ANNA UNIVERSITY:: CHENNAI 600 025
AFFILIATED INSTITUTIONS
M.TECH. CHEMICAL ENGINEERING
REGULATIONS – 2017
CHOICE BASED CREDIT SYSTEM
I TO IV SEMESTERS CURRICULUM AND SYLLABUS

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.

Programme Educational Objectives	Programme Outcomes								
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
I	✓				✓				✓
II				✓		✓	✓		
III	✓	✓			✓				
IV						✓		✓	✓
V			✓				✓		✓

			PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
YEAR I	SEM I	Advanced Numerical Methods		✓		✓					
		Advanced Transport Phenomena								✓	✓
		Catalytic Reaction Engineering			✓		✓				✓
		Fluid Phase Equilibria							✓		✓
		Professional Elective I									
		Professional Elective II									
		Computational Programme in Chemical Engineering Laboratory		✓	✓		✓			✓	✓
	SEM II	Chemical Process Design							✓	✓	
		Advanced Process Control		✓			✓		✓	✓	
		Advanced Separation Processes			✓		✓		✓		✓
		Multicomponent Distillation			✓		✓				
		Professional Elective III									
		Professional Elective IV									
		Seminar	✓					✓	✓		
YEAR II	SEM III	Process Modeling and Simulation	✓							✓	✓
		Professional Elective-V									
		Professional Elective-VI									
		Internship	✓	✓		✓		✓			✓
		Project Work Phase I	✓	✓		✓		✓			✓
	SEM IV	Project Work Phase II	✓	✓		✓		✓			✓

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SEMESTER I

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA5153	Advanced Numerical Methods	FC	5	3	2	0	4
2.	CX5101	Advanced Transport Phenomena	PC	4	4	0	0	4
3.	CX5102	Fluid Phase Equilibria	FC	3	3	0	0	3
4.	CX5151	Catalytic Reaction Engineering	PC	5	3	2	0	4
5.		Professioanl Elective I	PE	3	3	0	0	3
6.		Professioanl Elective II	PE	3	3	0	0	3
PRACTICALS								
7.	CX5111	Computational Programme in Chemical Engineering Laboratory	PC	4	0	0	4	2
			TOTAL	**27**	**19**	**4**	**4**	**23**

SEMESTER II

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	CX5201	Chemical Process Design	PC	3	3	0	0	3
2.	CX5202	Advanced Separation Processes	PC	3	3	0	0	3
3.	CX5251	Advanced Process Control	PC	3	3	0	0	3
4.	CX5252	Multicomponent Distillation	PC	3	3	0	0	3
5.		Professioanl Elective III	PE	3	3	0	0	3
6.		Professioanl Elective IV	PE	3	3	0	0	3
PRACTICALS								
7.	CX5211	Seminar	EEC	4	0	0	4	2
			TOTAL	**22**	**18**	**0**	**4**	**20**

SEMESTER III

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	CX5391	Process Modeling and Simulation	PC	5	3	2	0	4
2.		Professioanl Elective V	PE	3	3	0	0	3
3.		Professioanl Elective VI	PE	3	3	0	0	3
PRACTICALS								
4.	CX5311	Internship	EEC	2	0	0	2	1
5.	CX5312	Project Work Phase I	EEC	12	0	0	12	6
			TOTAL	**25**	**9**	**2**	**14**	**17**

SEMESTER IV

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
PRACTICALS								
1.	CX5411	Project Work Phase II	EEC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

TOTAL CREDITS :72

List of Professional Electives(PE)

SEMESTER - I, PROFESSIONAL ELECTIVE I

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	CX5071	Multiphase Flow	PE	3	3	0	0	3
2.	CX5072	Fluidization Engineering	PE	3	3	0	0	3
3.	CX5073	Piping and Instrumentation	PE	3	3	0	0	3
4.	ES5071	Environmental Risk Assessment	PE	3	3	0	0	3

SEMESTER - I, PROFESSIONAL ELECTIVE II

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	CX5074	Computational Fluid Dynamics	PE	3	3	0	0	3
2.	CX5075	Solvent Extraction	PE	3	3	0	0	3
3.	PP5391	Corrosion Engineering	PE	3	3	0	0	3
4.	CX5076	Industrial Instrumentation	PE	3	3	0	0	3

SEMESTER - II, PROFESSIONAL ELECTIVE III

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	ES5092	Design of Experiments	PE	3	3	0	0	3
2.	CX5091	Safety and Hazard Control	PE	3	3	0	0	3
3.	CX5092	Energy Management	PE	3	3	0	0	3
4.	CX5093	Pilot Plant and Scale up Methods	PE	3	3	0	0	3

SEMESTER - II, PROFESSIONAL ELECTIVE IV

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	CX5077	Project Engineering of Process Plants	PE	3	3	0	0	3
2.	CX5078	Process Optimization	PE	3	3	0	0	3
3.	CX5094	Hydrogen and Fuel Cells	PE	3	3	0	0	3
4.	CX5079	Environmental Nano Technology	PE	3	3	0	0	3

SEMESTER - III, PROFESSIONAL ELECTIVE V

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	CX5080	Operations Research	PE	3	3	0	0	3
2.	CX5081	Intellectual Property Rights	PE	3	3	0	0	3
3.	CX5095	Environment, Health and Safety in Industries	PE	3	3	0	0	3
4.	CX5096	Membrane Technologies for Water and Wastewater Treatment	PE	3	3	0	0	3

SEMESTER - III, PROFESSIONAL ELECTIVE VI

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	ES5091	Industrial Pollution Prevention	PE	3	3	0	0	3
2.	CX5082	Gas Transportation	PE	3	3	0	0	3
3.	CX5083	Green Chemistry and Engineering	PE	3	3	0	0	3
4.	CX5084	Fuel Cell Technology	PE	3	3	0	0	3

Foundation Courses(FC)

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA5153	Advanced Numerical Methods	FC	5	3	2	0	4
2.	CX5102	Fluid Phase Equilibria	FC	3	3	0	0	3

Professional Core(PC)

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1.	CX5101	Advanced Transport Phenomena	PC	5	3	2	0	4
2.	CX5151	Catalytic Reaction Engineering	PC	5	3	2	0	4
3.	CX5201	Chemical Process Design	PC	3	3	0	0	3
4.	CX5251	Advanced Process Control	PC	3	3	0	0	3
5.	CX5202	Advanced Separation Processes	PC	3	3	0	0	3
6.	CX5252	Multicomponent Distillation	PC	3	3	0	0	3
7.	CX5391	Process Modeling and Simulation	PC	5	3	2	0	4
8.	CX5111	Computational Programme in Chemical Engineering Laboratory	PC	4	0	0	4	2

Employability Enhancement Courses(EEC)

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	CX5211	Seminar	EEC	4	0	0	4	2
2.	CX5312	Project Work (Phase I)	EEC	12	0	0	12	6
3.	CX5411	Project Work (Phase II)	EEC	24	0	0	24	12
4.	CX5311	Internship	EEC	2	0	0	2	1

MA5153 ADVANCED NUMERICAL METHODS
(Common to Environmental Science and Technology, Chemical Engineering and PRPC)

L	T	P	C
3	2	0	4

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 12+3

Systems of linear equations : Gauss elimination method – Pivoting techniques – Thomas algorithm for tri diagonal system – Jacobi, Gauss Seidel, SOR iteration methods – Conditions for convergence - Systems of nonlinear equations : Fixed point iterations, Newton's method, Eigenvalue problems : Power method and Given's method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS 12+3

Runge - Kutta methods for system of IVPs – Numerical stability of Runge - Kutta method – Adams - Bashforth multistep method, Shooting method, BVP : Finite difference method, Collocation method and orthogonal collocation method.

UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATIONS 12+3

Parabolic equations : Explicit and implicit finite difference methods – Weighted average approximation - Dirichlet's and Neumann conditions – Two dimensional parabolic equations – ADI method : First order hyperbolic equations – Method of numerical integration along characteristics – Wave equation : Explicit scheme – Stability.

UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS 12+3

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 12+3

Basics of finite element method : Weak formulation, Weighted residual method – Shape functions for linear and triangular element – Finite element method for two point boundary value problems, Laplace and Poisson equations.

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 :

1. Burden, R.L., and Faires, J.D., "Numerical Analysis – Theory and Applications", 9^{th} Edition, Cengage Learning, New Delhi, 2016.
2. Gupta S.K., "Numerical Methods for Engineers", New Age Publishers, 1995.
3. Jain M. K., Iyengar S. R., Kanchi M. B., Jain, "Computational Methods for Partial Differential Equations", New Age Publishers ,1993.
4. Sastry, S.S., "Introductory Methods of Numerical Analysis", 5^{th} Edition, PHI Learning, 2015.
5. Saumyen Guha and Rajesh Srivastava, "Numerical methods for Engineering and Science", Oxford Higher Education, New Delhi, 2010.
6. Smith, G. D., "Numerical Solutions of Partial Differential Equations: Finite Difference Methods", Clarendon Press, 1985.

CX5101 ADVANCED TRANSPORT PHENOMENA L T P C
4 0 0 4

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 15

Phenomenological Equations and Transport properties, Rheological behaviour of fluids, Balance Equations – Differential and Integral equations.

UNIT II APPLICATIONS OF DIFFERENTIAL EQUATIONS OF CHANGE 15

Applications in laminar and turbulent transport in compressible and incompressible fluids.Boundary layer theory.

UNIT III APPLICATIONS OF INTEGRAL EQUATIONS OF CHANGE 15

Macroscopic balance for isothermal and nonisothermal systems and their applications in Momentum, Heat and Mass transport problems.

UNIT IV INTERPHASE AND MULTIPHASE MOMENTUM TRANSFER 15

Friction factor, Fluid –Fluid systems, Flow patterns in vertical and horizontal pipes, Formulation of bubbles and drops and their size distribution, Solid – fluid systems, Forces acting on stagnant and moving solids, Flow through porous medium, capillary tube model and its applications.

UNIT V INTERPHASE TRANSPORT IN NON-ISOTHERMAL SYSTEMS 15

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

1. Bird R.B., Stewart, W. E. and Lightfoot, E. N., “Transport Phenomena”, 2nd Edn.John Wiley and Sons, 2002.
2. Brodkey, R. S. and Hershey, H. C., “Transport Phenomena – A Unified Approach”, Brodkey Publishing, 2003.
3. Welty, J.R., Wicks, C. E. and Wilson, R. E., “Fundamentals of Momentum, Heat Mass Transfer”, 5th Edn., John Wiley and Sons, 2007.

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 9

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 9

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 9

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 9

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 9

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

TOTAL: 45 PERIODS

OUTCOME:

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

REFERENCES

1. Prausnitz, J.M., Lichten thaler R.M. and Azevedo, E.G., Molecular thermodynamics offluid-phase Equilibria, 3rd Edn, Prentice Hall Inc., New Jersey, 1999.
2. Rao., Y.V.C., Chemical Engineering Thermodynamics, University Press, Hyderabad,2005
3. Tester, J. W. and M. Modell, Thermodynamics and Its Applications. 3rd Edn. PrenticeHall, New Jersey, 1997..

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 constitutents, 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

Adsorption on Solid Catalysts. Rate Equations. Complex Catalytic Reactions. Experimental Reactors. Model Discrimination and Parameter Estimation. Sequential Design of Experiments. Physicochemicafl tests

UNIT III TRANSPORT PROCESSES WITH REACTIONS CATALYZED BY SOLIDS 16

Reaction of a component of a fluid at the surface of a solid. Mass and heat transfer resistances. Molecular-, Knudsen-, and surface diffusion in pores. Diffusion and reaction in a catalyst particle. Influence of diffusion limitations on the selectivities of coupled reactions. Criteria for the importance of intraparticle diffusion limitations. Multiplicity of steady states in catalyst particles. Diagnostic experimental criteria for the absence of internal and external mass transfer limitations. Nonisothermal particles.

UNIT IV CATALYST DEACTIVATION 11

Types of Catalyst Deactivation. Kinetics of Catalyst Poisoning. Kinetics of Catalyst Deactivation by Coke Formation.

UNIT V THE MODELING OF CHEMICAL REACTORS. 21

Approach. Aspects of Mass-, Heat- and Momentum Balances. Fixed bed catalytic reactors. Design and Modeling of Fixed Bed Reactors. Pseudohomogeneous Models-The Basic One- Dimensional Model. One-Dimensional Model with Axial Mixing. Two-Dimensional Pseudohomogeneous Models. One-Dimensional Model Accounting for Interfacial and Intraparticle Gradients. Two-Dimensional Heterogeneous Models. Fluidized bed and transport reactors -Introduction. Technological Aspects of Fluidized Bed and Riser Reactors. Some Features of the Fluidization and Transport of Solids. Heat Transfert in Fluidized Beds. Modeling of Fluidized Bed Reactors. Modeling of a Transport of Riser Reactor. Catalytic Cracking of Vacuum Gas Oil.

TOTAL : 75 PERIODS

OUTCOME:

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

REFERENCES

1. An Introduction to Chemical Engineering Kinetics & Reactor Design, Charles G. Hill, Jr., JohnWiley & Sons, 1977.
2. Chemical Reaction Engineering, Octave Levenspiel, John Wiley & Sons, 3^{rd} Edition, 1999.
3. Chemical Reactor Analysis and Design, Gilbert F. Froment and Kenneth B. Bischoff, John Wiley & Sons, 2nd Edition, 1990.
4. Elements of Chemical Reaction Engineering, H. Scott Fogler, Prentice Hall International Series, 3rd Edition, 2000.
5. Fundamentals of Chemical Reaction Engineering, Mark E. Davis and Robert J.Davis, McGrawHill, 2003.

CX5111 COMPUTATIONAL PROGRAMMING CHEMICAL ENGINEERING LABORATORY

L T P C
0 0 4 2

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
    - Runga-Kutta method
7. Predictor and corrector methods:
    - Milne-Simpson method
    - Adam Bash forth method
8. Rating of shell and tube heat exchanger.
9. Rating of Distillation column.
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
    - o C compiler
    - o MATLAB Single user license
    - o Open source office
    - o 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

1. Finlayson, B. A., Introduction to Chemical Engineering Computing, John Wiley & Sons, New Jersey, 2006.

CX5201	**CHEMICAL PROCESS DESIGN**	**L T P C**
		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

1. Douglas, J.M., "Conceptual Design of Chemical Process", McGraw Hill, New York,1988.
2. Smith, R., "Chemical Process Design", McGraw Hill, New York, 1995.

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 membranepemeators 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, addiuctive 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

1. Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
2. King, C. J., “Separation Processes”, Tata McGraw Hill Co., Ltd., 1982.
3. Nakagawal, O. V., “Membrane Science and Technology”, Marcel Dekker, 1992.
4. Rousseau, R. W., “Handbook of Separation Process Technology”, John Wiley, New York, 1987.

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 9

Z – Transform and inverse Z – transform properties, Discrete – Time Response of dynamic system, Pulse Transfer Function, Closed Loop System Stability.

UNIT V DIGITAL FEEDBACK CONTROLLERS 9

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

1. Bequette, B. W., Process Control: Modeling, Design, and Simulation, Prentice Hall,2003
2. Kannan M. Moudgalya, Digital Process Control, John Wiley & Sons Ltd,2007
3. Stephanopolous, G., “Chemical Process Control”, Prentice Hall of India, New Delhi,1985.

CX5252 MULTICOMPONENT DISTILLATION L T P C
3 0 0 3

OBJECTIVE:

- To provide comprehensive knowledge on multicomponent distillation principle, thermodynamic property evaluation and design.

UNIT I THERMODYNAMIC PRINCIPLES 9

Fundamental Thermodynamic principles involved in the calculation of vapor – liquid equilibria and enthalpies of multi component mixtures – Use of multiple equation of state for the calculation of K values – Estimation of the fugacity coefficients for the vapor phase of polar gas mixtures – calculation of liquid – phase activity coefficients.

UNIT II THERMODYNAMIC PROPERTY EVALUATION 9

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 9

General considerations in the design of columns – Column sequencing – Heuristics for column sequencing – Key components – Distributed components – Non-Distributed components – Adjacent keys. Definition of minimum reflux ratio – calculation of Rm for multi component distillation – Underwood method – Colburn method.

UNIT IV VARIOUS METHODS OF MCD COLUMN DESIGN 9

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 9

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 mulitcomponent distillation, fundamental concepts and its applications.

REFERENCES

1. Holland, C.D., “Fundamentals of Multi Component Distillation”, McGraw Hill Book Company,1981
2. Van Winkle, “Distillation Operations”, McGraw Hill Publications, 1987.

CX5211 SEMINAR

L T P C
0 0 4 2

OBJECTIVE:

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

OUTCOME:

- The sudents will get better emplyability 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

L T P C
3 2 0 4

OBJECTIVE:

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

UNIT I INTRODUCTION 9+6

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

UNIT II STEADY STATE LUMPED SYSTEMS 9+6

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 9+6

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

Analysis laminar flow in pipe, sedimentation, boundary layer flow, conduction, heat exchanger, heat transfer in packed bed, diffusion, packed bed adsorption, plug flow reactor, hierarchy in model development, classification and solution of partial differential equations - Empirical modeling, parameter estimation, population balance and stochastic modeling.

TOTAL : 75 PERIODS

OUTCOME:

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

REFERENCES

1. Felder, R. M. and Rousseau, R. W., "Elementary Principles of Chemical Processes",John Wiley, 2000.
2. Franks, R. G. E., "Mathematical Modelling in Chemical Engineering", John Wiley, 1967.
3. Luyben, W.L., "Process Modelling Simulation and Control", McGraw-Hill Book Co.,1973.
4. Ramirez, W., "Computational Methods in Process Simulation", 2nd Edn.,Butterworths, New York, 2000.

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

OBJECTIVE:

- To apply the principles learned from variorius 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 variorius 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 interation.

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

Equation of motion for a single particle, calculation of drag, motion of a particle in twodimensions, effects of unsteady and non-uniform flow fields, effect of acceleration, effect of coupling; Interaction between particles, mechanism of interaction, interparticle forces, hard sphere model, soft sphere model, discrete element modeling, semi-empirical methods, kinetic theory, force chains.

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.

TOTAL: 45 PERIODS

OUTCOME:

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

REFERENCES

1. Clift, R., Weber, M.E. and Grace, J.R., Bubbles, Drops, and Particles, Academic Press, New York, 2005.
2. Crowe, C. T., Sommerfeld, M. and Tsuji, Y., Multiphase Flows with Droplets and Particles, CRC Press, 2011
3. Fan, L. S. and Zhu, C., Principles of Gas-solid Flows, Cambridge University Press, 2005
4. Govier, G. W. and Aziz. K., “The Flow of Complex Mixture in Pipes”, Van Nostrand Reinhold, New York, 1972.
5. Kleinstreuer, C., Two-phase Flow: Theory and Applications, Taylor & Francis, 2003
6. Rhodes, M., Introduction to Particle Technology, John Wiley & Sons, New York.2008.
7. Wallis, G.B., “One Dimensional Two Phase Flow”, McGraw Hill Book Co., New York,

CX5072 **FLUIDIZATION ENGINEERING** **L T P C**
3 0 0 3

OBJECTIVE:

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

UNIT I INTRODUCTION 5

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 12

General bed behaviour, pressure drop, Flow regimes, Incipient Fluidization, Pressure fluctuations, Phase Holdups, Measurements Techniques, Empirical Correlations for Solids holdup, liquid holdup and gas holdup. Flow models – generalized wake model, structural wake model and other important models.

UNIT III SOLID MIXING AND SEGREGATION 8

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 12

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 8

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

1. Fan, L. S., "Gas- liquid Solid Fluidization Engineering", Butterworths, 1989,
2. Kunii, D. and Levenspiel, O., "Fluidization Engineering", 2nd Edn., Butterworth-Heinemann, London, 1991.
3. Kwauk, M., "Fluidization - Idealized and Bubbleless, with applications", Science Press, 2009.

CX5073 **PIPING AND INSTRUMENTATION** **L T P C**
3 0 0 3

OBJECTIVES

- Students gain knowledge on fundamentals of piping engineering, pipe hydraulics, piping supports and instrumentation.

UNIT I FUNDAMENTALS OF PIPING ENGINEERING 9

Definitions, Piping Components their introduction, applications. Piping MOC, Budget Codes and Standards, Fabrication and Installations of piping.

UNIT II PIPE HYDRAULICS AND SIZING 9

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 9

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 9

Different types of support based on requirement and its calculation.

UNIT V INSTRUMENTATION 9

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

1. Luyben, W. L.," Process Modeling Simulation and Control for Chemical Engineers,McGraw Hill, 1990.
2. Piping Design Handbook edited by Johan J McKetta, CRC Press, 1992.
3. Piping Handbook, 6 th edition, M.L. Nayyar, P.E., Mc Graw-Hill, Inc

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 9

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

UNIT II 9

Risk assessment – introduction and available methodologies, Risk assessment steps, Hazard identification, Hazard assessment (consequence analysis), probabilistic hazard assessment (Fault tree analysis)

UNIT III **9**

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 **9**

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

UNIT V **9**

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

1. Crowl,D.A and Louvar,J.F., Chemical process saftery; Fundamentals with applications,prentice hall publication inc., 2002.
2. Houstan,H.B., Process safety analysis, Gulf publishing company, 1997
3. Khan,F.I and Abbasi,S.A., Risk assessment of chemical process industries; Emerging technologies, Discovery publishing house, New Delhi, 1999.

CX5074 **COMPUTATIONAL FLUID DYNAMICS** **L T P C**
3 0 0 3

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 **9**

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 DIFFERNCE APPROXIMATION **9**

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 15

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 6

Pressure velocity coupling, staggered grid, SIMPLE algorithm, PISO algorithm for steady and unsteady flows

UNIT V GRID GENERATION 6

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

1. Anderson, J. D., "Computational Fluid Dynamics: The Basics with Applications", McGraw-Hill, 1995.
2. Chung T.J Computational Fluid Dynamics Cambridge University Press 2003.
3. Fletcher, C. A. J., "Computational Techniques for Fluid Dynamics", Springer Verlag, 1997.
4. Ghoshdastidar, P.S., "Computer Simulation of flow and heat transfer" Tata McGraw –Hill Publishing Company Ltd. 1998.
5. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", NarosaPublishing House, New Delhi, 2001.
6. Subas, V. Patankar "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation, 1980.
7. Taylor, C and Hughes, J.B. "Finite Element Programming of the Navier Stock Equation", Pineridge Press Limited, U.K., 1981.
8. Versteeg, H.K. and Malalasekera, W., "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", Pearson Education Ltd., 2007.

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 9

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 9

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 13

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 14

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.

TOTAL: 45 PERIODS

OUTCOME:

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

REFERENCES

1. Hanson, C., "Recent Advances in Liquid Extraction", Pergamon Press, London, 1972.
2. Hanson, C., Baird, M. H. I. and Lo, T. C., "Hand Book of Solvent Extraction", Wiley – International, New York, 1983.
3. Laddha, G. S. and Degaleesan, T. E., "Transport Phenomena in Liquid Extraction", Tata McGraw Hill, New Delhi, 1976.
4. Treybal, R. E., "Liquid Extraction", McGraw Hill, New York, 1963.

PP5391 CORROSION ENGINEERING L T P C

3 0 0 3

OBJECTIVES

- To impart knowledge on corrosion in petroleum refining.

UNIT I TYPES OF CORROSION AND TESTING METHODS 9

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 9

Corrosion inhibitors, electroplated coatings, conversion coatings, anodizing, hot dipping, spray metal coatings, zinc coating by alloying, electrophoteric 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 9

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 12

Corrosion in structure – corrosion of stainless steels – corrosion in power equipments, corrosion in electrical and electronic industry – corrosion and selection of materials of pulp and paper plants – corrosion aspects in nuclear power plants – corrosion of surgical implants and prosthetic devices.

UNIT V CORROSION AND COUNTRY'S ECONOMY 6

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

1. Fontana, M.G., "Corrosion Engineering", Edn 3, McGraw Hill, 1989
2. Roberge, P.R., Handbook of Corrosion Engineering, McGraw-Hill,2000

CX5076 INDUSTRIAL INSTRUMENTATION L T P C
3 0 0 3

OBJECTIVES

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

UNIT I 5

Introduction – Variables, Units & standards of measurement, Measurement terms – characteristic. Data Analysis.

UNIT II 12

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 12

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 **9**

Fundamentals of Automatic process control – Control algorithms-Automatic controllers – Electronic controllers -Electric controllers (Traditional) - Hydraulic controllers – Fluidics -Programmable controllers.

UNIT V **7**

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

1. Astrom K.J., Bjon wittenmark, Computer controlled systems, Prentice- Hall of India, New Delhi1994.
2. Cartis Johnson, Process Control Instrumentation Technology, Prentice-Hall of India, New Delhi 1993.
3. Considine D M and Considine G D “Process Instruments Controls” Handbook 3rd Edition, McGraw – Hill Book Co., NY, 1990.
4. Eckman D.P. “Industrial Instrumentation”, Wiley Eastern Ltd., 1989.
5. Ernest Doebelin, Measurement systems, McGraw – Hill Book, Co., NY, 1975.
6. Fribance, “Industrial Instrumentation Fundamentals” ,Mc Graw Hill Co. Inc. New York 1985
7. Scborg D E,.Edgar T.F and Mellichamp D.A, “Process Dynamics and Control” John Wiley 1989.

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 **5**

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 **10**

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 10

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 10

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 10

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

1. Angela M.Dean and Daniel Voss, Design and Analysis of Experiments, Springer texts in Statistics, 2000.
2. Douglus C.Montgomery, Design and Analysis of Experiments, John Wiley & Sons,2005
3. Philip J.Ross, Taguchi Techniques for Quality Engineering, Prentice Hall, 1989.

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 9

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 9

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

UNIT III 9

Safety in plant design and layout. Risk Assessment.

UNIT IV 9

Safety measures in handling and storage of chemicals, Process plant, personnel Protection, First Aid.

UNIT V **9**

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

1. Coulson J.M and Richardson J.F., Chemical Engineering, Vol. 1 (Chaper 4) Asian Book House Pvt. Ltd., New Delhi. 1998.
2. Frank P.Less, Loss Prevention in Process Industries, Vol. I and Vol II Butterworth, London, 1980.
3. Guidelines for Chemical Process Quantitative Risk Analysis, Published by Centre for Chemical Process Safety of the AICh.E., New York, USA. 1989.
4. Major Hazard Control, Manual by International Labour Organization, Geneva, 1990.
5. Marshal, V.C Major Chemical Hazards, Ellis Harwood Ltd. Chichester, U.K. 1987.
6. R.K.Sinnott, Coulson & Richardson's Chemical Engineering, Vol.6 Butlerworth – Heinmann. Oxford, 1996.
7. Raghavan, K.V and A.A Khan, Methodologies in Hazard Identification and Risk Assessment, Manual by CLRI., Dec, 1990.
8. Safety in Chemical and Petrochemical Industries, Report of the Inter Ministry Group, Dept. of Chemicals and Petrochemicals, Govt.of India, ICMA Publications. 1986.
9. Well, G.S Safety Process Plants Design, George Godwin Ltd., London, John Wilelys and Sons, New York, 1980.

CX5092 **ENERGY MANAGEMENT** **L T P C**

3 0 0 3

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 **9**

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 **9**

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 **9**

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 **9**

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 **9**

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

1. Gramlay, G. M., Energy , Macmillan Publishing Co., New York, 1975.
2. Krentz, J. H., Energy Conservation and Utilisation , Allyn and Bacur Inc., 1976.
3. Loftiness, R.L. – Energy Hand Book, Van Nostrand Reinhold Company, New York, 1978.
4. Rused, C. K., Elements of Energy Conservation , McGraw-Hill Book Co., 1985.

CX5093 **PILOT PLANT AND SCALE UP METHODS** **L T P C**
3 0 0 3

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 **9**

Introduction to scale-up methods, pilot plants and models and principles of similarity.

UNIT II DIMENSIONAL ANALYSIS AND SCALE-UP CRITERION **9**

Dimensional analysis, regime concept, similarity criterion and scale up methods used in chemical engineering.

UNIT III SCALE-UP OF HEAT TRANSFER EQUIPMENT **9**

Typical problems in scale-up of mixing equipment and heat transfer equipment

UNIT IV SCALE-UP OF MASS TRANSFER EQUIPMENT **9**

Scale-up of distillation columns and packed towers for continuous and batch processes

UNIT V SCALE-UP OF CHEMICAL REACTORS **9**

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

1. Donald G. Jordan,"Chemical Process Development" (Part 1 and 2), Interscience Publishers,1988.
2. Johnstone and Thring ," Pilot Plants Models and Scale-up methods in Chemical Engg.", McGraw Hill, New York, 1962.
3. Marko Zlokarnik, "Dimensional Analysis and Scale-up in Chemical Engg.", Springer Verlag, Berlin, Germany, 1986.

CX5077 PROJECT ENGINEERING OF PROCESS PLANTS L T P C
3 0 0 3

OBJECTIVE

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

UNIT I 9

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

UNIT II 9

Planning the process, Strategic and Managerial Planning, Organising the process planning, cost and costing, Cost Control systems, Economic Balancing, Network Planning, Methods (PERT/CPM), Engineering Flow Diagrams, Cost requirements, Analysis and Estimation of Process Feasibilities (Technical/Economical) Analysis, Cost – Benefit Ratio Analysis, Project Budgeting, Capital Requirements, capital Market, Cash Flow Analysis, Break even strategies.

UNIT III 9

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

UNIT IV 9

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 9

Government regulations on procurement of raw materials and its allocation. Export – Import regulations, Pricing policy, Industrial licensing procedure, Excise and other commercial taxes, Policies on depreciation and corporate tax, Labour laws, Social welfare legal measurements, Factory act, Regulations of Pollution Control Board.

TOTAL: 45 PERIODS

OUTCOME:

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

REFERENCES

1. Cheremisinoff, N. P., Practical Guide to Industrial Safety: Methods for Process Safety Professionals, CRC Press, 2001
2. Couper, J. R., Process Engineering Economics, CRC Press, 2003.
3. Perry, J. H. "Chemical Engineer's Hand Book", 8th Ed., McGraw Hill, New York, 2007.
4. Peters, M. S., Timmerhaus, C. D. and West, R. E., "Plant Design and Economics for Chemical Engineers", 5th Edn., McGraw Hill, 2003.
5. Silla, H., Chemical Process Engineering: Design and Economics, CRC Press, 2003
6. Vinoski, W., Plant Management Handbook, Pearson Education, Limited, 1998
7. Watermeyer, P., Handbook for Process Plant Project Engineers, John Wiley and Sons, 2002

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

1. Diwaker, U. W. "Introduction to Applied Optimization", Kluwer, 2003.
2. Edgar, T. F., Himmelblau, D. M. and Ladson, L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill, New York, 2003.
3. Joshi, M. C. and Moudgalya, K. M., "Optimization, Theory and Practice", Narosa, New Delhi, 2004.
4. Rao, S. S., Engineering Optimization: Theory and Practice, New Age Publishers, 2000

CX5094 HYDROGEN AND FUEL CELLS L T P C
3 0 0 3

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

Hydrogen – physical and chemical properties, salient characteristics. Production of hydrogen – steam reforming – water electrolysis – gasification and woody biomass conversion – biological hydrogen production – photo dissociation – direct thermal or catalytic splitting of water.

UNIT II HYDROGEN STORAGE AND APPLICATIONS 9

Hydrogen storage options – compressed gas – liquid hydrogen – Hydride – chemical Storage – comparisons. Hydrogen transmission systems. Applications of Hydrogen.

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 an d velocity distribution in single cell as well as stack.
- Design and stack making process for real field applications

REFERENCES

1. Rebecca L. and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Corporation, Oklahoma (2005)
2. Bent Sorensen (Sørensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications, Elsevier, UK (2005)
3. Kordesch, K and G.Simader, Fuel Cell and Their Applications, Wiley-Vch, Germany (1996).
4. Hart, A.B and G.J.Womack, Fuel Cells: Theory and Application, Prentice Hall, NewYork Ltd., London (1989)
5. Jeremy Rifkin, The Hydrogen Economy, Penguin Group, USA (2002).
6. Viswanathan, B and M AuliceScibioh, Fuel Cells – Principles and Applications, Universities Press (2006)

CX5079 **ENVIRONMENTAL NANOTECHNOLOGY** **L T P C**
3 0 0 3

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 abalation, 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, microfludics and lab on chip, catalytic and photocatalyic applications, Nonmaterials for ground water remediation, nanomaterials as adsorbents, 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
2. Environmental nanotechnology, Mark Wisener, Jeo Yues Bolteru, 2007, McGraw Hill.
3. The Chemistry of Nanomaterials, Sysnthesis, Properties and applications. Edited by C.N.R.Rao. Mulller, A.K.Cheetham Copyright 8 2004 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim
4. Handbook of Nanotechnology, Edi-Bharat Bhushan, Springer, 2004.

CX5080 **OPERATIONS RESEARCH** **L T P C**
3 0 0 3

OBJECTIVE

- To learn various methods of solving engineering problems using mathematical tools.

UNIT I MATHEMATICAL PROGRAMMING 12

Introduction, Linear Programming, Solution by simplex method, Duality, Sensitivity analysis, Dual simplex method, Integer Programming, Branch and bound method, Geometric programming and its application.

UNIT II DYNAMIC PROGRAMMING 10

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 9

Network representation of projects, Critical path calculation, construction of the timechart and resource leveling, Probability and cost consideration in project scheduling, Project control. Graphical Evaluation and Review Techniques.

UNIT IV ELEMENTS OF QUEUING THEORY 7

Basic elements of the Queuing model, M/M/1 and M/M/C Queues.

UNIT V ELEMENTS OF RELIABILITY THEORY 7

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

1. Carter, M. W. and Price, C. C., Operations Research: A Practical Introduction Contributor, CRC Press, 2001.
2. Edgar, T. F., Himmelblau, D. M. and Ladson, L. S., "Optimization of Chemical Processes", 2nd Ed., McGraw Hill, New York, 2003.
3. Hillier, F. S., and Lieberman, G. J., Introduction to Operations Research, McGraw- Hill, 2005
4. Taha, H. A., "Operations Research, An introduction", 6th Ed., Prentice Hall of India, New Delhi, 2006.

CX5081 INTELLECTUAL PROPERTY RIGHTS L T P C

3 0 0 3

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 5

Introduction – Invention and Creativity – Intellectual Property (IP) – Importance – Protection of IPR – Basic types of property (i). Movable Property ii. Immovable Property and iii. Intellectual Property.

UNIT II **10**

IP – Patents – Copyrights and related rights – Trade Marks and rights arising from Trademark registration – Definitions – Industrial Designs and Integrated circuits – Protection of Geographical Indications at national and International levels – Application Procedures..

UNIT III **10**

International convention relating to Intellectual Property – Establishment of WIPO – Mission and Activities – History – General Agreement on Trade and Tariff (GATT).

UNIT IV **10**

Indian Position Vs WTO and Strategies – Indian IPR legislations – commitments to WTO-Patent Ordinance and the Bill – Draft of a national Intellectual Property Policy – Present against unfair competition.

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.

TOTAL: 45 PERIDOS

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

1. Eli Whitney, United States Patent Number: 72X, Cotton Gin, March 14, 1794.
2. Intellectual Property Today: Volume 8, No. 5, May 2001, [www.iptoday.com].
3. Subbaram N.R. "Handbook of Indian Patent Law and Practice ", S. Viswanathan, Printers and Publishers Pvt. Ltd., 1998.
4. Using the Internet for non-patent prior art searches, Derwent IP Matters, July 2000.

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**

Need for developing Environment, Health and Safety systems in work places. Status and relationship of Acts, Regulations and Codes of Practice .Role of trade union safety representatives. International initiatives. Ergonomics and work place.

UNIT II **OCCUPATIONAL HEALTH AND HYGIENE** **9**

Definition of the term occupational health and hygiene. Categories of health hazards. Exposure pathways and human responses to hazardous and toxic substances. Advantages and limitations of environmental monitoring and occupational exposure limits. Hierarchy of control measures for occupational health risks. Role of personal protective equipment and the selection criteria. Effects on humans, control methods and reduction strategies for noise, radiation and excessive stress.

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

Elements of a health and safety policy and methods of its effective implementation and review. Functions and techniques of risk assessment, inspections and audits. Investigation of accidents-Principles of quality management systems in health and safety management. Relationship between quality manuals, safety policies and written risk assessments. Records and other documentation required by an organisation for health and safety. Industry specific EHS issues.

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 Services2005
2. Environmental and Health and Safety Management by Nicholas P. Cheremisinoff and Madelyn L. Graffia, William Andrew Inc. NY, 1995
3. The Facility Manager's Guide to Environmental Health and Safety by Brian Gallant, Government Inst Publ., 2007.

CX5096 MEMBRANE TECHNOLOGIES FOR WATER AND WASTEWATER TREATMENT L T P C 3 0 0 3

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-Membarne 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

Microfiltration – Ultrafiltration- Nano Filtration – Reverse Osmosis – Electro dialysis- Pervaporation -Membrane manufactures – Membrane Module/Element designs – Membrane System components – Design of Membrane systems - pump types and Pump selection – Plant operations – Economics of Membrane systems

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

1. Jorgen Wagner, Membrane Filtration handbook, Practical Tips and Hints, Second Edition, Revision2, Osmonics Inc., 2001
2. K. Yamamoto and Urase T, Membrane Technology in Environmental management, special issue, Water Science and technology, Vol.41, IWA Publishing, 2000
3. Mulder, M., Basic Principle of Membrane Technology, Kluwer Academic Publishers, 1996
4. Noble, R.D. and Stern, S.A., Membrane Separations Technology: Principles and Applications, Elservier, 1995.
5. Symon Jud, MBR Book – Principles and application of MBR in water and wastewater treatment,Elservier, 2006
6. Water Environment Federation (WEF), Membrane Systems for Wastewater Treatment, McGraw-Hill, USA, 2005

ES5091 **INDUSTRIAL POLLUTION PREVENTION** **L T P C**
3 0 0 3

OBJECTIVES:

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

UNIT I **9**

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 **9**

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 **9**

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 **9**

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 **9**

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:

1. Paul L. Bishop, “Pollution Prevention: Fundamentals and Practice”, McGraw-Hill International, 2000.
2. World Bank Group, “Pollution Prevention and Abatement Handbook-Towards Cleaner Production”, World Bank and UNE, Washington D.C., 1998.
3. Freeman, H.M, Industrial Pollution Prevention Handbook”, McGraw Hill”, 1995.

4. Industrial Wastewater Management Handbook, Azad, Hardom Singh, Editor-in-Chief, McGraw Hill, New York
5. Industrial Pollution Control –Issues and Techniques. Nancy, J. Sell, Van Nostrand Reinhold Co, NY.

CX5082 GAS TRANSPORTATION L T P C
3 0 0 3

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 9

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

UNIT II 9

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 9

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 9

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 9

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.

TOTAL: 45 PERIODS

OUTCOME:

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

REFERENCES

1. Liu, H., R. L. Gandhi, M. R. Carstens and G. Klinzing, "Freight pipelines: current status and anticipated use,"(Report of American Society of Civil Engineers (ASCE) Task Committee on freight Pipelines), ASCE J. of Transportation Engr., vol. 124, no. 4, pp.300-310, Jul/Aug 1998.
2. Liu, H and T. Marrero, "Pipeline engineering research and education at universitie in the United States," C.D. Proc. of Intl. Conf. on Engr. Education (ICEE-98), Rio de Janeiro Brazil, 15 pages, August 17-20, 1998.

CX5083 GREEN CHEMISTRY AND ENGINEERING L T P C
3 0 0 3

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 9

Overview of Major Environmental Issues, Global Environmental Issues. Air Quality Issues. Water Quality Issues, Ecology, Natural Resources, Description of Risk. Value of Risk Assessment in the Engineering Profession. Risk-Based Environmental Law. Risk Assessment Concepts. Hazard Assessment. Dose-Response. Risk Characterization.

UNIT II 9

Pollution Prevention- Pollution Prevention Concepts and Terminology. Chemical Process Safety. Responsibilities for Environmental Protection. Environmental Persistence. Classifying Environmental Risks Based on Chemical Structure. Exposure Assessment for Chemicals in the Ambient Environment.

UNIT III 9

Green Chemistry. Green Chemistry Methodologies. Quantitative/Optimization-Based Frameworks for the Design of Green Chemical Synthesis Pathways. Green Chemistry Pollution Prevention in Material Selection for Unit Operations. Pollution Prevention for Chemical Reactors. Pollution Prevention for Separation Devices. Pollution Prevention Applications for Separative Reactors. Pollution Prevention in Storage Tanks and Fugitive Sources.

UNIT IV 9

Process Energy Integration. Process Mass Integration. Case Study of a Process Flow sheet-Estimation of Environmental Fates of Emissions and Wastes.

UNIT V 9

Magnitudes of Environmental Costs. A Framework for Evaluating Environmental Costs. Hidden Environmental Costs. Liability Costs. Internal Intangible Costs. External Intangible Costs. Introduction to Product Life Cycle Concepts. Life-Cycle Assessment. Life-Cycle Impact Assessments. Streamlined Life-Cycle Assessments. Uses of Life- Cycle Studies.

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

1. Allen, D.T., Shonnard, D.R, Green Engineering: Environmentally Conscious Design of Chemical Processes. Prentice Hall PTR 2002.
2. MukeshDoble and Anil Kumar Kruthiventi, Green Chemistry and Engineering, Elsevier, Burlington, USA, 2007.

CX5084 **FUEL CELL TECHNOLOGY** **L T P C**
3 0 0 3

OBJECTIVES

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

UNIT I **9**

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 **9**

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 **9**

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 **9**

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

UNIT V **9**

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

1. Bard,A. J. , L. R., Faulkner,Electrochemical Methods, Wiley, N.Y.(2004) Ref Book.
2. Basu,S.(Ed) Fuel Cell Science and Technology,Springer, N.Y.(2007).
3. Fuel cell tech nology handbook, edited by Gregor Hoogers, CRC Press 2003.
4. Liu, H.,Principles of fuel cells, Taylor & Francis, N.Y. (2006).
5. O'Hayre, R.P.,S. Cha,W. Colella, F.B.Prinz, Fuel Cell Fundamentals,Wiley, NY (2006).