SRI VENKATESWARA COLLEGE OF ENGINEERING
(An Autonomous Institution, Affiliated to Anna University, Chennai)
SRIPERUMBUDUR TK. - 602 117
REGULATION – 2016
M.E. CHEMICAL ENGINEERING
CURRICULUM AND SYLLABUS

SEMESTER I

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	MA16186	Advanced Numerical Methods for Chemical Engineers	3	1	0	4
2	CL16101	Advanced Chemical Reaction Engineering	3	0	0	3
3	CL16102	Computational Methods in Chemical Engineering	2	1	0	3
4	CL16103	Fluid Phase Equilibria	2	1	0	3
5	CL16104	Process Modeling and Simulation	3	0	0	3
6		Elective I	3	0	0	3
PRACTICALS						
7	CL16111	Instrumental methods of analysis lab	0	0	3	2
		TOTAL	**16**	**3**	**3**	**21**

SEMESTER II

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16201	Chemical Process Design	2	1	0	3
2	CL16202	Advanced Process Control	2	1	0	3
3	CL16203	Modern Separation Processes	3	0	0	3
4		Elective II	3	0	0	3
5		Elective III	3	0	0	3
6		Elective IV	3	0	0	3
PRACTICALS						
7	CL16211	Process Modeling and Simulation Lab	0	0	3	2
		TOTAL	**16**	**2**	**3**	**20**

SEMESTER III

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16301	Advanced Transport Phenomena	3	0	0	3
2		Elective V	3	0	0	3
3		Elective VI	3	0	0	3
PRACTICALS						
4	CL16311	Project Work (Phase I)	0	0	12	6
		TOTAL	**9**	**0**	**12**	**15**

SEMESTER IV

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICALS						
1	CL16411	Project Work (Phase II)	0	0	24	12
		TOTAL	**0**	**0**	**24**	**12**

ELECTIVE I

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16001	Electrochemical Engineering	3	0	0	3
2	CL16002	Environmental Engineering	3	0	0	3
3	CL16003	Fluidization Engineering	3	0	0	3
4	CL16004	Membrane Technologies for Wastewater Treatment	3	0	0	3
5	CL16005	Polymer Technology	3	0	0	3

ELECTIVE II

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16006	Electrochemical Process Engineering	3	0	0	3
2	CL16007	Environmental Management	3	0	0	3
3	CL16008	Multiphase flow	3	0	0	3
4	CL16009	Soil Pollution Engineering	3	0	0	3
5	CL16010	Solvent Extraction	3	0	0	3

ELECTIVE III

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16011	Electrochemical Processes for Clean Technology	3	0	0	3
2	CL16012	Environmental Policies and Legislation	3	0	0	3
3	CL16013	Computational Fluid Dynamics for Chemical Engineers	3	0	0	3
4	CL16014	Waste Management and Energy Recovery	3	0	0	3
5	CL16015	Project Engineering of Process Plants	3	0	0	3

ELECTIVE IV

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16016	Fuel Cell Technology	3	0	0	3
2	CL16017	Environmental Risk Assessment	3	0	0	3
3	CL16018	Wastewater Engineering	3	0	0	3
4	CL16019	Risk Analysis and Management	3	0	0	3
5	CL16020	Design of Experiments	3	0	0	3

ELECTIVE V

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16021	Hydrogen and Fuel Cells	3	0	0	3
2	CL16022	Environmental Sustainability	3	0	0	3
3	CL16023	Gas Transportation	3	0	0	3
4	CL16024	Pollution Abatement	3	0	0	3
5	CL16025	Operations Research for Chemical Engineers	3	0	0	3

ELECTIVE VI

SL. No	COURSE CODE	COURSE TITLE	L	T	P	C
1	CL16026	Green Chemistry and Engineering	3	0	0	3
2	CL16027	Environmental Nanotechnology	3	0	0	3
3	CL16028	Piping and Instrumentation	3	0	0	3
4	CL16029	Safety and Hazard Control	3	0	0	3
5	CL16030	Total Quality Management for Chemical Engineers	3	0	0	3

MA16186 ADVANCED NUMERICAL METHODS FOR CHEMICAL ENGINEERS

L	T	P	C
3	1	0	4

UNIT I ALGEBRAIC EQUATIONS 12

Systems of linear equations – Jacobi, Gauss Seidel, SOR methods, Thomas algorithm for tridiagonal systems; Systems of nonlinear equations - successive approximation method, methods for improved convergence, Newton Method and its variants, continuation methods for multiple solutions.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS – IVPS 12

RungeKutta Methods, step size control and estimates of error, numerical stability, solution of stiff ODEs, ODE-IVPs coupled with algebraic equations.

UNIT III ORDINARY DIFFERENTIAL EQUATIONS – BVPS 12

Finite difference method, orthogonal collocation method, orthogonal collocation with finite element method, Galerkin finite element method, shooting technique.

UNIT IV PARTIAL DIFFERENTIAL EQUATIONS – FINITE DIFFERENCE METHODS 12

Parabolic equations – Different explicit and implicit methods, alternating direction explicit and implicit methods; Elliptic equations – Point iterative methods, line iterative methods, ADI methods; First order hyperbolic equations – method of characteristics, different explicit and implicit methods; numerical stability analysis, method of lines.

UNIT V PARTIAL DIFFERENTIAL EQUATIONS – FINITE ELEMENT METHOD 12

Partial differential equations – Finite element method - orthogonal collocation method, orthogonal collocation with finite element method, Galerkin finite element method.

TOTAL: 60 PERIODS

Course Outcome

- Gain knowledge on the algebraic equations for the linear system.
- Solving the stiff ODs, ODE-IVPs coupled with algebraic equations.
- Distinguish the analysis methods for the boundary value problems
- Interpret the different explicit and implicit methods for the solution of finite difference.
- Using finite element method to solve partial differential equations

REFERENCES:

1. Gupta, S.K., Numerical Methods for Engineers, New Age Publishers, 1995
2. Jain, M. K., S. R. Iyengar, M. B. Kanchi, R. K. Jain, Computational Methods for Partial Differential Equations, New Age Publishers, 1993.

CL16101 ADVANCED CHEMICAL REACTION ENGINEERING

L	T	P	C
3	0	0	3

UNIT I KINETICS OF HETEROGENEOUS REACTIONS 9

Catalytic reactions, rate controlling steps, Langmuir-Hinshelwood model, EleyRideal-mechanism, steady state approximation, noncatalytic fluid-solid reactions, shrinking and un-reacted core model.

UNIT II EXTERNAL DIFFUSION EFFECTS IN HETEROGENEOUS REACTIONS 9

Mass and heat transfer coefficients in packed beds, quantitative treatment of external transport effects, modeling diffusion with and without reaction.

UNIT III CATALYSIS AND CATALYTIC REACTORS 9

Catalyst properties – Adsorption Isotherms – Surface reactors – Desorption – Rate limiting steps – Is adsorption of Cumene rate limiting – Cumene decomposition – Chemical vapour deposition catalyst deactivation – reaction engineering in microelectronic device fabrication.

UNIT IV INTERNAL TRANSPORT PROCESSES IN POROUS CATALYSTS 9

Interpellet mass and heat transfer, evaluation of effectiveness factor, mass and heat transfer with reaction.

UNIT V ANALYSIS AND DESIGN OF HETEROGENEOUS REACTORS 9

Isothermal and adiabatic fixed bed reactors, non-isothermal and non-adiabatic fixed bed reactors. Two-phase fluidized bed model, slurry reactor model, trickle bed reactor model. Experimental determination and evaluation of reaction kinetics for heterogeneous systems.

TOTAL: 45 PERIODS

Course Outcome

- Ability to exhibit the skill to develop kinetic equation for the heterogeneous reactions.
- Impart the mass and heat transfer coefficients in packed bed reactor with modelling of diffusion.
- Distinguish between the catalytic and non-catalytic reactors with the rate limiting steps.
- Evaluate the effectiveness factor for catalytic reaction with the heat and mass transfer effects.
- Develop the kinetic equation of the suspended and packed bed reactors for both single and two phase.

REFERENCES:

1. Carberry, J. J., “Chemical and Catalytic Reaction Engineering”, Dover Publications, 2001.
2. Froment, G. F. and Bischoff, K. B., “Chemical Reactor Design and Analysis”, 2nd Edition, John Wiley & Sons, New York, 1997.

CL16102	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING	L	T	P	C
		2	1	0	3

UNIT I MATRIX ALGEBRA **9**

Matrix, determinants and properties – Elementary Row transformations – Applications in Chemical Engineering - Eigenvalue Problem - Solution of a set of algebraic equations; Solution of a set of ordinary differential equations; Solution of a set of nonhomogeneous first order ordinary differential equations - Applications of eigen value problems: rank of Matrix – Implications in Chemical Engineering.

UNIT II VECTOR SPACES & ORTHOGONOLIZATION **9**

Introduction of vector space - Metric, Norm, Inner Product space- Functions - Onto, into, one to one function - completeness of space. Vectors - Linear combination of vectors, dependent/independent vectors - Orthogonal and orthonormal vectors; Gram-Schmidt orthogonalization; Contraction Mapping: Definition; Applications in Chemical Engineering.

UNIT III STABILITY, BIFURCATION & CHAOS **9**

Stability analysis – Lyapunov stability Analysis; Bifurcation theory – Hopf Bifurcation – Flip bifurcation – tuning fork bifurcation – transcritical bifurcation – Chaos – Limit cycles – Phase Plane analysis.

UNIT IV ORDINARY DIFFERENTIAL EQUATIONS **9**

Boundary conditions; Principle of Linear superposition - Special ODEs and Adjoint operators: Properties of adjoint operator; Theorem for eigenvalues and eigen functions – Sturm Louiville Theory, Separation of Variables, Green's functions – Physical interpretation of Green's function – Wronskian determinant and linear independence of solutions.

UNIT V PARTIAL DIFFERENTIAL EQUATIONS **9**

Partial Differential equations - Classification of equations; Characteristic curves - Solution of linear, homogeneous PDEs by separation of variables: Cartesian coordinate system & different classes of PDEs; Cylindrical coordinate system ;Spherical Coordinate system - Solution of non-homogeneous PDEs by Green's theorem - Solution of PDEs by Similarity solution method - Solution of PDEs by Integral method - Solution of PDEs by Laplace transformation - Solution of PDEs by Fourier transformation.

TOTAL: 45 PERIODS

Course Outcome

- Determine the solution of algebraic equations, ordinary differential equations, nonhomogeneous first order ordinary differential equations
- Gain knowledge on vector spaces and orthogonalization in chemical Engineering applications.
- Impart the knowledge on bifurcation theory, limit cycles and hopf bifurcation to do stability analysis.
- Explore the special properties of adjoint operator, theorem for eigenvalues and eigen functions.
- Ability to solve using Laplace transformation and Fourier transformations.

REFERENCES:

1. Pushpavanam, S., Mathematical Methods in Chemical Engineering, Prentice Hall of India, 1998.
2 Jenson, V. G., Jeffreys, G. F., Mathematical Methods in Chemical Engineering, Elsevier, 1997.
3. Arvind Varma and M. Morbidelli, Mathematical Methods in Chemical Engineering, Oxford University Press, 2008.
4. R. G. Rice & D. D. Do, Applied Mathematics and Modeling for Chemical Engineers, Wiley 2012.
5. N. W. Loney ,Applied Mathematical Methods for Chemical Engineers , CRC Press 2006.
6. Kuznetsov, A., Elements of Applied Bifurcation Theory, Springer, 1995.

CL16103 **FLUID PHASE EQUILIBRIA** **L T P C**

2 1 0 3

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

Course Outcome

- Explore the basic concept of fluid phase equilibria and Maxwell's relations.
- Gain knowledge on the stability and phase equilibria of the thermodynamic systems.
- Explore the Wilson, NRTL, UNIQUAU equations and UNIFAC methods for the ideal and non-ideal solutions.
- Gain ability to develop phase equilibrium based on vapor liquid equilibrium.
- Develope the chemical equilibrium for the homogenous gas and liquid phase reactions.

REFERENCES:

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

CL16104 PROCESS MODELLING AND SIMULATION

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION 9

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

UNIT II STEADY STATE LUMPED SYSTEMS 9

Degree of freedom analysis, single and network of process units, systems yielding linear and non-linear algebraic equations, flow sheeting – 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

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

Analysis of compressible flow, heat exchanger, packed columns, plug flow reactor, solution of ODE boundary value problems.

UNIT V UNSTEADY STATE DISTRIBUTED SYSTEM 9

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: 45 PERIODS

Course Outcome

- Gain knowledge on the fundamental of modeling and simulation, system analysis and evaluation
- Apply degree of freedom analysis to find out solution of linear and non-linear chemical system.
- Develop mathematical model for Chemical Processes and simulate tank systems.
- Simulate heat exchangers and reactors and identify the solution of boundary value problems.
- Evaluate the mathematical model and validate with the simulation results obtained in the chemical processes.

REFERENCES:

1. Franks, R. G. E., “Mathematical Modelling in Chemical Engineering“, John Wiley, 1967.
2. Bequette, B. W., Process Control: Modeling, Design and Simulation, Prentice Hall.
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.
5. Felder, R. M. and Rousseau, R. W., “Elementary Principles of Chemical Processes“,John Wiley, 2000.

CL16111 INSTRUMENTAL METHODS OF ANALYSIS LAB

L	T	P	C
0	0	3	2

LIST OF EXPERIMENTS:

1. Estimation of copper (Cu) and chromium (Cr) in a given soil sample using Atomic Absorption Spectroscopy (AAS).
2. Determination of the concentration of Potassium permanganate using UV Visible Spectrophotometer.
3. Study the effect of temperature in the hydrated sample of copper sulphate using Thermo Gravimetric Analyzer (TGA).
4. Determination of the prisms of iso-propyl alcohol in the given sample using Gas Chromatography.
5. Estimation of iron (Fe) and nickel (Ni) in a given wastewater sample using Atomic Absorption Spectroscopy (AAS).
6. Estimation of zinc (Zn) and manganese (Mn) in a given wastewater sample using Atomic Absorption Spectroscopy (AAS).
7. Determination of the corrosion rate of a given sample using tafel plot.
8. Determination of standard redox potential of a given sample using cyclic voltammetry.
9. Determination of the concentration of malachite green using UV Visible Spectrophotometer.
10. Demonstration of High Performance Liquid Chromatography (HPLC).

TOTAL: 45 PERIODS

Course outcome

- Estimate the heavy metal quantity present in the tested sample using Atomic Absorption Spectroscopy (AAS).
- Gain knowledge on the importance of UV visible spectrophotometer analysis.
- Ability to exhibit the skill to operate Gas Chromatography for the analysis of gas samples.
- Exhibit the skill to operate High Performance Liquid Chromatography for the analysis of liquid samples.
- Explore knowledge on determination of standard redox potential and corrosion rate of a given sample.

LIST OF EQUIPMENTS:

1. UV Visible Spectrophotometer
2. Laser Particle Size Diffraction Analyzer
3. Gas Chromatography
4. High Performance Liquid Chromatography
5. Atomic Absorption Spectrophotometer
6. Thermo Gravimetric Analyzer
7. Automated Capillary Micro Flow Porometer
8. Electrochemical Workstation

CL16201 **CHEMICAL PROCESS DESIGN**

L	T	P	C
2	1	0	3

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

Course outcome

- Gain Knowledge on the importance of chemical process Design and the approaches to design
- Develop the complete process design of reactors and separators.
- Gain ability to synthesize reaction, reaction mechanism and to construct separation systems.
- Explore the distillation Sequencing Using thermal coupling.
- Develop heat exchanger networks and various process utilities used in chemical industries

REFERENCES:

1. Smith, R., “Chemical Process Design”, McGraw Hill, New York, 1995.
2. Douglas, J.M., “Conceptual Design of Chemical Process”, McGraw Hill, New York,1988.
3. Seider, W.D. and Seader, J.D., “Product and Process Design Principles: Synthesis, Analysis and Evaluation”, John Wiley, 2nd ed., 2004.
4. Biegler, L.T., Grossmann, E.I. and Westerberg, A.W., “Systematic Methods of Chemical Process Design”, Prentice Hall International Inc. Series in the Physical and Chemical Engg. Sciences, 1997.

CL16202 ADVANCED PROCESS CONTROL

	L	T	P	C
	2	1	0	3

UNIT I ADVANCED CONTROL STRATEGIES 9

Feed forward control , cascade control, dead time compensation, split range control, 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.

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, Dahlin's algorithms, Dead – beat algorithm, ringing, IMC algorithm, simplified model predictive algorithm.

TOTAL: 45 PERIODS

Course outcome

- Explore the dynamic response of advanced control systems.
- Develop and design Internal Model based PID control system.
- Enumerate the control loop interaction and multi-variable control strategies.
- Describe control strategies and Discrete – Time Response of dynamic system.
- Design of digital feedback controllers and algorithms.

REFERENCES:

1. Bequette, B. W., Process Control: Modeling, Design and Simulation, Prentice Hall, 2003.
2. Coughnowr, D., " Process Systems Analysis and Control ", 3rd Edn., McGraw Hill, New York, 2008.
3. Pradeep B. Deshpande, Raymond H. Ash , Elements of Computer Process Control with Advanced Control Applications , Instrument Society of America,1981.
4. Stephanopolous, G., "Chemical Process Control", Prentice Hall of India, New Delhi,2003 1985.

CL16203 MODERN SEPARATION PROCESSES

L	T	P	C
3	0	0	3

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 membrane permeators 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, adductive crystallization, other separation processes, supercritical fluid extraction, oil spill management, industrial effluent treatment by modern techniques.

TOTAL: 45 PERIODS

Course outcome

- Explore the recent advances in separation techniques based on the properties of substances.
- Enumerate the mechanism and equipment used in membrane separations.
- Identify the importance of chormotographic techniques and separation based on adsorption.
- Ability to exhibit the skill to develop ionic separation and electrophoresis..
- Apply the latest concepts like pervaporation, lyophilisation etc., in Chemical process industries.

REFERENCES:

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

CL16211	PROCESS MODELING AND SIMULATION LAB	L	T	P	C
		0	0	3	2

Matlab

Introduction of Matlab; Numerical Integration; Polynomial Curve fitting; simultaneous algebraic equations ; Matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++.

ASPEN

Introduction of Aspen Plus; Physical and thermodynamic property estimations; Mass and Energy balances; Simulation and design of reactors, distillation column, heat exchangers, absorbers; Simulation of flow in pipes, performing sensitivity analysis; analysis of pipeline hydraulics using Aspen Hysys, Pipesys.

CFD

Introduction of CFD, Construction of geometry and grid generation ; Implementation of boundary conditions ;Fluid flow modeling; convection and diffusion problems ; pressure, velocity, temperature profile; Turbulence modeling; multiphase flow; Unsteady state simulations.

TOTAL: 45 PERIODS

Course outcome

- Develop mathematical models for various chemical processes.
- Ability to perform modeling and simulation of flow systems using CFD.
- Modeling of various chemical processes and to simulate using MATLAB.
- Apply various simulation approaches in chemical engineering systems.
- Simulate a process using process simulators (ASPEN Plus/ ASPEN Hysys).

REFERENCES:

1. Kamal I.M. Malah, “MATLAB Numerical Methods with Chemical Engineering Applications” McGraw Hill Education, 2014.
2. Jana A.K., “Chemical Process Modelling and Computer Simulation” Prentice Hall.2008.
3. Jana A.K., “Process Simulation and Control using ASPEN” Prentice Hall.2009.
4. Versteeg, H.K. and Malalasekera, W., “An Introduction to Computational Fluid Dynamics: The Finite Volume Method” Pearson Education Limited, 2007.

CL16301	ADVANCED TRANSPORT PHENOMENA	L	T	P	C
		3	0	0	3

UNIT I INTERPHASE TRANSPORT IN ISOTHERMAL SYSTEMS 6

Definition of Friction Factors, Friction Factors for Flow in Tubes, Pressure Drop Required for a Given Flow, Flow Rate for a Given Pressure Drop, Friction Factors for Flow around Spheres Determination of the Diameter of a Falling Sphere, Friction Factors for Packed Columns. Case studies.

UNIT II MACROSCOPIC BALANCES FOR ISOTHERMAL FLOW SYSTEMS AND POLYMERIC LIQUIDS 12

The Macroscopic Mass Balance, The Macroscopic Momentum Balance, The Macroscopic Mechanical Energy Balance, Estimation of the Viscous Loss, Power Requirement for Pipeline Flow, Use of the Macroscopic Balances for Steady-State, Pressure Rise and Friction Loss in a Sudden Enlargement, Isothermal Flow of a Liquid through an Orifice.

Examples of the Behavior of Polymeric Liquids, Rheometry and Material Functions, Non-Newtonian Viscosity and the Generalized Newtonian Models, Laminar Flow of a compressible Power-Law Fluid in a Circular Tube, Flow of a Power-Law Fluid in a Narrow Slit, Tangential Annular Flow of a Power- Law Fluid, Elasticity and the Linear Viscoelastic Models, Molecular Theories for Polymeric Liquids. Practical applications. Case studies.

UNIT III INTERPHASE TRANSPORT IN NON ISOTHERMAL SYSTEMS 9

Definitions of Heat Transfer Coefficients, Calculation of Heat Transfer Coefficients from Experimental Data , Analytical Calculations of Heat Transfer Coefficients for Forced Convection through Tubes and Slits , Heat Transfer Coefficients for Forced Convection in Tubes , Design of a Tubular Heater , Heat Transfer Coefficients for Forced Convection around Submerged Objects , Heat Transfer Coefficients for Forced Convection through Packed Beds , Heat Transfer Coefficients for Free and Mixed Convection, Heat Loss by Free Convection from a Horizontal Pipe , Heat Transfer Coefficients for Condensation of Pure Vapors on Solid Surfaces. Case studies.

UNIT IV MACROSCOPIC BALANCES FOR NON ISOTHERMAL SYSTEMS 9

The Macroscopic Energy Balance, The Macroscopic Mechanical Energy Balance, Use of the Macroscopic Balances to Solve Steady-State Problems with Flat Velocity Profiles, The Cooling of an Ideal Gas, Mixing of Two Ideal Gas Streams, Parallel- or Counter- Flow Heat Exchangers, Flow of Compressible Fluids through Head Meters. Case studies.

UNIT V INTERPHASE TRANSPORT IN NON ISOTHERMAL MIXTURES 9

Definition of Transfer Coefficients in One Phase, Analytical Expressions for Mass Transfer Coefficients, Correlation of Binary Transfer Coefficients in One Phase, Evaporation from a Freely Falling Drop, Mass Transfer in Creeping Flow through Packed Beds, Mass Transfer to Drops and Bubbles, Definition of Transfer Coefficients in Two Phases, Determination of the Controlling Resistance, Estimation of the Interfacial Area in a Packed Column, Estimation of Volumetric Mass Transfer Coefficients. Case studies.

TOTAL: 45 PERIODS

Course Outcome

- Enumerate the mechanism of momentum, heat and mass transport for steady and unsteady flow.
- Establish momentum, energy and mass balances for a given system at macroscopic and microscopic scale.
- Elucidate the governing equations to obtain velocity, temperature and concentration profiles.
- Model the momentum, heat and mass transport under turbulent conditions.
- Develop analogies among momentum, energy and mass transport.

REFERENCES:

1. Bird R.B., Stewart, W. E. and Lightfoot, E. N., "Transport Phenomena", 2nd Edn., John Wiley and Sons, 2007.
2. Welty, J.R., Wicks, C. E. and Wilson, R. E., "Fundamentals of Momentum, Heat and Mass Transfer", 5th Edn., John Wiley and Sons, 2010.
3. Brodkey, R. S. and Hershey, H. C., "Transport Phenomena – A Unified Approach", Brodkey Publishing, 2004.
4. Shyy, W., Thakur, S.S., Ouyang., Liu, J. and Blosch, E., " Computational Techniques for Complex Transport Phenomena" , Cambridge University Press, I st edition, 1997.
5. R.W.Fahien, "Elementary Transport Phenomena", McGraw-Hill, New York, 1983.

CL16001 **ELECTROCHEMICAL ENGINEERING**

L	T	P	C
3	0	0	3

UNIT I **9**

Review basics of electrochemistry: Faraday's law -Nernst potential –Galvanic cells – Polarography, The electrical double layer: It's role in electrochemical processes – Electro capillary curve –Helmoltz layer –Guoy –Steven's layer –fields at the interface.

UNIT II **9**

Mass transfer in electrochemical systems: diffusion controlled electrochemical reaction- the importance of convention and the concept of limiting current. over potential, primary secondary current distribution –rotating disc electrode.

UNIT III **10**

Introduction to corrosion, series, corrosion theories derivation of potential-current relations of activities controlled and diffusion controlled corrosion process. Potential-pH diagram, Forms of corrosion- definition, factors and control methods of various forms of corrosion-corrosion control measures- industrial boiler water corrosion control – protective coatings – Vapor phase inhibitors – cathodic protection, sacrificial anodes –Paint removers.

UNIT IV **8**

Electro deposition –electro refining –electroforming –electro polishing –anodizing – Selective solar coatings, Primary and secondary batteries –types of batteries, Fuel cells.

UNIT V **9**

Electrodes used in different electrochemical industries: Metals-Graphite –Lead dioxide – Titanium substrate insoluble electrodes –Iron oxide –semi conducting type etc. Metal finishing-cell design. types of electrochemical reactors, batch cell, fluidized bed electrochemical reactor, filter press cell, Swiss roll cell, plug flow cell, design equation, figures of merits of different type of electrochemical reactors.

TOTAL: 45 PERIODS

Course outcome

- Analyze the electrode synthesis by different methods and its application in effluent treatment.
- Explain the different electrochemical methods to treat the industrial effluent and about combined methods.
- Illustrate the various membrane treatment methods.
- Apply the principles of electrochemistry in mitigating the various types of corrosion

REFERENCES:

1. Hartmut Wendt and Gerhard Kreysa, "Electrochemical Engineering: Science and Technology in Chemical and Other Industries" Springers, 1999.
2. Picket, "Electrochemical Engineering", Prentice Hall. 1977.
3. Newman, J. S., " Electrochemical systems ", Prentice Hall, 1973.
4. Barak, M. and Stevenge, U. K., " Electrochemical Power Sources - Primary and Secondary Batteries" 1980.
5. Mantell, C., "Electrochemical Engineering", McGraw Hill, 1972.

CL16002 ENVIRONMENTAL ENGINEERING

L	T	P	C
3	0	0	3

UNIT I ENVIRONMENT AWARENESS 9

Environment- friendly chemical process; Hazard and risk analysis; Environmental Audit.

UNIT II CHEMICAL ENGINEERING PROCESSES 9

Unit Operations – application of - Abatement of water pollution; Current strategies to control air pollution; Disposal of solid wastes.

UNIT III RECYCLING METHODOLOGY 9

Economic recovery and recycling of waste; Transport fuel- Bio-diesel for a cleaner environment.

UNIT IV CLEAN TECHNOLOGY 9

Towards Eco- friendly products of chemical industry; Pesticides –Their transfer and Transformation in the environment, Biological and electrochemical technology for effluent treatments.

UNIT V POLLUTION PREVENTION 9

Mass exchange network synthesis for pollution control and minimization Implications of environmental constraints for process design, policies for regulation of environmental impacts, Concept of common effluent treatment; Environmental legislations, Role of Government and Industries.

TOTAL: 45 PERIODS

Course outcome

- Impart the knowledge on the environmental chemical engineering processes.
- Discuss unit operations required for treatment water, air and solid wastes.
- Ability to perform hazard and risk analysis and to apply the appropriate recylcing methodology.
- Analyzing the technologies to produce the eco-friendly products from chemical industries.

REFERENCES:

1. Rao, C.S Environmental Pollution control Engineering, Wiley- Eastern Ltd. 1991.
2. Peavy H.S. Rowe D.R., and George Technologies, Environmental Engineering, McGraw Hill Book Company, NY, 1985.
3. Rao M.N and H.V.N. Rao. “Air pollution” ,Tata McGraw Hill Publishing Co. Ltd.1989.
4. Theodore L and Buomlore A.J Air pollution control equipments. Prentice Hall Inc, NY. 1982.

CL16003 **FLUIDIZATION ENGINEERING** **L T P C**
3 0 0 3

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 SOLIDS 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

Course outcome

- Aquire knowledge on the behaviour of fluids in fluidized bed
- Evaluate the characterization of particles in different fluidization regimes and to gain knowledge on various flow models
- Comparing the heat and mass transfer in fluidization systems
- Obtaining the knowledge on the applicability of fluidized beds in chemical industries and ability to do power calculations

REFERENCES:

1. Fan, L. S., "Gas- liquid Solid Fluidization Engineering", Butterworths, 1989.
2. Kwauk, M., "Fluidization - Idealized and Bubbleless, with applications", Science Press, 1992.
3. Kunii, D. and Levenspiel, O., "Fluidization Engineering", 2nd Edn., Butterworth-Heinemann, London, 1991.

CL16004	MEMBRANE TECHNOLOGIES FOR WASTEWATER TREATMENT	L	T	P	C
		3	0	0	3

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**

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

Course outcome

- Gain fundamental knowledge related to physicochemical phenomena governing membrane separation processes
- Explain the factors affecting the selection, design and operation and of membrane separation processes.
- Describe challenges of membrane fouling and cleaning
- Explain the concepts of zero liquid discharge

REFERENCES:

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

CL16005 **POLYMER TECHNOLOGY** **L T P C**

3 0 0 3

UNIT I GENERAL ASPECTS OF POLYMERS 9

Classification, mechanisms and methods of polymerization, properties-molecular weight, glass transition temperature, crystallinity, thermal, electrical and mechanical properties.

UNIT II APPLICATION ORIENTED POLYMERS 9

Resins-PVC-Silicon oil and resin, fibrous polymers-nylon 66, polyacrylonitrile, adhesivesepoxides, phenol formaldehyde, urea formaldehyde.

UNIT III ELASTOMERS 9

Natural rubber, styrene-butadiene, poly isopropane-neoprene, silicon rubber, thermoplastic elastomer.

UNIT IV PROCESSING OF POLYMERS 9

Processing additives, plasticzer, antiaging additives, surface and optical properties, modifiers, fire retardants, additives for rubber and elastomer, various molding techniques.

UNIT V PHYSICAL AND CHEMICAL TESTING OF PLASTICS 9

Mechanical properties, tensile strength and hardness, electrical properties, volume resistivity, dielectric strength, optical properties glass, light transmission and refractive index, chemical analysis-elemental and functional analysis.

TOTAL: 45 PERIODS

Course outcome

- Describe the techniques and limitations in synthesis of polymers.
- Identifying the structure-processing-property relationship of polymers and elastomers.
- Apply various processing and manufacturing techniques of polymers
- obtain the knowledge on characterization of polymers.

REFERENCES:

1. Miles, D.C &Briston, J.H. Polymer Technology, Chemical publishing Co: Inc: NY:1979.
2. Maturine Morton, “Rubber Technology”, 3rd Edition, Van Nostrand Re Inhold, NY:1987.
3. Masic, L. “Thermoplastics Materials Engineering”, Applied science publishers Ltd, NY:1986

CL16006 ELECTROCHEMICAL PROCESS ENGINEERING

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION OF ELECTROCHEMICAL ENGINEERING 9

Industrial importance of electrolytic processes, Basic concepts and definitions, Criteria for reactor performance, Electrochemical and catalytic reactions and reactors. Fundamentals of reaction kinetics, rate of electrochemical reaction, electrochemical thermodynamics, practical cell voltage requirements and polarization, single electrochemical reactions, potentiostatic operations of first order reaction and galvanostatic operation of first order reactions.

UNIT II ASPECTS OF MASS AND HEAT TRANSFER IN ELECTROLYTIC CELL SYSTEMS 9

Basic aspects of fluid dynamics, mass transfer-mass flux in a fully developed turbulent regime, entrance and exit effects, obtaining numerical values of mass transfer coefficient by calculation and experiment, mass transfer in two phase flow, energetic and energy balances, CSTR with general order reactions, effect of mass transport and side reaction.

UNIT III RATE PROCESSES AND REACTION MODELS 9

Rate processes, kinetics of elementary reactions, reaction mechanism and rate laws, transition state theory, derivation of kinetic relationships, reaction models.

UNIT IV REACTOR MODELS 9

General considerations, batch reactor and continuous reactor. Fed batch, continuous, cell recycle, plug flow reactor, two stage reactors, Reactor dynamics and stability. Reactors with non-ideal mixing. Other types of reactors- fluidized bed reactors; packed bed reactors, bubble column reactors, trickle bed reactors.

UNIT V ELECTROLYTIC REACTOR DESIGN, SELECTION AND SCALE UP 9

Electrolytic reactor designs, Electrolytic reactor selection, scale up of electrolytic reactors, effect of scale up on mass transfer, effect of scale up on current distribution, multiple electrode models and time factors.

TOTAL: 45 PERIODS

Course outcome

- Elucidate in detail the fundamental concepts in Electro Chemical Processing.
- Elaborate of Heat and mass transfer concepts in electrolytic cell.
- Access of various kinetic models with its mechanism.
- Illustrate the various kinetic models with its applications.

REFERENCES:

1. F.Goodridge, K.Scott, Electrochemical process engineering. A guide to the design of electrolytic plant, Plenum Press, 1995.
2. Bockris, John O'M, Bockris, Ralph E.White, B.E. Conway, Modern aspects of electrochemistry, volume 28, Plenum Press, New York 1985.
3. Newman and Thomas- Alyea, Electrochemical systems, 3rd edition, Wiley & Sons, Hoboken, 2004.
4. Pletcher. D and Walsh F.C, Industrial electrochemistry, 2nd edition, Chapman and Hall, London, 1990.

5. Hartmut Wendt, Gerhard Kreysa, Electrochemical engineering, Science and technology in chemical and other industries, Springer, 1999.
6. Krishnan Rajeshwar, JORGE G. IBANEZ, Environmental Electrochemistry, Fundamentals and applications in Pollution Abatement, ACADEMIC PRESS, Inc,1997.

CL16007 **ENVIRONMENTAL MANAGEMENT**

L	T	P	C
3	0	0	3

UNIT I **8**

Environmental legislations in India , Europe, USA and Canada – Development of Legislation, Standards and Guidelines, USEPA.

UNIT II **9**

Water (Prevention and control of Pollution) Act 1974, Air (Prevention and Control of Pollution) Act 1981, Environmental Protection Act 1986, Hazardous Waste Management Rules and Guidelines for siting of industries. Standards for discharge of treated liquid effluent into water bodies, including inland water bodies, and sea, standards for disposal of air emissions (SO_2,SPM,NH_3, H_2S and HC) into atmosphere.

UNIT III **8**

Factory Act 1987 of India, Occupational health and safety requirements and standards of ILO, Compliance of rules and guidelines of Factory Act applicable to industries.

UNIT IV **10**

Principles of Environmental impact assessment and audit guidelines and legislature requirements for siting of industrial units in estates/complex. Preparatory procedures for EIA study, Evaluation of impact on air, water and land environment.

UNIT V **14**

Principles of Environmental Auditing, Cleaner Technologies in Industrial Processes and evaluation of processes Auditing techniques in Preparing EA. Monitoring of ambient environment, including air, water and land, noise, liquid and solid waste management.

TOTAL: 45 PERIODS

Course outcome

- Impart the Standards of various guidelines of legislations with environment
- Acquire the knowledge on various act in Occupational safety.
- Implementation of various acts related with Air, water and Hazards
- Infer the assessment in checking quality of air

REFERENCES:

1. Mike Russo., Environmental Management: Readings and Cases, 2nd Edition, Sage Publications, 2008.
2. Canter, W.L., Environmental Impact Assessment, McGraw-Hill Inc., 1992.
3. Jain, R.K., Urban, L.V., Stacey, G.S. and Balbach, H.E., Environmental Assessment, McGraw-Hill, 1993.
4. UNEP/IED Technical Report Serial No.2., Environmental Auditing, 1990.

CL16008 **MULTIPHASE FLOW** **L T P C**

3 0 0 3

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 two dimensions, 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

Course outcome

- Identifying the parameters of Multiphase flow with its characteristics.
- Illustrate the particle of fluid with its interaction studies.
- Elaborate the conservation equation applied in fluid flow.
- Acquiring the knowledge on various predicted models in fluid 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. Wallis, G.B., “One Dimensional Two Phase Flow”, McGraw Hill Book Co., New York, 1969.

CL16009 **SOIL POLLUTION ENGINEERING**

L	T	P	C
3	0	0	3

UNIT I PHYSICS AND CHEMISTRY OF SOIL **8**

Soil formation – composition – soil fabric – mass-volume relationship – Index properties and soil classification – hydraulic and consolidation characteristics – Chemical properties – soil pH– Surface charge and point of zero charge– Anion and Cation exchange capacity of clays– Specific surface area- bonding in clays-soil pollution-factors governing soil-pollutant interaction.

UNIT II INORGANIC AND ORGANIC GEOCHEMISTRY **9**

Inorganic geochemistry – Metal contamination – Distribution of metals in soils – Geochemical processes controlling the distribution of metals in soils – Chemical analysis of metal in soil – Organic geochemistry – Organic contamination – Distribution of NAPLs in soils – Process controlling the distribution of NAPLs in soil – Chemical analysis of NAPLs in soils.

UNIT III TRANSPORT OF CONTAMINANTS IN SOIL **9**

Transport processes – advection – diffusion – dispersion – chemical mass transfer processes - sorption and desorption – precipitation and dissolution – oxidation and reduction – acid base reaction – complexation – ion exchange – volatilization – hydrolysis – biological process- microbial transformation of heavy metals.

UNIT IV GROUND IMPROVEMENT TECHNIQUES IN WASTE MANAGEMENT **9**

Role of Ground Improvement-Drainage and Ground Water Lowering-Electro Osmotic Methods- Diaphragm walls-Thermal and Freezing methods – In-situ Densification – Deep Compaction - Dynamic Compaction -Blasting Sand piles pre-loading with sand drains- Stone Columns Lime piles- Earth reinforcement -rock bolts Cables and guniting Geotextiles as reinforcement Filtration. Drainage and Erosion control.

UNIT V SOIL REMEDIATION TECHNOLOGIES **10**

Contaminated site characterization – Containment – Soil vapour extraction – Soil washing – Solidification and Stabilization – Electro-kinetic remediation – Thermal desorption – Vitrification – In-situ and Ex-situ Bioremediation – Phytoremediation – Soil fracturing – Biostimulation – Bioaugmentation –Chemical oxidation and reduction.

TOTAL: 45 PERIODS

Course outcome

- Acquire the fundamental concepts of soil with its characteristics
- Elucidate the Organic and Inorganic geochemistry
- Elaborate the various processes in analyzing the contaminants of soil
- Discuss the various types of remediation of soil

REFERENCES:

1. Calvin Rose, An Introduction to the Environmental Physics of Soil, Water and Water heds, Cambridge University Press, 2004.
2. Paul Nathanail C. and Paul Bardos R., Reclamation of Contaminated Land, John Wiley & Sons Limited, 2004.
3. Hari D. Sharma and Krishna R. Reddy, Geo-Environmental Engineering : Site
4. Marcel Vander Perk, Soil and Water Contamination from Molecular to Catchment Scale, Taylor &Francis, 2006.

CL16010 SOLVENT EXTRACTION

	L	T	P	C
	3	0	0	3

UNIT I EQUILIBRIUM IN LIQUID-LIQUID SYSTEM 12

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 coefficients.

UNIT II DIFFERENTIAL / STAGE-WISE EQUILIBRIUM CONTACT OPERATIONS 12

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 9

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 12

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

Course outcome

- Predicting the diffusivity in liquids and its transport processes
- Acquiring the knowledge on Equilibrium operation in stagewise contact.
- Illustrate the characteristics of dispersion with types of extractors
- Elaborate the different column of liquid liquid extraction

REFERENCES:

1. Laddha, G. S. and Degaleesan, T. E., ”Transport Phenomena in Liquid Extraction”, Tata McGraw Hill, New Delhi, 1978.
2. Teh C. Lo, Malcolm H. I. Baird, Carl Hanson “Hand Book of Solvent Extraction” Krieger Publishing Company, 1991.
3. Hanson, C., “Recent Advances in Liquid Extraction”, Pergamon Press, London,1972.
4. Treybal, R. E., “Liquid Extraction”, McGraw Hill, New York, 1963.
5. Jan Rydberg “Solvent Extraction Principles and Practice”, second edition, Revised and

Expanded, CRC Press, 2004.

CL16011 ELECTROCHEMICAL PROCESSES FOR CLEAN TECHNOLOGY

L	T	P	C
3	0	0	3

UNIT I THE ELECTROCHEMICAL CELL AND REACTOR 9

The electrochemical cell, Faraday's Law and current efficiency, Electrode potential and current density, The Electrochemical reactor – Production Capacity, Energy Requirements and Cell Voltage, Temperature Control, Hydrodynamics and mass transport, Reactor Operating Factors. Electrode Materials – Chemical Suitability, Electrode Materials in Synthesis and Effluent treatment.

UNIT II ELECTROCHEMICAL CELL DESIGN AND ENGINEERING 9

Operating Factors in Electrochemical Reactor Design – Modes of Operation, In-cell and Ex-cell Reactions, Recycle Operation, Electrical Power supply, Distribution of Powers in Electrolysers. Cell Design, Design Concepts. Electrochemical Reactor Designs – Parallel Plate. Electrolysers, General Purpose Flow Electrolyser, Other Reactor Design, Reactor Design for Multiphase Reactions. Electrochemical Reactor Analysis, Mass Transport and Reactor Design.

UNIT III ELECTROCHEMICAL MEMBRANE PROCESS 9

Transport in Membranes and Diaphragms- Transport Process in Diaphragms, Membrane and the Transport of Ions. Ion-Selective Membranes in Salt Regeneration, Recycling and Effluent Treatment, Electrohydrolysis, Treatment of Plating Bath Rinse Waters and Waste Streams. Bipolar Membranes, Characteristics of Bipolar Membranes. Electrochemically enhanced Microfiltration and Ultrafiltration.

UNIT IV THE TREATMENT OF INDUSTRIAL PROCESS STREAMS AND EFFLUENTS 9

Treatment of Organic Chemicals-Direct Anodic Oxidation, Chlorine and Chlorinated compounds, Indirect Oxidation Process. Treatment of Waste Water Containing Inorganic Compounds-Cyanides and Thiocynates, Chromium Liquors, Sterilisation of Water and Waste. Metal Recovery by Electrode position- Electrode position from Single Metal Ion Solutions, Metal separation from Mixed Metal Ion solutions, Combined Electrochemical Processes.

UNIT V ORGANIC AND INORGANIC ELECTROCHEMICAL SYNTHESIS 9

Types of Organic Electro synthesis, Limitations in Solubility, Indirect electro synthesis, Heterogeneous Redox Catalysis, Electrosorbed hydrogen, Direct electro organic Synthesis, Examples of electro organic Synthesis. Inorganic electrochemical Process- The Electro winning and Refining of Metals, Electrochemical Generation of Arsine, Other Processes, The scope for Inorganic Electro synthesis.

TOTAL: 45 PERIODS

Course outcome

- Explain the fundamental principles of electrochemistry and its properties.
- Design Electrochemical cells and reactors using principles of mass transfer
- Apply the principles of electrochemistry in membrane process technology
- Discuss the application of combined electrochemical processes for industrial effluent treatment and metal recovery
- Demonstrate the fundamental knowledge of organic and inorganic electrochemical

synthesis

REFERENCES:

1. Scott.K, Electrochemical processes for clean technology, Standards media, 1995.
2. Marcel Mulder, Basic Principles of Membrane Technology, 2nd edition, Kluwer Academic Publishers, 2003.
3. Ralph E. White, Electrochemical Cell Design, Springer, 2011.
4. Krishnan Rajeshwar, JORGE G. IBANEZ, Environmental Electrochemistry, Fundamentals and applications in Pollution Abatement, ACADEMIC PRESS, Inc,1997.
5. Bockris, John O'M, Bockris, Ralph E.White, B.E. Conway, Modern aspects of electrochemistry, volume 28, Plenum Press, New York 1985.

CL16012 ENVIRONMENTAL POLICIES AND LEGISLATION

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION **9**

Indian Constitution and Environmental Protection – National Environmental policies – Precautionary Principle and Polluter Pays Principle – Concept of absolute liability – multilateral environmental agreements and Protocols – Montreal Protocol, Kyoto agreement, Rio declaration – Environmental Protection Act, Water (P&CP) Act, Air (P&CP) Act – Institutional framework (SPCB/CPCB/MoEF).

UNIT II WATER (P&CP) ACT, 1974 **8**

Power & functions of regulatory agencies - responsibilities of Occupier Provision relating to prevention and control Scheme of Consent to establish, Consent to operate – Conditions of the consents – Outlet – Legal sampling procedures, State Water Laboratory – Appellate Authority – Penalties for violation of consent conditions etc. Provisions for closure/directions in apprehended pollution situation.

UNIT III AIR (P&CP) ACT, 1981 **8**

Power & functions of regulatory agencies - responsibilities of Occupier Provision relating to prevention and control Scheme of Consent to establish, Consent to operate – Conditions of the consents – Outlet – Legal sampling procedures, State Air Laboratory – Appellate Authority– Penalties for violation of consent conditions etc. Provisions for closure/directions in apprehended pollution situation.

UNIT IV ENVIRONMENT (PROTECTION) ACT 1986 **13**

Genesis of the Act – delegation of powers – Role of Central Government – EIA Notification – Sitting of Industries – Coastal Zone Regulation - Responsibilities of local bodies mitigation scheme etc., for Municipal Solid Waste Management – Responsibilities of Pollution Control Boards under Hazardous Waste rules and that of occupier, authorisation – Biomedical waste rules – responsibilities of generators and role of Pollution Control Boards.

UNIT V OTHER TOPICS **7**

Relevant Provisions of Indian Forest Act, Public Liability Insurance Act, CrPC, IPC - Public Interest Litigation - Writ petitions - Supreme Court Judgments in Landmark cases.

TOTAL: 45 PERIODS

Course outcome

- Illustrate the national environmental principles and policies, international environmental agreements
- Discuss the application of regulatory and legal aspects of Water act
- Explain the application of regulatory and legal aspects of Air act
- Elucidate the role of pollution control boards in implementing the Environment (Protection) act
- Illustrate the procedure for court proceedings and penal codes for Environment pollution cases

REFERENCES:

1. CPCB, "Pollution Control acts, Rules and Notifications issued there under "Pollution Control

Series – PCL/2/1992, Central Pollution Control Board, Delhi, 1997.
2. Shyam Divan and Armin Roseneranz “Environmental law and policy in India “Oxford University Press, New Delhi, 2001.
3. Greger I. Megregor, “Environmental law and enforcement”, Lewis Publishers, London, 1994.

CL16013 **COMPUTATIONAL FLUID DYNAMICS FOR CHEMICAL ENGINEERS**

L	T	P	C
3	0	0	3

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

Course outcome

- Explain the application turbulence models and the conservation equations of transport phenomena
- Apply numerical methods for the discretization of Partial differential equations for Finite difference approximations
- Illustrate the application of Finite Volume methods in flow and pressure field computations
- Analyze the algorithms for pressure field computations
- Demonstrate the generation of computational grids

REFERENCES:

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

1980.
8. Taylor, C and Hughes, J.B. "Finite Element Programming of the Navier Stock Equation", Pineridge Press Limited, U.K., 1981.

CL16014 WASTE MANAGEMENT AND ENERGY RECOVERY

L	T	P	C
3	0	0	3

UNIT I SOLID WASTE – CHARACTERISTICS AND PERSPECTIVES 6

Definition - types – sources – generation and estimation. Properties: physical, chemical and biological – regulation.

UNIT II COLLECTION, TRANSPORTATION AND PROCESSING TECHNIQUES 8

Onsite handling, storage and processing – types of waste collection mechanisms - transfer Stations : types and location – manual component separation - volume reduction : mechanical, thermal – separation : mechanical, magnetic electro mechanical.

UNIT III ENERGY GENERATION TECHNIQUES 16

Basics, types, working and typical conversion efficiencies of composting – anaerobic digestion – RDF – combustion – incineration – gasification – pyrolysis.

UNIT IV HAZARDOUS WASTE MANAGEMENT 8

Hazardous waste – definition - potential sources - waste sources by industry – impacts – waste control methods – transportation regulations - risk assessment – remediation technologies – Private public parternership – Government initiatives.

UNIT V ULTIMATE DISPOSAL 7

Landfill – classification – site selection parameters – design aspects – Leachate control – environmental monitoring system for Land Fill Gases.

TOTAL: 45 PERIODS

Course outcome

- Discuss the characteristics of solid waste and regulation of solid waste management
- Explain the process of waste collection, transportation and processing techniques
- Elucidate the various techniques for conversion of waste to energy
- Explain the control, transportation and management of hazardous wastes
- Demonstrate knowledge on the design and environmental aspects of landfills

REFERENCES:

1. Tchobanoglous, Theisen and Vigil, Integrated Solid Waste Management, 2d Ed. McGraw-Hill, New York, 1993.
2. LaGrega, M., et al., Hazardous Waste Management, McGraw-Hill, c. 1200 pp., 2nd ed., 2001.
3. Parker, Colin and Roberts, Energy from Waste – An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985.
4. ManojDatta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997.

CL16015 PROJECT ENGINEERING OF PROCESS PLANTS

L	T	P	C
3	0	0	3

UNIT I **9**

Project definition, Project Profile and standards, Feedback 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

Course outcome

- Explain the different elements of a project Engineering
- Perform the cost analysis of a process engineering project
- Explain the concepts of plant engineering management
- Discuss the safety aspects of in material handling and process plant operations
- Explain the statutory acts and policies of government regulatory bodies.

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.

CL16016 **FUEL CELL TECHNOLOGY** **L T P C**
3 0 0 3

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

Course outcome

- Apply the principles of thermodynamics in the design and analysis of fuel cells
- Formulate design equations for fuel cells using the principles of chemical kinetics
- Develop mathematical models for fuel cells and its characterization
- Perform life cycle analysis of fuel cells
- Explain the functioning of fuel cell power plants

REFERENCES:

1. Supramaniam Srinivasan , “Fuel cells : From fundamental to application, 1st Edition, Springer, 2006.
2. Gregorhoogers, Fuel cell technology – Hand book, 1st Edition, CRC Press,2002.
3. Viswanathan, B and M AuliceScibioh, Fuel Cells – Principles and Applications Universities Press (2006).

CL16017 ENVIRONMENTAL RISK ASSESSMENT

L	T	P	C
3	0	0	3

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: Fluxborough – Mexico – Bhopal analysis. Government policies to manage environmental risk.

TOTAL: 45 PERIODS

Course outcome

- Develop the methods identification, evaluation and control of risk.
- Identify , asses and Analyse the hazards associated with risk.
- Develop onsite and off site emergency plan for risk management
- Design Safety measures and models for prevention of industrial accidents
- Illustrate the various accidents with case studies.

REFERENCES:

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

CL16018 WASTE WATER ENGINEERING

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION 10

Industrial scenario - Uses of Water by industry - Sources and types of industrial wastewater – Industrial wastewater disposal and environmental impacts - Reasons for treatment of industrial wastewater – Regulatory requirements - Industrial waste survey - Industrial wastewater generation rates, characterization and variables – Population equivalent - Toxicity of industrial effluents and Bioassay tests - Preventing and minimizing wastes at the source - Individual and Common Effluent Treatment Plants - Joint treatment of industrial wastewater.

UNIT II INDUSTRIAL WASTEWATER TREATMENT 10

Equalisation - Neutralisation - Oil separation - Flotation - Precipitation - Heavy metal Removal – Refractory organics separation by adsorption - Aerobic and anaerobic biological treatment - Sequencing batch reactors – High Rate reactors.

UNIT III ADVANCED WASTEWATER TREATMENT AND REUSE 8

Chemical oxidation - Ozonation - Photocatalysis - Wet Air Oxidation - Evaporation – Ion Exchange – Membrane Technologies - Nutrient removal - Land Treatment.

UNIT IV RESIDUALS MANAGEMENT 5

Residuals of industrial wastewater treatment - Quantification and characteristics of Sludge - Thickening, digestion, conditioning, dewatering and disposal of sludge -
Management of RO rejects.

UNIT V CASE STUDIES 12

Industrial manufacturing process description, wastewater characteristics and waste treatment flow sheet for Textiles - Tanneries - Pulp and paper.

TOTAL: 45 PERIODS

Course outcome

- Elucidate appropriate treatment schemes to remove certain pollutants present in water or wastewater.
- Design a water or wastewater treatment component.
- Identify advance wastewater treatment process
- Develop methodology for residual Management
- Analyze the existing wastewater treatment processes .

REFERENCES:

1. Eckenfelder, W. W., "Industrial Water Pollution Control", Mc-Graw Hill, 1999.
2. Arceivala, S. J., "Wastewater Treatment for Pollution Control", Tata McGraw Hill,1998.
3. Nelson Leonard Nemerow, Industrial waste treatment - Contemporary practice and vision for the future. Elsevier, Singapore 2007.
4. Wastewater Engineering: Treatment and Resource Recovery 5th Edition by Inc. Metcalf & Eddy (Author), George Tchobanoglous (Author), H. David Stensel (Author), Ryujiro Tsuchihashi (Author), Franklin Burton (Author) McGraw-Hill Education, 2003.

CL16019 **RISK ANALYSIS AND MANAGEMENT** **L T P C**
3 0 0 3

UNIT I **9**

General: Risk types, Completion, Permitting, Resource, Operating, Environmental, Manageable, Insurable, Risk Causes, Risk Analysis types and causes.

UNIT II **9**

Techniques: General, Risk adjusted discounted rate method, Certainty Equivalent Coefficient method, Quantitative Sensitivity analysis, Probability distribution, Coefficient of variation method, Simulation method, Crude Procedures, Payback period, Expected monetary value method, Refined procedures, Shackle approach, Hiller's model, Hertz model, Goal programming.

UNIT III **9**

Risk Management: Emergency relief Systems, Diers program, Bench scale experiments, Design of emergency relief systems, Internal emergency planning, Risk management plan, mandatory technology option analysis, Risk management alternatives, risk management tools, risk management plans, Risk index method, Dowfire and explosion method, Mond index Method.

UNIT IV **9**

Risk Assurance and Assessment: Property Insurance, Transport insurance, Liability insurance, Pecunious insurance, Risk Assessment, Scope Canvey study, Rijimond pilot study, Low Probability high consequence events. Fault tree analysis, Event tree analysis, Zero Infinity dilemma.

UNIT V **9**

Risk Analysis in Chemical Industries: Handling and storage of Chemicals, Process plants, Personnel protection equipments. Environmental risk analysis, International environmental management system, Corporate management system, Environmental risk assessment, Total quality management, Paradigms and its convergence.

TOTAL: 45 PERIODS

Course outcome

- Identify the core types of project risks
- Compare the qualitative and quantitative risk assessment methods;
- Design of risk management program, tools and plans for emergency.
- Develop the various methodology to asses and assure risk.
- Analyze the risk associated with chemical Industries.

REFERENCES:

1. Srivastav, S., "Industrial Maintenance Management", Sultan Chand & Co., 1998.
2. Rao, P. C. K., "Project Management and Control", Sultan Chand & Co., Ltd., 1996.
3. Sincero, A. P. and Sincero, G. A., "Environmental Engineering – A Design Approach", Prentice Hall of India, 1996.
4. Pandya, C. G., "Risks in Chemical Units", Oxford and IBH Publishers, 1992.
5. Fawcett, H. H., "Safety and Accident Prevention in Chemical Operations by John Wiley & Sons, 1982.
6. Kind, R. W., "Industrial Hazard and Safety Handbook" Butterworth, 1982.
7. Steiner, H. M., "Engineering Economic Principles", McGraw Hill Book Co., New York, 1996.

CL16020 DESIGN OF EXPERIMENTS

	L	T	P	C
	3	**0**	**0**	**3**

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

Course outcome

- Identify the fundamental concepts and terminology for the design of experiments
- Design of single factor experiments
- Design of factorial experiments
- Develop experimental design with conditions
- Ability to analyze and interpret the experiment results by analysis of variance

REFERENCES:

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

CL16021 **HYDROGEN AND FUEL CELLS**

L	T	P	C
3	0	0	3

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

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

Course outcome

- Gain knowledge on the existing techniques for production of hydrogen
- Identify various options for storage of different forms of hyrogen
- Illustrate an insight into the performance of fuel cells
- Enumerate the various types of fuel cell and its application
- Elucidate the economic and environmental analysis on use of hydrogen cells for various 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).

CL16022 **ENVIRONMENTAL SUSTAINABILITY** **L T P C**
3 0 0 3

UNIT I **9**

Valuing the Environment: Concepts, Valuing the Environment: Methods, Property Rights, Externalities, and Environmental Problems.

UNIT II **9**

Sustainable Development: Defining the Concept, The Population Problem, Natural Resource Economics: An Overview, Energy, Water, Agriculture.

UNIT III **9**

Biodiversity, Forest Habitat, Commercially Valuable Species, Stationary-Source Local Air Pollution, Acid Rain and Atmospheric Modification, Transportation.

UNIT IV **9**

Water Pollution, Solid Waste and Recycling, Toxic Substances and Hazardous Wastes, Global Warming.

UNIT V **9**

Development, Poverty, and the Environment, Visions of the Future, Environmental economics and policy by Tom Tietenberg, Environmental Economics.

TOTAL: 45 PERIODS

Course outcome

- Examine the systemic analysis across both physical and behavioral dimensions involving society, environment and economy.
- Identify the sustainability and assess the ways in which they are approached by a diversity of academic disciplines.
- Elaborate how globalized processes impact socioecological systems.
- Assess the role of environmental sustainability in the promotion of comprehensive justice and equity.
- Apply critical thinking skills to provide sustainable solutions and build resilient communities.

REFERENCES:

1. Andrew Hoffman, Competitive Environmental Strategy -A Guide for the Changing Business Landscape, Island Press.
2. Stephen Doven, Environment and Sustainability Policy: Creation, Implementation, Evaluation, The Federation Press, 2005.

CL16023	GAS TRANSPORTATION	L T P C
		3 0 0 3

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 cost effectiveness of pipelines with alternative modes of transport such as truck or railroad.. Legal, safety and environmental issues about pipelines.

TOTAL: 45 PERIODS

Course outcome

- Compose the types, features and advantages of pipelines
- Illustrate the awareness on various ty protection techniques in pipelines
- Examine the types of pipes and other flow related components
- Investigate the Design of pipeline for transportation of gases.

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 universities 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.

CL16024 **POLLUTION ABATEMENT**

L	T	P	C
3	0	0	3

UNIT I

Man and environment, types of pollution, pollution controls aspects, industrial pollution pollution monitoring and analysis of pollutants, Indian pollution regulations.

UNIT II

Water pollution- source of water pollution- measurement of quality- BOD- COD- colour and odor- PH- heavy metals-treatments etc (qualitatively). Industrial waste water treatment (qualitatively) and recycle.

UNIT III

Solid wastes- quantities and characterizations – industrial –hazardous waste- radio active waste- simple treatments and disposal techniques (qualitatively treatment).

UNIT IV

Air pollution-types and sources of gaseous pollutants-particulate matter-hazardous air pollutants- global and atmospheric climatic change (Green house effect)-acid rain Industrial exhaust – characterization and Methods of decreasing the pollutants content in exhaust gasses (qualitatively).

UNIT V

Noise pollution –sound level-measuring transient noise-acoustic environment-health effects of noise –noise control. Introduction to cosmic pollution.

TOTAL: 45 PERIODS

Course outcome

- Ability to identify, monitor and analyze different types of pollution
- Assess the water quality parameters quantitatively and qualitatively
- Gain insight into the solid hazardous wastes and their disposal techniques
- Gain knowledge on the gaseous pollutants and their control techniques
- Demonstrate the effects of noise pollution on health

REFERENCES:

1. Jeffrey Pierce J, Environmental pollution and control, Butterworth-Heinemann; 4th edn1997.
2. Rao. C.S. Environmental Pollution Control Engineering, New age International Publishers, 2006.

CL16025 OPERATIONS RESEARCH FOR CHEMICAL ENGINEERS

L	T	P	C
3	0	0	3

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

Course outcome

- Gaining knowledge on various mathematical and dynamic programming techniques
- Categorize the various projects using PERT, CPM and GERT
- Compare and contrast on queuing and reliability theory

REFERENCE

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.

CL16026 GREEN CHEMISTRY AND ENGINEERING

	L	T	P	C
	3	0	0	3

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**57** Life-Cycle Impact Assessments. Streamlined Life-Cycle Assessments. Uses of Life Cycle Studies.

TOTAL: 45 PERIODS

Course outcome

- Assess the risk involved due to Environmental issues in air, water and soil.
- Discuss the Pollution prevention techniques by assessing physico-chemical characteristics of chemical compounds.
- Design an optimized green chemical synthesis pathways.
- Integration of the Process in terms of mass and energy conservation concepts.
- Evaluate the Cost benefit analysis of environmental pollution abatement process and Life cycle assessment.

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.
3. Sanjay Kumar Sharma Ackmez mudhoo “Green Chemistry for Environmental

Sustainability", CRC Press (Taylor and Francis Group).

4. Albert Matelack., "Introduction to Green chemistry", Second Edition, CRC Press (Taylor and Francis Group).
5. S. Suresh, S. Sundaramoorthy, "Green Chemical Engineering: An Introduction to Catalysis, Kinetics, and Chemical Processes, CRC Press (Taylor and Francis Group).

CL16027 **ENVIRONMENTAL NANOTECHNOLOGY**

L	T	P	C
3	0	0	3

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, microfludics and lab on chip, catalytic and photocatalyic applications Nonmaterials for ground water remediation, nanomaterials as adsorbents, membrane, process.

TOTAL: 45 PERIODS

Course outcome

- Gain knowledge on fundamental concepts of Nanotechnology.
- List of techniques for the fabrication and synthesis of Nanomaterials.
- Identifying the structural characteristics by analytical methods
- Nanoparticles transfer, separation, deposition, storage with its applications.
- Illustrate the application of Nanomaterials related with environment

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.

CL16028 PIPING AND INSTRUMENTATION

L	T	P	C
3	0	0	3

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

Course outcome

- Identify the various components involved in piping.
- Explain the principles of pipe hydraulics and sizing
- Solving the calculations on stress analysis and pipe support.
- Design of Chemical process industries with their plot plan layout .
- Developing the PFD and P&ID diagrams

REFERENCES:

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

CL16029 **SAFETY AND HAZARD CONTROL** **L T P C**

3 0 0 3

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

Course outcome

- Identify health and environmental hazards associated with various processes.
- Gain knowledge on analysis of causes and consequences of accidents
- Design of plant and plant layout in line with risk assessment.
- Safe handling and storage of hazardous materials
- Manage and mitigate disaster by emergency preparedness and plan

REFERENCES:

1. Well, G.S Safety Process Plants Design, George Godwin Ltd., London, John Wilelys and Sons, New York, 1980.
2. Major Hazard Control, Manual by International Labour Organization, Geneva, 1990.
3. Frank P.Less, Loss Prevention in Process Industries, Vol. I and Vol II Butterworth, London, 1980.
4. Marshal, V.C Major Chemical Hazards, Ellis Harwood Ltd. Chichester, U.K. 1987.

CL16030 TOTAL QUALITY MANAGEMENT FOR CHEMICAL ENGINEERS

L	T	P	C
3	0	0	3

UNIT I CONCEPTS OF TQM 5

Philosophy of TQM, Customer focus, organization, top management commitment, team work, quality philosophies of Deming, Crosby and Muller.

UNIT II TQM PROCESS 12

QC Tools, Problem solving methodologies, new management tools, work habits, quality circles, bench marking, strategic quality planning.

UNIT III TQM SYSTEMS 8

Quality policy deployment, quality function deployment, Standardization, designing for quality, manufacturing for quality.

UNIT IV QUALITY SYSTEM 10

Need for ISO 9000 system, Advantages, clauses of ISO 9000, Implementation of ISO9000, quality costs, quality, auditing, case studies.

UNIT V IMPLEMENTATION OF TQM 10

Steps, KAIZEN, 5s, JIT, POKAYOKE, Taguchi methods, case studies.

TOTAL: 45 PERIODS

Course outcome

- Develop action plans for customer centric business on the basis of various quality philosophies.
- Apply total quality management techniques for design and manufacture of highly reliable products and services.
- Develop a statistical process control charts for monitoring the health manufacturing systems.
- Solve various industrial problems using Six Sigma and related techniques.
- Design a system with a focus on enhancing reliability and availability.

REFERENCES:

1. Rose J. E., “Total quality Management”, Kogan Page Ltd, 1999.
2. Bank, J., “The essence of Total Quality Management”, Prentice Hall of India, 1993.
3. Bonds, G., “Beyond Total Quality Management”, McGraw Hill, 1994.
4. Osada, T., “The 5S’s, The Asian Productivity Organization”, 1991.