of metals, environmental degradation of materials, corrosion and inspection managements in chemical processing and petrochemical industries.

UNIT IV        CORROSION IN SPECIFIC CASES AND CONTROL

UNIT V        CORROSION AND COUNTRY’S ECONOMY
Corrosion protection management–process maintenance procedures under corrosion Environments

TOTAL : 45 PERIODS

OUTCOMES
- Students learn about the types of corrosion, protection methods, corrosion in specific environments, corrosion in specific cases and control.

REFERENCE

CX5076        INDUSTRIAL INSTRUMENTATION

OBJECTIVES
- Students get the knowledge on how to measure process variables, analytical instrumentation, automatic process controls.

UNIT I

UNIT II
Process Variables Measurement–Temperature systems– Thermocouples, Thermo resistive system, Filled-system thermometers, Radiation thermometry, Location of temperature measuring devices in equipments, Pressure system – Mechanical pressure elements Pressure Transducers and Transmitters, Vacuum measurement, Resonant wire pressure Transducer, Flow system – Differential producers, Variable area flow meters, Velocity, vortex, mass, ultrasonic & other flow meters, positive displacement flow meters, Open – channel flow measurements, Force systems, Strain gauges Humidity Moisture system, Humidity Measurement, Moisture measurement system, Rheological system, Viscosity measurement, Radiation system, Nuclear radiation instrumentation.

UNIT III
Analytical instrumentation – Analysis instruments, Sample conditioning for process analyzers, X-ray Analytical methods, Quadrupole mass spectrometry, Ultra violet Absorption Analysis, Infra red process analyzers, Photometric reaction product analysers Oxygen analyzers, Oxidation – reduction potential measurements, pH measuring systems, Electrical conductivity and Resistivity
measurements, Thermal conductivity, gas analysis, Combustible, Total hydro carbon, and CO analyzer, Chromatography.

UNIT IV

UNIT V
Sensors, Transmitters and control valves - Pressure, Flow, Level, Temperature and Composition sensors, Transmitters, Pneumatic and electronic control valves, Types, Actuator, accessories, Instrumentation symbols and Labels.

TOTAL: 45 PERIODS

OUTCOMES
• Students get the knowledge on how to measure process variables, analytical instrumentation, automatic process controls.

REFERENCES

ES5092 DESIGN OF EXPERIMENTS L T P C
3 0 0 3

OBJECTIVE:
• To impart basic knowledge on statistical design of experiments.
• To learn about various methods employed for the design of experiments.

UNIT I CONCEPTS AND TERMINOLOGY
Review of hypothesis testing – P Value, “t” Vs paired “t” test, simple comparative experiment, planning of experiment – steps. Terminology - factors, levels, variables, Design principles – replication, randomization, blocking, confounding, Analysis of variance, sum of squares, degrees of freedom.

UNIT II SINGLE FACTOR EXPERIMENTS
Completely randomized design, Randomized block design, effect of coding the observations, Latin Square design, orthogonal contrasts, comparison of treatment means – Duncan’s multiple range test, Newman-Keuel’s test, Fisher’s LSD test, Tukey’s test.
UNIT III  FACTORIAL EXPERIMENTS  
Main and interaction effects, Rules for sum of squares and expected mean square, two and three factor full factorial design, 2k designs with two and three factors, Yate’s algorithm, practical applications.

UNIT IV  SPECIAL EXPERIMENTAL DESIGNS  
Blocking and confounding in 2k design, nested design, split – plot design, two level fractional factorial design, fitting regression models, introduction to response surface methods- Central composite design.

UNIT V  TAGUCHI TECHNIQUES  
Introduction, Orthogonal designs, data analysis using ANOVA and response graph, parameter design – noise factors, objective functions (S/N ratios), multi-level factor OA designs, applications.

TOTAL : 45 PERIODS

OUTCOME:
- The students will be in a position to solve problems involving many factors.
- Be familiar with statistical tools for environmental applications

REFERENCES
2. Douglas C.Montgomery, Design and Analysis of Experiments, John Wiley & Sons, 2005

CX5091  SAFETY AND HAZARD CONTROL  L T P C  3 0 0 3

OBJECTIVES
- Become a skilled person in HAZOP and hazard analysis and able to find out the root cause of an accident. Gain knowledge in devising safety policy and procedures to be adopted to implement total safety in a plant.

UNIT I  
Conventional and modern concepts of safety, Basic Principles and concepts in hazard identification, Chemical hazards, Process and operation hazard, Hazards from utilities like air, water, steam etc., Occupational health hazards, Hazard and operability Studies, Safety Audits.

UNIT II  
Past Accident Analysis, Consequence Analysis of fire, gas/vapour, Dispersions and explosion, Vulnerability models, Fault and Event Tree Analysis.

UNIT III  
Safety in plant design and layout. Risk Assessment.

UNIT IV  
Safety measures in handling and storage of chemicals, Process plant, personnel Protection, First Aid.
UNIT V
Disaster mitigation, Emergency Preparedness plans.

TOTAL: 45 PERIODS

OUTCOME:
- Students understand that behind each fatality or serious injury there are thousands of at-risk behaviours and unidentified hazards that contributed to the incident
- State the definition of a hazard and explain how to identify hazards in the industries/workplace.
- Determine methods for controlling hazards in the workplace.
- Complete a Job Hazard Analysis for a typical worker task.

REFERENCES

CX5092 ENERGIE MANAGEMENT

OBJECTIVES
- Students gain the knowledge on energy sources, various forms, demand, power requirements, conservation and optimization techniques and the sources of continuous power.

UNIT I
Energy sources; coal oil, natural gas; nuclear energy; hydro electricity, other fossil fuels; geothermal; supply and demand; depletion of resources; need for conservation; uncertainties; national and international issues.

UNIT II
Forecasting techniques, energy demand, magnitude and pattern, input and output analysis, energy modeling and optimal mix of energy sources. Energy - various forms, energy storage, structural properties of environment.
UNIT III
Bio-geo-chemical cycles; society and environment population and technology. Energy and evolution, growth and change, patterns of consumption in developing and advances countries, commercial generation of power requirements and benefit.

UNIT IV
Chemical industries, classification, conservation in unit operation such as separation, cooling tower, drying, conservation applied to refineries, petrochemical, fertilizers, cement, pulp and paper, food industries, chloro alkali industries, conservation using optimization techniques.

UNIT V
Sources of continuous power, wind and water, geothermal, tidal and solar power, MHD, fuel cells, hydrogen as fuel. Cost analysis, capacity; production rate, system rate, system cost analysis, corporate models, production analysis and production using fuel inventories, input-output analysis, economics, tariffs.

TOTAL: 45 PERIODS

OUTCOME
- The students will be in a position to develop energy efficient process
- Students will focus on the conservation of energy while developing industrial processes

REFERENCES

CX5093 PILOT PLANT AND SCALE UP METHODS

OBJECTIVE
- To impart knowledge on scale up techniques
- To understand the application of scale up of Chemical equipments

UNIT I PRINCIPALS OF SIMILARITY, PILOT PLANTS & MODELS
Introduction to scale-up methods, pilot plants and models and principles of similarity.

UNIT II DIMENSIONAL ANALYSIS AND SCALE-UP CRITERION
Dimensional analysis, regime concept, similarity criterion and scale up methods used in chemical engineering.

UNIT III SCALE-UP OF HEAT TRANSFER EQUIPMENT
Typical problems in scale-up of mixing equipment and heat transfer equipment

UNIT IV SCALE-UP OF MASS TRANSFER EQUIPMENT
Scale-up of distillation columns and packed towers for continuous and batch processes

UNIT V SCALE-UP OF CHEMICAL REACTORS
Kinetics, reactor development & scale-up techniques for chemical reactors.

TOTAL : 45 PERIODS
OUTCOME:

- Students will be in a position to design large scale plant based on pilot plant studies and scale-up methods.

REFERENCES


CX5077 PROJECT ENGINEERING OF PROCESS PLANTS L T P C

OBJECTIVE

- Students should be able to design a project at the end of the course by themselves.

UNIT I

Project definition, Project Profile and standards, Feed back information (MIS), Evaluation and Modification, Selection, Criteria.

UNIT II


UNIT III

Plant Engineering Management, Objectives, Programme, Control, Plant Location and Site Selection, Layout diagrams, Selection and procurement of equipment and machineries, Installation, Reconversion, Commissioning and performance appraisal, Strategies choice and Influence, Product planning and development, Provision and maintenance of service facilities.

UNIT IV

Process safety, Materials safety and Handling regulations, Safety in equipment and machinery operations, Design considerations of safety organization and control, Pollution, Pollution control and Abatement, Industrial Safety Standard Analysis.

UNIT V


TOTAL: 45 PERIODS

OUTCOME:

- Students will understand the significance of management information system, planning, budgeting, process plant safety and government regulations for process industries.
REFERENCES

CX5078 PROCESS OPTIMIZATION L T P C 3 0 0 3

OBJECTIVE
• Students should be able to optimize the process for a given chemical industry at the end of the course.

UNIT I INTRODUCTION 5
Problem formulation, degree of freedom analysis, objective functions, constraints and feasible region, Types of optimization problem.

UNIT II LINEAR PROGRAMMING 10
Simplex method, Barrier method, sensitivity analysis, Examples.

UNIT III NONLINEAR UNCONSTRAINED OPTIMIZATION 10
Convex and concave functions unconstrained NLP, Newton’s method Quasi-Newton’s method, Examples.

UNIT IV CONSTRAINED OPTIMIZATION 10
Direct substitution, Quadratic programming, Penalty Barrier Augmented Lagrangian Methods.

UNIT V MULTI OBJECTIVE OPTIMIZATION 10
Weighted Sum of Squares method, Epsilon constrain method, Goal attainment, Examples. Introduction to optimal control and dynamic optimization.

TOTAL: 45 PERIODS

OUTCOME:
• Understanding of different objective functions and analytical methods.
• Ability to solve various multivariable optimization problems.

REFERENCES
OBJECTIVES

- Different types of fuel cells and their applications would be studied. Hydrogen production techniques, storage and applications would be studied.

UNIT I  HYDROGEN – BASICS AND PRODUCTION TECHNIQUES  9

UNIT II  HYDROGEN STORAGE AND APPLICATIONS  9

UNIT III  FUEL CELLS  9
History – principle – working – thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell

UNIT IV  FUEL CELL – TYPES  9
Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – relative merits and demerits

UNIT V  APPLICATION OF FUEL CELL AND ECONOMICS  9
Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space. Economic and environmental analysis on usage of Hydrogen and Fuel cell. Future trends in fuel cells.

TOTAL: 45 PERIODS

OUTCOMES:
After completing the course, student should have learnt

- Basics and working principles of the Fuel cell technology.
- Selection the suitable materials for electrode, catalyst, membrane for the fuel cells.
- The mass transfer process such as pressure drop and velocity distribution in single cell as well as stack.
- Design and stack making process for real field applications

REFERENCES

OBJECTIVES

- To make students understand the principles behind synthesis and fabrication of nanomaterials, their characteristics, features and environmental applications.

UNIT I  GENERAL  9
Background of nanotechnology, particle size and surface area, quantum dot. Converging science and technology, nanotechnology as a tool for sustainability, health, safety and environmental issues.

UNIT II  SYNTHESIS AND FABRICATION OF NANOMATERIALS  9
Preparation of nano scale metal oxides, metals, CNT, functionalized nano porous adsorbents, nano composite- Chemical vapour deposition, sol gel, sonochemical, microwave, solvothermal, plasma, pulsed laser ablation, magnetron sputtering, electrospinning, Molecular imoring.

UNIT III  CHARACTERISATION OF NANOMATERIALS  9
AFM, STM, SEM, TEM, XRD, ESCA, IR & Raman, UV-DRS, of nanomaterials for structural & chemical nature.

UNIT IV  OTHER FEATURES OF NANO PARTICLES  9
Nanoparticle transport, aggregation & deposition. Energy applications-H2 storage.

UNIT V  ENVIRONMENTAL APPLICATIONS  9
Gas sensors, microfluidics and lab on chip, catalytic and photocatalyic applications, Nonmaterials for ground water remediation, nanomaterials as adsorbsents, membraneprocess.

TOTAL : 45 PERIODS

OUTCOME

- Students will be in a position to use
- Nanostructured catalysts such as TiO$_2$ nanoparticles for water purification.
- Nanoparticles for treatment of chlorinated organic contaminants.
- Nanoparticles for treatment of arsenic, environmental risks of nanomaterials

REFERENCES

1. Environmental applications of nanomaterials-Synthesis, Sorbents and Sensors, edited by Glen E Fryxell and Guozhong Cao, worldscibooks, UK
3. The Chemistry of Nanomaterials, Synthesis, Properties and applications. Edited by C.N.R.Rao, Muller, A.K.Cheetham Copyright 8 2004 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim
UNIT I  MATHEMATICAL PROGRAMMING  

UNIT II  DYNAMIC PROGRAMMING  
Elements of DP models, Bellman’s optimality criteria, Recursion formula, Solution of multistage decision problem by DP method. Application is Heat Exchange Extraction systems.

UNIT III  PERT, CPM and GERT  

UNIT IV  ELEMENTS OF QUEUING THEORY  
Basic elements of the Queuing model, M/M/1 and M/M/C Queues.

UNIT V  ELEMENTS OF RELIABILITY THEORY  
General failure distribution, for components, Exponential failure distributions, General model, Maintained and Non-maintained systems, Safety Analysis.

TOTAL: 45 PERIODS

OUTCOMES:
- Understand the mathematical tools that are needed to solve optimization problems.
- Understand to use mathematical softwares to solve the proposed models.
- Understand to identify and develop operation research models for the real systems and to solve it.

REFERENCES

CX5081  INTELLECTUAL PROPERTY RIGHTS  
OBJECTIVES
- After completing the course, the students will have capacity to solve, on their own hand, minor juridical questions within “Intellectual Property Rights”. They will also be able to follow and understand more complex juridical discussions.

UNIT I  
UNIT II 10

UNIT III 10

UNIT IV 10

UNIT V 10
Case Studies on – Patents (Basumati rice, turmeric, Neem, etc.) – Copyright and related rights – Trade Marks – Industrial design and Integrated circuits – Geographic indications – Protection against unfair competition.

OUTCOMES:
- After completing the course, the students will have capacity to solve, on their own hand, minor juridical questions within “Intellectual Property Rights”. They will also be able to follow and understand more complex juridical discussions.

REFERENCES

TOTAL: 45 PERIODOS

CX5095 ENVIRONMENT, HEALTH AND SAFETY IN INDUSTRIES L T P C 3 0 0 3

OBJECTIVE
- To make students to get a clear picture of environment, health and safety systems, their features and techniques used and the principles and methods of effective training.

UNIT I INTRODUCTION 9

UNIT II OCCUPATIONAL HEALTH AND HYGIENE 9

UNIT III WORKPLACE SAFETY AND SAFETY SYSTEMS 9
Features of the satisfactory design of work premises HVAC, ventilation. Safe installation and use of electrical supplies. Fire safety and first aid provision. Significance of human factors in the establishment and effectiveness of safe systems. Safe systems of work for manual handling operations. Control methods to eliminate or reduce the risks arising from the use of work equipment. Requirements for the safe use of display screen equipment. Procedures and precautionary measures necessary when handling hazardous substances. Contingency arrangements for events of serious and imminent danger.

UNIT IV TECHNIQUES OF ENVIRONMENTAL SAFETY 9

UNIT V EDUCATION AND TRAINING 9
Requirements for and benefits of the provision of information, instruction, training and supervision. Factors to be considered in the development of effective training programmes. Principles and methods of effective training. Feedback and evaluation mechanism.

TOTAL: 45 PERIODS

OUTCOME
- On completion of the course, the students are expected to be familiar with accident prevention techniques, hazard analysis techniques and legislations pertaining to safety in chemical industries.

REFERENCES
1. Effective Environmental, Health, and Safety Management Using the Team Approach by Bill Taylor, Culinary and Hospitality Industry Publications Services 2005
2. Environmental and Health and Safety Management by Nicholas P. Cheremisinoff and Madelyn L. Graffia, William Andrew Inc. NY, 1995

CX5096 MEMBRANE TECHNOLOGIES FOR WATER AND WASTEWATER TREATMENT 3003

OBJECTIVE
- To make students understand about the principles behind separation systems, membrane processes and systems, membrane bioreactors and pretreatment systems.

UNIT I INTRODUCTION 10
Solid Liquid separation systems-Filtration systems- Theory of Membrane separation – mass Transport Characteristics Cross Flow filtration-Membrane Filtration- Types and choice of
membranes, porous, non porous, symmetric and assymmetric – Plate and Frame, spiral wound and hollow fibre membranes – Liquid Membranes

UNIT II MEMBRANE PROCESSES AND SYSTEMS 10

UNIT III MEMBRANE BIOREACTORS 9
Introduction and Historical Perspective of MBRs, Biotreatment Fundamentals, Biomass Separation MBR Principles, Fouling and Fouling Control, MBR Design Principles, Design Assignment, Alternative MBR Configurations, Commercial Technologies, Case Studies

UNIT IV PRETREATMENT SYSTEMS 8
Membrane Fouling – Pretreatment methods and strategies – monitoring of Pretreatment – Langlier Index, Silt Density Index, Chemical cleaning, Biofoulant control

UNIT V CASE STUDIES 8
Case studies on the design of membrane based water and wastewater treatment systems – zero Liquid effluent discharge Plants

TOTAL: 45 PERIODS

OUTCOMES:
- Students will be able to apply various transport models for the calculation of membrane fluxes and the extent of separation for various membrane systems
- They will identify the types of experimental data needed for the calculation of membrane parameters.
- They will select a membrane process and design components to carry out a specific separation.
- They will make advancements in membrane techniques to solve environmental problems.

REFERENCES
6. Water Environment Federation (WEF), Membrane Systems for Wastewater Treatment, McGraw-Hill, USA, 2005
OBJECTIVES:

- To provide knowledge on sources and characteristics of industrial pollution, techniques and approaches for minimizing the generation of pollutants.
- Application of physicochemical and biological treatment methods for recovery, reuse and disposal supported with case studies under Indian situations.

UNIT I
Industrial wastes & their sources: various industrial processes, sources and types of wastes—solid, liquid, gaseous, noise & radiation emissions. Sources for industrial water usages and various industrial processes requiring water use and water quality.

UNIT II
Processes responsible for deterioration in water quality. Various waste water streams. Control and removal of specific pollutants in industrial wastewaters, e.g., oil and grease, bio-degradable organics, chemicals such as cyanide, fluoride, toxic organics, heavy metals, radioactivity etc. Wastewater re-uses & recycling, concept of zero discharge effluent.

UNIT III
Control of gaseous emissions: hood and ducts, tall stacks, particulate and gaseous pollutant control; Solid waste generation and disposal management; Hazardous wastes: definitions, concepts and management aspects; Noise & radiation: generation, control and management.

UNIT IV
Recent trends in industrial waste management, cradle to grave concept, life cycle analysis, clean technologies; Case studies of various industries, e.g., dairy, fertilizer, distillery, sugar, pulp and paper, iron and steel, metal plating, thermal power plants, etc.

UNIT V
Pollution Prevention and Cleaner Production Project development and implementation - Overview of CP Assessment steps and skills, Preparing the site, Information gathering, and Flow diagram, Material balance, PP and CP Option generation, Technical and Environmental Feasibility analysis, Total Cost analysis - PP and CP Financing, Establishing a Program - Organizing a Program - Preparing a program plan - Measuring progress – Pollution Prevention and Cleaner Production Awareness Plan - Waste Audit- Environmental Statement

TOTAL : 45 PERIODS

OUTCOMES:

- Understand the different types of wastes generated in an industry, their environmental regulatory legislations and standards.
- Understand about the quantification and analysis of wastewater treatment, atmospheric dispersion of air pollutants, and air pollution control devices.
- Understand about analysis and quantification of hazardous and nonhazardous solid waste wastes, treatment and disposal.

REFERENCES:

OBJECTIVES

- Students gain knowledge on selection of right type of transport and various types of pipes, pipeline protection techniques and design of pipeline.

UNIT I
Introduction, widespread use, the various types, the advantages and the special features of pipelines.

UNIT II
The fluid mechanics of various types of pipe flow including incompressible and compressible flows of Newtonian fluids, non-Newtonian fluids, flow of solid/liquid mixture (slurry), flow of solid/air mixture (pneumatic transport), and flow of capsules (capsule pipelines).

UNIT III
Various types of pipes (steel, concrete, PE, PVC, etc.), valves (gate, globe, ball, butterfly, etc.) and pressure regulators in pipelines. Blowers and compressors (for gases). Various kinds of flowmeters, sensors, pigs (scrapers) and automatic control systems used in pipelines.

UNIT IV
Various means to protect pipelines against freezing, abrasion and corrosion, such as cathodic protection, Planning, construction and operation of pipelines, including modern use of advanced technologies such as global positioning systems (GPS), directional drillings, automatic control using computers, and pipeline integrity monitoring such as leak detection.

UNIT V
Structural design of pipelines — load considerations and pipe deformation and failure. Economics of pipelines including life-cycle, Cost analysis and comparison of the costeffectiveness of pipelines with alternative modes of transport such as truck or railroad. Legal, safety and environmental issues about pipelines.

OUTCOME:
- Students will be able to select right type of transport, pipeline protection techniques and design of pipeline.

REFERENCES
OBJECTIVE

- To make students aware of global environmental issues, concepts behind pollution prevention, environmental risks, green chemistry, methods to evaluate environmental costs and life cycle assessments.

UNIT I

UNIT II

UNIT III

UNIT IV

UNIT V

TOTAL: 45 PERIODS

OUTCOMES

- Upon completion of this course, the students would understand the fundamentals of green chemistry and engineering
- Application of these principles during the design, retrofit and management of chemical processes for a more sustainable chemical manufacturing

REFERENCES
OBJECTIVES
• Students gain knowledge on fuel cell principles, kinetics, in-situ and ex-situ characterization, fuel cell power plant and applications.

UNIT I
Overview of fuel cells: Low and high temperature fuel cells; Fuel cell thermodynamics - heat, work potentials, prediction of reversible voltage, fuel cell efficiency.

UNIT II
Fuel cell reaction kinetics - electrode kinetics, overvoltage, Tafel equation, charge transfer reaction, exchange currents, electro catalysis - design, activation kinetics, Fuel cell charge and mass transport - flow field, transport in electrode and electrolyte.

UNIT III
Fuel cell characterization - in-situ and ex-situ characterization techniques, i-V curve, frequency response analysis; Fuel cell modelling and system integration: - 1D model – analytical solution and CFD models.

UNIT IV
Balance of plant; Hydrogen production from renewable sources and storage; safety issues, cost expectation and life cycle analysis of fuel cells.

UNIT V
Fuel cell power plants: fuel processor, fuel cell power section (fuel cell stack), power conditioner; automotive applications, portable applications

TOTAL : 45 PERIODS

OUTCOME:
After completing the course, student should have learnt
• Basics and working principles of the Fuel cell, reaction kinetics, characterization.
• Design and stack making process for real field applications

REFERENCES