UNIVERSITY DEPARTMENTS

ANNA UNIVERSITY:: CHENNAI 600 025

REGULATIONS - 2015

I TO IV SEMESTERS CURRICULUM AND SYLLABUS (FULL TIME)

M.TECH. CHEMICAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES (PEOs) :

The Chemical Engineering Post graduate Program is designed to provide advanced courses such as transport phenomena, applied mathematics, thermodynamics, kinetics and reaction engineering on which students can build successful and sustainable careers in chemical engineering or a related field. In addition, students will select a number of electives courses to develop knowledge and expertise in specialized fields such as energy engineering, materials engineering, bioengineering, environmental engineering, engineering design, and control .

The following strategies are used in the Chemical Engineering Post graduate program to achieve these program educational objectives:

1. To prepare students for rapidly changing technological environments with the core knowledge central to multidisciplinary development and personal improvement.
2. To incorporate social, ethical, environmental and economic considerations, including the concept of sustainable development, into chemical engineering practice.
3. To inculcates collaborative work approach in multidisciplinary teams to tackle complex problems that may require different approaches and viewpoints to arrive at a successful solution.
4. To enrich students with experience in learning and applying tools (e.g., computer skills) to solve theoretical and open-ended chemical engineering problems.
5. Provide students with opportunities to design systems, components, and chemical processes to meet specific needs and constraints through cultural diversity and international opportunities or experiential learning.

PROGRAMME OUTCOMES (POs):

On successful completion of the programme

1. Each graduate will have the ability to work as a member of multidisciplinary teams, and have an understanding of team leadership.
2. Each graduate will have the ability to identify, formulate, and solve chemical engineering problems using modern engineering tools necessary for engineering practice.
3. Student will be able to successfully apply advanced concepts of chemical engineering to the analysis, design and development of chemical reactors, processes and chemical plants to meet the desired needs of society, professionally and ethically.
4. Students will be able to analyze and interpret data and thus to put forward the scientific findings at national and international levels successfully
5. Will develop an ability to apply a multi-disciplinary approach to conceive, plan, design, and implement solutions to chemical engineering problems in the field of energy and sustainability.
6. Will have the ability to express ideas and positions clearly and concisely, both orally and in writing
7. Will know the importance of safety and environmental aspects in the design and operation of process engineering systems.
8. Will have the ability to accomplish basic design and optimization of process components and systems.
9. Will have a complete working knowledge on advanced material and energy balances applied to chemical processes; thermodynamics of physical and chemical equilibria; heat, mass and momentum transfer; chemical reaction engineering; continuous and stage-wise separation processes; process dynamics and control; process design and appropriate modern experimental and computing techniques.

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

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

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

			PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
YEAR 1	SEM 1	Advanced Numerical Methods		✓		✓					
		Analysis of Transport Phenomena								✓	✓
		Chemical Reactor Theory			✓		✓				✓
		Fluid Phase Equilibria							✓		✓
		Computational Methods in Chemical Engineering			✓	✓					✓
		Elective-I									
	SEM 2	Modern Control Theory							✓	✓	
		Chemical Process Design		✓			✓		✓	✓	
		Modern Separation Processes									
		Elective-II									
		Elective-III									
		Elective-IV									
		Seminar	✓					✓	✓		
YEAR 2	SEM 1	Process Modeling and Simulation	✓							✓	✓
		Elective-V									
		Elective-VI									
		Project Work Phase I	✓	✓		✓		✓			✓
	SEM 2	Project Work Phase II	✓	✓		✓		✓			✓

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

UNIVERSIT DEPARTMENTS

ANNA UNIVERSITY:: CHENNAI 600 025

REGULATIONS - 2015

I TO IV SEMESTERS CURRICULUM AND SYLLABUS (FULL TIME)

M.TECH. CHEMICAL ENGINEERING

SEMESTER - I

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA7155	Advanced Numerical Methods	FC	4	4	0	0	4
2.	CL7101	Analysis of Transport Phenomena	PC	5	3	2	0	4
3.	CL7102	Chemical Reactor Theory	PC	5	3	2	0	4
4.	CL7103	Computational Methods in Chemical Engineering	PC	5	3	0	2	4
5.	CL7104	Fluid Phase Equilibria	PC	3	3	0	0	3
6.		Elective I	PE	3	3	0	0	3
Practicals								
7.	CL7111	Instrumental methods of analysis lab	PC	2	0	0	2	1
			TOTAL	**25**	**19**	**4**	**4**	**23**

SEMESTER - II

S.No	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	CL7201	Chemical Process Design	PC	3	3	0	0	3
2.	CL7202	Modern Control Theory	PC	3	3	0	0	3
3.	CL7203	Modern Separation Processes	PC	3	3	0	0	3
4.		Elective II	PE	3	3	0	0	3
5.		Elective III	PE	3	3	0	0	3
6.		Elective IV	PE	3	3	0	0	3
Practicals								
7.	CL7211	Seminar	PC	4	0	0	4	2
			TOTAL	**22**	**18**	**0**	**4**	**20**

SEMESTER - III

S.No	COURSE CODE	COURSE TITLE	CATEG ORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	CL7301	Process Modeling and Simulation	PC	5	3	2	0	4
2.		Elective V	PE	3	3	0	0	3
3.		Elective VI	PE	3	3	0	0	3
Practicals								
4.	CL7311	Project Work Phase I	PC	12	0	0	12	6
			TOTAL	**23**	**9**	**2**	**12**	**16**

SEMESTER – IV

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
Practicals								
1.	CL7411	Project Work Phase II	PC	24	0	0	24	12
			TOTAL	**24**	**0**	**0**	**24**	**12**

TOTAL CREDITS : 71

Foundation Courses(FC)

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.		Advanced Numerical Methods	FC	5	3	2	0	4

Professional Core(PC)

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.		Analysis of Transport Phenomena	PC	5	3	2	0	4
2.		Chemical Reactor Theory	PC	5	3	2	0	4
3.		Fluid Phase Equilibria	PC	3	3	0	0	3
4.		Computational Methods in Chemical Engineering	PC	5	3	0	2	4
5.		Modern Control Theory	PC	3	3	0	0	3
6.		Process Modeling and Simulation	PC	5	3	2	0	4
7.		Chemical Process Design	PC	3	3	0	0	3
8.		Modern Separation Processes	PC	3	3	0	0	3

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

rofessional Electives(PE)

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	CL7001	Bio Energy Conservation Techniques	PE	3	3	0	0	3
2.	CL7071	Computational Fluid Dynamics	PE	3	3	0	0	3
3.	CL7002	Electrochemical Engineering	PE	3	3	0	0	3
4.	CL7003	Electrochemical Process Engineering for Chemical Engineers	PE	3	3	0	0	3
5.	CL7004	Electrochemical Processes for Clean Technology	PE	3	3	0	0	3
6.	CL7005	Environmental Engineering	PE	3	3	0	0	3
7.	CL7006	Environmental Management	PE	3	3	0	0	3
8.	CL7072	Environmental Policies and Legislation	PE	3	3	0	0	3
9.	CL7007	Environmental Risk Assessment	PE	3	3	0	0	3
10.	CL7008	Environmental Sustainability	PE	3	3	0	0	3
11.	CL7073	Fluidization Engineering	PE	3	3	0	0	3
12.	CL7074	Fuel Cell Technology	PE	3	3	0	0	3
13.	EY7012	Hydrogen and Fuel Cell	PE	3	3	0	0	3
14.	CL7009	Membrane Technologies for Water and Wastewater Treatment	PE	3	3	0	0	3
15.	PP7251	Multicomponent distillation	PE	3	3	0	0	3
16.	CL7076	Multiphase flow	PE	3	3	0	0	3
17.	CL7010	Pollution Abatement	PE	3	3	0	0	3
18.	CL7011	Polymer Technology	PE	3	3	0	0	3
19.	CL7077	Process Optimization	PE	3	3	0	0	3
20.	CL7078	Project Engineering of Process Plants	PE	3	3	0	0	3
21.	CL7012	Risk Analysis and Management	PE	3	3	0	0	3
22.	CL7013	Safety and Hazard Control	PE	3	3	0	0	3

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

23.	CL7014	Soil Pollution Engineering	PE	3	3	0	0	3
24.	CL7079	Solvent Extraction	PE	3	3	0	0	3
25.	CL7080	Total Quality Management	PE	3	3	0	0	3
26.	CL7081	Waste Management and Energy Recovery	PE	3	3	0	0	3
27.	CL7015	Waste Water Engineering	PE	3	3	0	0	3

Employability Enhancement Courses(EEC)

S.No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.		Seminar	EEC	4	0	0	4	2
2.		Project work Phase - I	EEC	12	0	0	12	6
3.		Project work Phase – II	EEC	24	0	0	24	12

MA7155 ADVANCED NUMERICAL METHODS L T P C
4 0 0 4

OBJECTIVE:

- The course objective is to impart knowledge on advanced numerical methods for solving differential equations in science and engineering.
- Analysis and application of advanced numerical methods for solving Partial Differential Equations (PDEs).

UNIT I ALGEBRAIC EQUATIONS 6
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 6
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 METHOD 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 9
Partial differential equations – Finite element method - orthogonal collocation method, orthogonal collocation with finite element method, Galerkin finite element method.

L: 45, T: 15, TOTAL: 60 PERIODS

OUTCOME:

- Be familiar with numerical solution of ODEs.
  Setup and solve partial differential equations numerically

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.

CL7101 ANALYSIS OF TRANSPORT PHENOMENA L T P C
3 2 0 4

UNIT I BASIC CONCEPTS 15
Phenomenological Equations and Transport properties, Rheological behaviour of fluids, Balance Equations – Differential and Integral equations.

UNIT II APPLICATIONS OF DIFFERENTIAL EQUATIONS OF CHANGE 15
Applications in laminar and turbulent transport in compressible and incompressible fluids.Boundary layer theory.

UNIT III APPLICATIONS OF INTEGRAL EQUATIONS OF CHANGE 15

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

UNIT IV INTERPHASE AND MULTIPHASE MOMENTUM TRANSFER 15

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

UNIT V INTERPHASE TRANSPORT IN NON-ISOTHERMAL SYSTEMS 15

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

TOTAL: 75 PERIODS

REFERENCES

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

CL7102 CHEMICAL REACTOR THEORY L T P C
3 2 0 5

UNIT I KINETICS OF HETEROGENEOUS REACTIONS 15

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

UNIT II EXTERNAL DIFFUSION EFFECTS IN HETEROGENEOUS REACTIONS 15

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 15

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 15

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

UNIT V ANALYSIS AND DESIGN OF HETEROGENEOUS REACTORS 15

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: 75 PERIODS

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.

CL7103 COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING L T P C
3 0 2 4

UNIT I MATRIX ALGEBRA 15

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 15

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 15

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 15

Boundary conditions; Principle of Linear superposition - Special ODEs and Adjoint operators: Properties of adjoint operator; Theorem for eigenvalues and eigenfunctions – 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 15

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: 75 PERIODS

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. Kuznetsov, A., Elements of Applied Bifurcation Theory, Springer, 1995.
5. Strogatz, S., Non-linear Dynamics and Chaos, Westview Press, 2014.

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7104 FLUID PHASE EQUILIBRIA L T P C
3 0 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

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. PrenticeHall, New Jersey, 1997.
3. Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular thermodynamics offluid-phase Equilibria, 3rd Edn, Prentice Hall Inc., New Jersey, 1999.

CL7111 INSTRUMENTAL METHODS OF ANALYSIS LAB L T P C
0 0 2 1

LIST OF EXPERIMENTS
1. UV-Visible spectrophotometer
2. Infrared spectrophotometer
3. Gas chromatograph.
4. High performance liquid chromatograph
5. Atomic absorption spectrophotometer.
6. Flame photometer
7. Thermo gravimetric analyzer
8. Differential scanning calorimeter
9. Differential thermal analyzer

TOTAL : 30 PERIODS

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7201 CHEMICAL PROCESS DESIGN L T P C
3 0 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

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.

CL7202 MODERN CONTROL THEORY L T P C
3 0 0 3

UNIT I INTRODUCTION 9
Review of single input single out put (SISO) systems – Process Identification techniques for SISO and MIMO systems - Frequency response Analysis, Bode and Nyquist plots, effect of process parameters on Bode and Nyquist plots - Closed loop stability concepts, Bode and Nyquist stability – Degrees of freedom Analysis – Control degrees of freedom Analysis – Interaction – Bristol Arrays – Niederlinski index.

UNIT II STATE SPACE AND TRANSFER FUNCTION 9
State space and transfer function representation and their interrelationships – Control of a dynamic plant – Observability and controllability - Z-transforms - Discrete-time systems - Parameter-optimized controllers - General linear controllers and cancellation controllers - Controllers for finite settling time - System identification for self-tuning - Clarke and Gawthrop's self-tuning controller - Ydstie's extended horizon controller - Pole placement design method for controllers – Skogestaad Controller tuning parameters.

UNIT III CONTROL- LOOP INTERACTION 9
Introduction - Motivation - General pairing problem, relative gain array, properties and application of the RGA, RGA and sensitivity, using the RGA to determine variable pairings - Multivariable control - Zeros and performance limitations - Scaling considerations - Directional sensitivity and operability - Block-diagram analysis - Decoupling - Control strategies (centralized and decentralized)

UNIT IV ADVANCED CONTROL STRATEGIES 9
Models forms of model predictive control - Constrained and unconstrained approach - Analysis of dynamic matrix control - Extension to multivariable system - Other MPC methods.

Internal Model Control - Practical open-loop controller design - Generalization of the open-loop control design procedure - Model uncertainty and disturbances - IMC structure - IMC design procedure - Effect of model uncertainty and disturbances.

UNIT V OPTIMAL CONTROL **9**

Optimal Control with Complete Information on the Plant- Control of a Static Plant - Problems of Optimal Control for Dynamical Plants - Discrete Plant - Continuous Plant - Principle of Optimality and Dynamic Programming .Bellman Equation - Maximum Principle - Linear-quadratic Problem – Observer Design – Kalman filters

TOTAL : 45 PERIODS

REFERENCES

1. Smith, C. A., and Corripio, A. B., Principles and Practice of Automatic Process Control, John Wiley and Sons, New York, 1989
2. Bubnicki, Z., Modern Control Theory, Springer Verlag, 2005.
3. Ogata, K., Modern Control Engineering, Prentice Hall, 2009.
4. Ogata, K., Discrete Time Control Systems, Prentice Hall, 1995.
5. Bequette, B. W., Process Control: Modeling, Design and Simulation, Prentice Hall, 2003
6. Marlin, T. E., Process Control: Designing Processes and Control Systems for Dynamic Performance, 2nd Edition, Mc Graw Hill, 2000
7. Luyben, W. L., Process Modeling Simulation and Control for Chemical Engineers, 2nd Edition, Mc Graw Hill, 1990
8. D.E.Seborg, T. F.Edgar, D.A. Mellichamp, Process Dynamics and Control, Wiley, 2003.
9. Control System Design, by Graham C. Goodwin,Stefan F. Graebe, Mario E. Salgado,Prentice Hall, 2000.

CL7203 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 membranepemeators involving dialysis, reverse osmosis, nanofiltration, ultrafiltration, microfiltration and Donnan dialysis, economics of membrane operations, ceramic membranes.

UNIT III SEPARATION BY ADSORPTION TECHNIQUES **8**

Mechanism, types and choice of adsorbents, normal adsorption techniques,affinity chromatography and immuno chromatography, types of equipment and commercial processes, recent advances and process economics

UNIT IV IONIC SEPARATIONS **8**

Controlling factors, Applications, Types of equipment employed for electrophoresis, dielectrophoresis, Ion Exchange chromatography and electrodialysis, Commercial processes

UNIT V OTHER TECHNIQUES **9**

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

TOTAL : 45 PERIODS

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

CL7211 SEMINAR L T P C
0 0 4 2

Students are expected to present two seminars along with report on any recent topic in chemical engineering.

CL7301 PROCESS MODELING AND SIMULATION L T P C
3 2 0 4

UNIT I INTRODUCTION 15

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

UNIT II STEADY STATE LUMPED SYSTEMS 15

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

UNIT III UNSTEADY STATE LUMPED SYSTEMS 15

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 15

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

UNIT V UNSTEADY STATE DISTRIBUTED SYSTEM 15

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

TOTAL : 75 PERIODS

REFERENCES

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

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7311	PROJECT WORK (PHASE I)	L T P C 0 0 12 6

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

CL7411	PROJECT WORK (PHASE II)	L T P C 0 0 24 12

Phase II of Project Work is a continuation of Phase I of Project. Students submit a report at the end of Phase II.

CL7001	BIO ENERGY CONSERVATION TECHNIQUES	L T P C 3 0 0 3

UNIT I INTRODUCTION **8**

Biomass: types – advantages and drawbacks – Indian scenario – characteristics – carbon neutrality – conversion mechanisms – fuel assessment studies

UNIT II BIOMETHANATION **8**

Microbial systems – phases in biogas production – parameters affecting gas production – effect of additives on biogas yield – possible feed stocks. Biogas plants – types – design – constructional details and comparison – biogas appliances – Burner, illumination and power generation – effect on engine performance.

UNIT III COMBUSTION **10**

Perfect, complete and incomplete – equivalence ratio – fixed Bed, fluid Bed – fuel and ash handling – steam cost comparison with conventional fuels. Briquetting: types of Briquetting – merits and demerits – feed requirements and preprocessing – advantages – drawbacks

UNIT IV GASIFICATION **10**

Types – comparison – application – performance evaluation – economics – dual fuel engines – 100 % Gas Engines – engine characteristics on gas mode – gas cooling and cleaning train.

UNIT V PYROLYSIS AND CARBONIZATION **9**

Types – process governing parameters – thermo gravimetric analysis – differential thermal analysis – differential scanning calorimetry – Typical yield rates.

TOTAL: 45 PERIODS

TEXT BOOKS

1. David Boyles, Bio Energy Technology Thermodynamics and costs, Ellis HoknoodChichester, 1984.
2. Khandelwal KC, Mahdi SS, Biogas Technology – A Practical Handbook, Tata McGraw Hill, 1986

REFERENCES

1. Mahaeswari, R.C. Bio Energy for Rural Energisation, Concepts Publication,1997
2. Tom B Reed, Biomass Gasification – Principles and Technology, Noyce Data Corporation, 1981
3. Best Practises Manual for Biomass Briquetting, I R E D A, 1997
4. Eriksson S. and M. Prior, The briquetting of Agricultural wastes for fuel, FAO Energy and Environment paper, 1990
5. Iyer PVR et al, Thermochemical Characterization of Biomass, M N E S

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7071 COMPUTATIONAL FLUID DYNAMICS L T P C
3 0 0 3

AIM

To educate engineering graduates in the principles of computational fluid dynamics modeling and in interpretation of fluid dynamics principles.

OBJECTIVE

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

UNIT I CONSERVATION LAWS AND TURBULENCE MODELS 9

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

UNIT II FINITE DIFFERNCE APPROXIMATION 9

Mathematical behaviour of PDE, finite difference operators, basic aspects of discretization by FDM, explicit and implicit methods, error and stability analysis

UNIT III FINITE VOLUME METHOD 15

Diffusion problems – explicit and implicit time integration; Convection-diffusion problems – properties of discretisation schemes, central, upwind, hybrid, QUICK schemes; Solution of discretised equations.

UNIT IV FLOW FIELD COMPUTATION 6

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

UNIT V GRID GENERATION 6

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

TOTAL : 45 PERIODS

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.

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7002 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 – Electrocapillary 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-currentrelations of activities controlled and diffusion controlled corrosion process. Potential-pH diagram, Forms of corrosion- definition, factors and control methods of various forms of corrosion-corrosioncontrol 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

TEXT BOOKS

1. Picket, " Electrochemical Engineering ", Prentice Hall. 1977.
2. Newman, J. S., " Electrochemical systems ", Prentice Hall, 1973.

REFERENCES

1. Barak, M. and Stevenge, U. K., " Electrochemical Power Sources - Primary and Secondary Batteries" 1980
2. Mantell, C., " Electrochemical Engineering ", McGraw Hill, 1972.

CL7003 ELECTROCHEMICAL PROCESS ENGINEERING FOR CHEMICAL ENGINEERS **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

TEXT BOOKS

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.

CL7004 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, Characterstics 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

TEXT BOOKS

1. Scott.K, Electrochemical processes for clean technology, Standardsmedia, 1995.
2. F.Goodridge, K.Scott, Electrochemical Process Engineering. A guide to the design of electrolytic plant, Plenum press, 1995.
3. Cynthia, G.Zoski, Handbook of electrochemistry, 1st edition, Elsevier science, 2007.
4. Picket, Electrochemical Engineering, Prentice Hall, 1977.
5. Marcel Mulder, Basic Principles of Membrane Technology, 2nd edition, Kluwer Academic Publishers, 2003.
6. Krishnan Rajeshwar, JORGE G. IBANEZ, Environmental Electrochemistry, Fundamentals and applications in Pollution Abatement, ACADEMIC PRESS, Inc,1997.
7. K. Scott, Electrochemical reaction engineering, London, ACADEMIC PRESS, 1991.

CL7005 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

REFERENCES

1. Rao, C.S Environmental Pollution control Engineering, Wiley- Eastern Ltd. 1991.
2. Peavy H.S. Rowe D.R., and George Technologious, Environmental Engineering, Mc Graw 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.
5. Coulson, J.M. Richardson, J.F and R.K Sinnott, Chemical Engineering Vol. 6, Pergomon Press, 1989.
6. Gilbert M.Mastrs, Introduction to Environmental Engineering and Science, Prentice - Hall of India, New Delhi, 1994.
8. Wahi S.K., Agnihotri A.K and Sharmma J.S (Editors) Environmental Management in Petroleum Industry, Wiley Eastern Ltd., New Delhi 1996.
9. Smith, R., “Chemical Process Design”, McGraw Hill, New York, 1995.
10. Paul L Bishop (2000) “Pollution Prevention Fundamentals and Practice”, Mc Graw Hill, International.

CL7006 ENVIRONMENTAL MANAGEMENT **L T P C**

3 0 0 3

UNIT I **8**

Environmental Legislations in India, Europe, USA and Canada – Development of Legislations, Standards and Guidelines

UNIT II **5**

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 (SO2,SPM,NH3, H2S 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

REFERENCES

1. Mike Russo., Environmental Management: Readings and Cases, 2 nd Edition, Sage Publications, 2008.
2. Canter, W.L., Environmental Impact Assessment, McGraw-Hill Inc., 1992
3. Rau, J.G and Wooten, D.C., Environmental Impact Analysis Handbook, McGraw-Hill, 1980.
4. Jain, R.K., Urban, L.V., Stacey, G.S. and Balbach, H.E., Environmental Assessment, McGraw-Hill, 1993.
5. UNEP/IED Technical Report Serial No.2., Environmental Auditing, 1990.

CL7072 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

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. GregerI.Megregor, “Environmental law and enforcement”, Lewis Publishers, London, 1994.

CL7007 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: Flux borough – Mexico – Bhopal analysis. Government policies to manage environmental risk

TOTAL : 45 PERIODS

REFERENCES

1. Crowl,D.A and Louvar,J.F., Chemical process saftery; 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.

CL7008 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

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

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.

CL7073 FLUIDIZATION ENGINEERING L T P C
3 0 0 3

UNIT I INTRODUCTION 5

The Fluidized state, Nature of hydrodynamic suspension, particle forces, species ofFluidization, 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

REFERENCES

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

CL7074 FUEL CELL TECHNOLOGY L T P C
3 0 0 3

OBJECTIVE

To understand about fuel cells, their working principle, Types, Design and performance analysis.

Course outcome

After completing the course, student should have learnt

- Basics and workingprinciples of the Fuel cell technology.
- Selection the suitable materials for electrode, catalyst, membrane for the fuel cells.

- The mass transfer process such as pressure drop and velocity distribution in single cell as well as stack.
- Design and stack making process for real field applications

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

REFERENCES

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

EY7012 HYDROGEN AND FUEL CELLS **L T P C**
3 0 0 3

OBJECTIVES

- To detail on the hydrogen production methodologies, possible applications and various storage options
- To discuss on the working of a typical fuel cell, its types and to elaborate on its thermodynamics and kinetics
- To analyze the cost effectiveness and eco-friendliness of Fuel Cells

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 – Metal Hydrides – chemical Storage – comparisons. Safety and management of hydrogen. 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. Selection and use of Materials.

UNIT V APPLICATION OF FUEL CELL AND ECONOMICS 9

Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space. Economic and environmental analysis on usage of Hydrogen and Fuel cell. Future trends in fuel cells

TOTAL: 45 PERIODS

OUTCOME

- Fundamentally strong understanding on the working of various fuel cells, their relative advantages / disadvantages and hydrogen generation/storage technologies

REFERENCES

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

CL7009 MEMBRANE TECHNOLOGIES FOR WATER AND 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-Membarne Filtration- Types and choice of membranes, porous, non porous, symmetric and assymmetric – Plate and Frame, spiral wound and hollow fibre membranes – Liquid Membranes

UNIT II MEMBRANE PROCESSES AND SYSTEMS 10

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

UNIT III MEMBRANE BIOREACTORS 9

Introduction and Historical Perspective of MBRs, Biotreatment Fundamentals, Biomass Separation MBR Principles, Fouling and Fouling Control, MBR Design Principles, Design Assignment, Alternative MBR Configurations, Commercial Technologies, Case Studies.

UNIT IV PRETREATMENT SYSTEMS 8

Membrane Fouling – Pretreatment methods and strategies – monitoring of Pretreatment – Langlier Index, Silt Density Index, Chemical cleaning, Biofoulant control

UNIT V CASE STUDIES 8

Case studies on the design of membrane based water and wastewater treatment systems – zero Liquid effluent discharge Plants

TOTAL : 45 PERIODS

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

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,Elservier, 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, Elservier, 1995

PP7251 MULTICOMPONENT DISTILLATION L T P C
3 0 0 3

UNIT I THERMODYNAMIC PRINCIPLES 9

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

UNIT II THERMODYNAMIC PROPERTY EVALUATION 9

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

UNIT III MINIMUM REFLUX RATIO FOR MCD SYSTEM 9

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

UNIT IV VARIOUS METHODS OF MCD COLUMN DESIGN 9

Theta method of convergence – Kb method and the constant composition method – Application of the Theta method to complex columns and to system of columns – Lewis Matheson method – Stage and reflux requirements – Short cut methods and Simplified graphical procedures.

UNIT V VARIOUS TYPES OF MCD COLUMNS 9

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

TOTAL : 45 PERIODS

TEXT BOOKS

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

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7076 **MULTIPHASE FLOW** **L T P C**
3 0 0 3

OBJECTIVE
To analyze, characterize the multiphase systems and appreciate the role of structure in multiphase flows. To understand the limitations of modeling in multiphase flows and to comprehend engineering problems involving multiphase flows

OUTCOMES
Students develop a sound knowledge on underlying concepts of multiphase flows and different approaches to model such flows under different conditions.

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

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
3. Govier, G. W. and Aziz. K., "The Flow of Complex Mixture in Pipes", Van Nostrand Reinhold, New York, 1972.
4. Kleinstreuer, C., Two-phase Flow: Theory and Applications, Taylor & Francis, 2003
7. Rhodes, M., Introduction to Particle Technology, John Wiley & Sons, New York. 2008.
4. Wallis, G.B., "One Dimensional Two Phase Flow", McGraw Hill Book Co., New York, 1969.

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7010 POLLUTION ABATEMENT L T P C
3 0 0 3

UNIT I **9**
Man and environment, types of pollution, pollution controls aspects, industrial pollution, pollution monitoring and analysis of pollutants, Indian pollution regulations.

UNIT II **9**
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 **9**
Solid wastes- quantities and characterizations – industrial –hazardous waste- radioactive waste- simple treatments and disposal techniques (qualitatively treatment).

UNIT IV **9**
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 **9**
Noise pollution –sound level-measuring transient noise-acoustic environment-health effects of noise –noise control. Introduction to cosmic pollution.

TOTAL : 45 PERIODS

REFERENCES

1. Jeffrey Pierce J, Environmental pollution and control, Butterworth-Heinemann; 4th edn, 1997
2. Rao. C.S. Environmental Pollution Control Engineering, New age International Publishers, 2006.

CL7011 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

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

CL7077	PROCESS OPTIMIZATION	L T P C
		3 0 0 3

UNIT I INTRODUCTION **5**

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

UNIT II LINEAR PROGRAMMING **10**

Simplex method, Barrier method, sensitivity analysis, Examples.

UNIT III NONLINEAR UNCONSTRAINED OPTIMIZATION **10**

Convex and concave functions unconstrained NLP, Newton’s method Quasi-Newton’s method, Examples.

UNIT IV CONSTRAINED OPTIMIZATION **10**

Direct substitution, Quadratic programming, Penalty Barrier Augmented Lagrangian Methods.

UNIT V MULTI OBJECTIVE OPTIMIZATION **10**

Weighted Sum of Squares method, Epsilon constrain method, Goal attainment, Examples.Introduction to optimal control and dynamic optimization.

TOTAL : 45 PERIODS

REFERENCES

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

CL7078	PROJECT ENGINEERING OF PROCESS PLANTS	L T P C
		3 0 0 3

UNIT I **9**

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

UNIT II **9**

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

UNIT III **9**

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

UNIT IV **9**

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

UNIT V **9**

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

TOTAL : 45 PERIODS

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

CL7012 **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

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 DesignApproach", Prentice Hall of India, 1996.
2. Pandya, C. G., "Risks in Chemical Units", Oxford and IBH Publishers, 1992.
3. Fawcett, H. H., "Safety and Accident Prevention in Chemical Operations by John
4. Wiley & Sons, 1982.
5. Kind, R. W., "Industrial Hazard and Safety Handbook" Butterworth, 1982.
6. Steiner, H. M., "Engineering Economic Principles", McGraw Hill Book Co., New York,
7. 1996.

CL7013 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

REFERENCES

1. Well, G.S Safety Process Plants Design, George Godwin Ltd., London, John Wilelyand Sons, New York, 1980
2. Safety in Chemical and Petrochemical Industries, Report of the Inter Ministry Group Dept. of Chemicals and Petrochemicals, Govt.of India, ICMA Publications. 1986.
3. Major Hazard Control, Manual by International Labour Organization, Geneva, 1990.
4. Frank P.Less, Loss Prevention in Process Industries, Vol. I and Vol II Butterworth,London, 1980.
5. Marshal, V.C Major Chemical Hazards, Ellis Harwood Ltd. Chichester, U.K. 1987.
6. Guidelines for Chemical Process Quantitative Risk Analysis, Published by Centre for Chemical Process Safety of the AICh.E., New York, USA. 1989.
7. Raghavan, K.V and A.A Khan, Methodologies in Hazard Identification and Risk

Assessment, Manual by CLRI., Dec, 1990.
8. R.K.Sinnott, Coulson & Richardson's Chemical Engineering, Vol.6 Butlerworth – Heinmann.Oxford, 1996.
9. Coulson J.M and Richardson J.F., Chemical Engineering, Vol. 1 (Chaper 4) Asian Book House Pvt. Ltd., New Delhi. 1998.

CL7014 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 propertiesand 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 CONTAMINANT FATE AND TRANSPORT 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 - Insitu 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

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. Remediation, Water Contaminant and Emerging Water Management Technologies, John Wiley & Sons Limited, 2004.
8. Marcel Vander Perk, Soil and Water Contamination from Molecular to Catchment Scale, Taylor & Francis, 2006.
9. William J. Deutsch, Groundwater Geochemistry: Fundamentals and Applications to Contamination, Lewis Publishers, 1997.

CL7079 **SOLVENT EXTRACTION** **L T P C**
3 0 0 3

AIM
To impart knowledge on principles of solvent extraction and the design of extractors.

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

UNIT I EQUILIBRIUM IN LIQUID-LIQUID SYSTEM 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 9
Equilibrium stage-wise contact, Single and multiple contacts with co-current and counter current flow of phases for immiscible and partially miscible solvent phases, Calculation methods, Fractional extraction with reflux of raffinate and extract. Differential contact,HETS, NETS, HTU, NTU concepts and Estimation of these parameters, Mass transfer efficiency, Axial mixing and Residence time distribution in extractors and their estimation.

UNIT III DISPERSION AND COALESCENCE IN EXTRACTORS 12
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

REFERENCES

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

Attested
DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

CL7080 TOTAL QUALITY MANAGEMENT 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 ISO 9000, quality costs, quality, auditing, case studies.

UNIT V IMPLEMENTATION OF TQM 10
Steps, KAIZEN, 5s, JIT, POKAYOKE, Taguchi methods, case studies.

TOTAL : 45 PERIODS

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 Organisation", 1991.

CL7081 WASTE MANAGEMENT AND ENERGY RECOVERY L T P C
3 0 0 3

AIM
To focus on characteristics of various industrial wastes, management and energy recovery.

OBJECTIVE
To make students understand about characteristics of various waste, their collection, transport and processing techniques,

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

TEXT BOOKS

1. Tchobanoglous, Theisen and Vigil, Integrated Solid Waste Management, 2d Ed.McGraw-Hill, New York, 1993.
3. Howard S. Peavyetal, Environmental Engineering, McGraw Hill International Edition,1985

REFERENCES

1. LaGrega, M., et al., Hazardous Waste Management, McGraw-Hill, c. 1200 pp., 2nd ed., 2001.
2. Stanley E. Manahan. Hazardous Waste Chemistry, Toxicology and Treatment, Lewis Publishers, Chelsea, Michigan, 1990
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.

CL7015 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 - metal finishing - Petroleum Refining - Chemical industries - Sugar and Distilleries -Dairy - Iron and steel - fertilizers - Industrial clusters and Industrial Estates.

TOTAL : 45 PERIODS

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. "Pollution Prevention and Abatement Handbook – Towards Cleaner Production ",World Bank and UNEP, Washington, 1998.
4. Nelson Leonard Nemerow, Industrial waste treatment - Contemporary practice and vision for the future. Elsevier, Singapore 2007.