SRI VENKATESWARA COLLEGE OF ENGINEERING
(An Autonomous Institution, Affiliated to Anna University, Chennai)
SRIPERUMBUDUR TK - 602 117
REGULATION – 2018
M.TECH. CHEMICAL ENGINEERING
Choice Based Credit System
I - IV Semesters CURRICULUM

SEMESTER I

S. No.	Course Code	Course title	Category	Contact periods	L	T	P	C	Pre requisites	Fixed/ Movable
1.	MA18184	Mathematical and Statistical Methods in Chemical Engineering	PC	4	3	1	0	4		F
2.	CL18101	Advanced Thermodynamics for chemical engineerrs	PC	4	3	1	0	4		F
3.	CL18102	Advanced Separation Processes	PC	3	3	0	0	3		F
4.	CL18103	Process modeling and simulation	PC	3	3	0	0	3		F
5.		Professional Elective-I	PE	3	3	0	0	3		F
6.	CL18111	Technical Seminar	EEC	2	0	0	2	1		F
7.	CL18112	Instrumental Methods of Analysis laboratory	PC	4	0	0	4	2		F
8.	CL18113	Process Modeling and Simulation laboratory	PC	4	0	0	4	2		F
			TOTAL	**27**	**15**	**2**	**10**	**22**		

SEMESTER II

S. No.	Course code	Course title	Category	Contact periods	L	T	P	C	Pre requisites	Fixed/ Movable
1.	CL18201	Advanced transport phenomena	PC	4	3	1	0	4		F
2.	CL18202	Advanced Chemical Reaction Engineering	PC	4	3	1	0	4		F
3.	CL18203	Advanced Process control	PC	3	3	0	0	3		F
4.	MC18081	Introduction to Research Methodology and IPR	MC	2	2	0	0	2		F
5.		Professional Elective-II	PE	3	3	0	0	3		F
6.	CL18211	Mini Project	EEC	4	0	0	4	2		F
7.	CL18212	Advanced Chemical Reaction Engineering Laboratory	PC	4	0	0	4	2		F
8.	CL18213	Advanced Chemical Engineering Laboratory	PC	4	0	0	4	2		F
			TOTAL	**28**	**14**	**2**	**12**	**22**		

SEMESTER III

S. No.	Course code	Course title	Category	Contact periods	L	T	P	C	Pre requisites	Fixed/ Movable
1.		Professional Elective- III	PE	3	3	0	0	3		F
2.		Professional Elective- IV	PE	3	3	0	0	3		F

3.	CL18311	Project Work Phase – I	EEC	12	0	0	12	6		F
			TOTAL	**18**	**6**	**0**	**12**	**12**		

SEMESTER IV

S. No.	**Course code**	**Course title**	**Category**	**Contact periods**	**L**	**T**	**P**	**C**	**Pre requisites**	**Fixed/ Movable**
1.	CL18411	Project Work Phase – II	EEC	24	0	0	24	12		F
			TOTAL	**24**	**0**	**0**	**24**	**12**		

TOTAL: 68 CREDITS

PROFESSIONAL ELECTIVES (PE)

S. No.	**Course code**	**Course title**	**Category**	**Contact hours**	**L**	**T**	**P**	**C**	**Pre-Requisite**	**Fixed/ Movable**
ELECTIVE - I										
1	CL18001	Electrochemical processes for clean technology	PE	3	3	0	0	3		
2	CL18002	Solar Energy Engineering	PE	3	3	0	0	3		
3	CL18003	Down Stream Processes in Petroleum Engineering	PE	3	3	0	0	3		
4	CL18004	Environmental engineering	PE	3	3	0	0	3		
5	CL18005	Waste water engineering	PE	3	3	0	0	3		
ELECTIVE - II										**E**
1	CL18006	Electrochemical process for chemical Engineers	PE	3	3	0	0	3		
2	CL18007	Process integration	PE	3	3	0	0	3		
3	CL18008	Gas Transportation	PE	3	3	0	0	3		
4	CL18009	Environmental policies and legislation	PE	3	3	0	0	3		
5	CL18010	Bioprocess Engineering	PE	3	3	0	0	3		
ELECTIVE - III										**E**
1	CL18011	Fuel cell technology	PE	3	3	0	0	3		
2	CL18012	Chemical Reactor Analysis	PE	3	3	0	0	3		
3	CL18013	Fluidization Engineering	PE	3	3	0	0	3		
4	CL18014	Design of Experiments and Parameter Estimation	PE	3	3	0	0	3		
5	CL18015	Micro and Nano fluidics	PE	3	3	0	0	3		
ELECTIVE - IV										**E**
1	CL18016	Electrochemical engineering	PE	3	3	0	0	3		
2	CL18017	Energy management	PE	3	3	0	0	3		
3	CL18018	HSE in Petroleum Industries	PE	3	3	0	0	3		
4	CL18019	Environmental sustainability	PE	3	3	0	0	3		
5	CL18020	Process Design and Synthesis	PE	3	3	0	0	3		

SEMESTER – I

SUB CODE	SUBJECT TITLE	L	T	P	C
MA18184	MATHEMATICAL AND STSTISTICAL METHODS IN CHEMICAL ENGINEERING	3	1	0	4

OBJECTIVES:

- To impart knowledge on advanced theoretical and numerical methods that will come in handy to solve problems relevant to chemical Engineering. The students are in a position to identify appropriate statistical methods to analyze and interpret data.

UNIT I	**ALGEBRAIC EQUATIONS**	**12**

Systems of linear equations: Gauss Elimination method, pivoting techniques, Thomas algorithm for tridiagonal system –Gauss Seidel, SOR iteration methods - Systems of nonlinear equations: Fixed point iterations, Newton Raphson Method, Eigen value problems.

UNIT II	**ORDINARY DIFFERENTIAL EQUATIONS**	**12**

Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, shooting method, BVP: Finite difference method, orthogonal collocation method, orthogonal collocation with finite element method, Galerkin finite element method.

UNIT III	**BOUNDARY VALUE PROBLEMS**	**12**

. Parabolic equations: explicit and implicit finite difference methods, weighted average approximation - Laplace and Poisson's equations in a rectangular region: Five point finite difference schemes, Leibmann's iterative methods Dirichlet and Neumann conditions –different explicit and implicit methods; numerical stability analysis, method of lines – Wave equation: Explicit scheme- Stability of above schemes.

UNIT IV	**TESTING OF HYPOTHESIS**	**12**

Sampling distributions-Large samples and Small samples. Testing of Null hypothesis-Z test, t- test and Ψ^2 test. Type I and Type II errors. Fisher's F Test. Goodness of fit.

UNIT V	**ANALYSIS OF VARIANCE**	**12**

Design of Experiments –One way, Two way classifications – Randomized Block Designs-

Latin Square Designs	
	TOTAL: (45+15): 60 PERIODS

OUTCOMES:

- Solve algebraic equations for the linear system.
- Identify the solution of stiff ODs, ODE-IVPs coupled with algebraic equations.
- Distinguish the analysis methods for the boundary value problems.
- Evaluate Null hypothesis with Z-test, t-test and F-test.
- Evaluate design of experiments by one and two way classifications and predict the analysis of variance.

TEXT BOOKS:

1.	Probability and Statistics for Engineers 6^{th} Edition. Prentice Hall By R.A.Johnson.
2.	Statistical Quality control for the Food Industry. By MERTON R.HUBBARD Mathematical Statistics By V.C.Kapoor and Gupta.

REFERENCES:

1.	Saumyen Guha and Rajesh Srivastava, "Numerical methods for Engineering and Science", Oxford Higher Education, New Delhi, 2010.
2.	Gupta S.K., "Numerical Methods for Engineers", New Age Publishers, 1995
3.	Burden, R.L., and Faires, J.D., "Numerical Analysis – Theory and Applications", Cengage Learning, India Edition, New Delhi, 2009.
4.	Jain M. K., Iyengar S. R., Kanchi M. B., Jain , "Computational Methods for Partial Differential Equations", New Age Publishers,1993.
5.	Morton K.W. and Mayers D.F., "Numerical solution of partial differential equations", Cambridge University press, Cambridge, 2009.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18101	**ADVANCED THERMODYNAMICS FOR CHEMICAL ENGINEERRS**	**3**	**1**	**0**	**4**

OBJECTIVES:

- To introduce the principles of chemical engineering thermodynamics and illustrate their applications in the design of chemical process plants.

UNIT I	**BASIC CONCEPTS**	**12**
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**	**12**
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**	**12**
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**	**12**
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**	**12**
Homogeneous gas and liquid phase reactions, heterogeneous reactions – phase and chemical equilibrium.		
	TOTAL: (45+15):60 PERIODS	

OUTCOMES:

- Analyze the basic concept of fluid phase equilibria and Maxwell's relations.
- Assess the stability and phase equilibria of the thermodynamic systems.
- Explain the Wilson, NRTL, UNIQUAC equations and UNIFAC methods for ideal and non-ideal solutions.
- Develop phase equilibrium based on vapor liquid equilibrium.
- Identify chemical equilibrium for the homogenous gas and liquid phase reactions.

TEXT BOOKS:

1.	Tester, J. W. and M. Modell, Thermodynamics and Its Applications. 3rd Edn. Prentice Hall, New Jersey, 1997
2.	Rao., Y.V.C., Chemical Engineering Thermodynamics, University Press, Hyderabad, 2005
REFERENCES:	
1.	Prausnitz, J.M., Lichtenthaler R.M. and Azevedo, E.G., Molecular thermodynamics of fluid-phase Equilibria, 3rd Edn, Prentice Hall Inc., New Jersey, 1999
2.	Dodge, B.F., "Chemical Engineering Thermodynamics", McGraw-Hill, 1960.
3.	Smith, J.M., VanNess, H.C., & Abbot M.C, "Introduction to Chemical Engineering Thermodynamics", McGraw Hill VII Edition 2004.
4.	Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics"53Prentice Hall of India Pvt. Ltd. 2001.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18102	**ADVANCED SEPARATION PROCESS**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To familiarize students with various advanced aspects of separation processes and the selection of separation processes.
- To enable students to understand the principles and processes of adsorption, membrane separation and chromatography and to design an absorber or a membrane unit to achieve a specified separation
- To introduce them to new trends used in the separation technologies

UNIT I		**12**

Introduction: Conventional separation processes - Absorption, Adsorption, Conventional separation processes - Distillation, Drying, Conventional separation processes - Extraction, Diffusion, Conventional separation processes - Leaching, Crystallization, Advances in separation techniques based on size, Advances in separation techniques based on surface properties, Advances in separation techniques based on ionic properties, Cross flow filtration, Electro filtration, Dual functional filter, Surface based solid-liquid separations involving a second liquid, Sirofloc filter

UNIT II		**12**
Bubble and Foam Fractionation: Nature of bubbles and foams, stability of foams, foam fractionation techniques, batch, continuous, single stage and multistage columns. Types and choice of membranes, Plate and frame, spiral wound membranes, Tubular and hollow fiber membrane reactors, Membrane Permeates: Dialysis, Reverse osmosis, Nano filtration, ultra filtration, microfiltration, Donnan dialysis, Ceramic membranes.		
UNIT III		**8**
Membrane Separation: Characteristics of organic and inorganic membranes, basis of membrane selection, osmotic pressure, partition coefficient and permeability, concentration polarization, electrolyte diffusion and facilitated transport, macro-filtration, ultra-filtration, reverse osmosis, electro-dialysis. Industrial applications		
UNIT IV		**8**
Special Processes: Liquid membrane separation, super-critical extraction, adsorptive separation-pressure, vacuum and thermal swing, pervaporation and permeation, nano-separation.		
UNIT V		**5**
Chromatographic Methods of Separation: Gel, solvent, ion and high performance liquid chromatography of cleaner production.		
	TOTAL: (45+0):45 PERIODS	

OUTCOMES:

- Enumerate the recent advances in separation techniques based on the properties of substances.
- Enumerate the mechanism and equipment used in various separation techniques.
- Identify the mechanism and equipment used in membrane separations.
- Apply modern concepts like pervaporation and lyophilisation in Chemical process industries.
- Identify the importance of chromatographic techniques and separation based on adsorption.

TEXT BOOKS:

1.	Rousseau, R. W., “Handbook of Separation Process Technology”, John Wiley, New York,

	2009
2.	King C.J., “Separation Processes”, Tata McGraw Hill. 1982.
REFERENCES:	
1.	Nakagawal, O. V., “Membrane Science and Technology”, Marcel Dekker, 1992
2.	Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
3.	Phillip C. Wankat , Separation Process Engineering (2nd Edition),Printice Hall,2007

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18103	**PROCESS MODELING AND SIMULATION**	**3**	**0**	**0**	**3**

OBJECTIVES:

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

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, flowsheeting – sequential modular and equation-oriented approach, tearing, partitioning and precedence ordering, solution of linear and non-linear algebraic equations.

UNIT III	**UNSTEADY STATE LUMPED SYSTEMS**	**9**

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+0): 45 PERIODS

OUTCOMES:

- To impart knowledge on the fundamentals 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.
- Analyze and 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.

TEXT BOOKS:

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.

REFERENCES:

1. Asghar Husain, “Chemical Process Simulation”, Wiley, 1986
2. Felder, R. M. and Rousseau, R. W., “Elementary Principles of Chemical Processes”, John Wiley, 2000.
3. Franks, R. G. E., “Mathematical Modelling in Chemical Engineering“, John Wiley, 1967.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18111	TECHNICAL SEMINAR	0	0	2	1

OBJECTIVES:

- During the seminar session each student is expected to prepare and present a topic on Energy related issues / technology, for a duration of about 30 minutes.
- Students are encouraged to use various teaching aids such as over head projectors, power

point presentation and demonstrative models.		
	TOTAL: (L: 0 + T: 30): 30 PERIODS	

OUTCOMES:

At the end of the course, the student will be able to:

- Give talk on a selected topics of chemical engineering
- Learn to use various teaching aids such as over head projectors, power point presentation and demonstrative models.

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18112	**INSTRUMENTAL METHODS OF ANALYSIS LABORATORY**	**0**	**0**	**4**	**2**

OBJECTIVES:

- To give basic knowledge on instrumental methods of chemical analysis and train students to perform practical work on real samples to get acquainted with instrumentation and equipment which is needed in monitoring of environmental pollution and in investigating current environmental processes.

LIST OF EXPERIMENTS

1. Analysis of Sample Mixture Using Gas Chromatography
2. High Performance Liquid Chromatography (HPLC)
3. Thermo-gravimetric Analysis
4. Estimation of Amount of Copper and Chromium in the given water sample
5. Estimation of Iron in the given water sample
6. Cyclic Voltametry
7. Tafel Plot
8. Determination of Absorption Curve and Concentration of different dyes using UV-Visible Spectrophotometer
9. Determination of Chromium and Manganese Concentration in solution
10. Determination of Arsenic in solution

	TOTAL: (L: 0+ T: 60): 60 PERIODS	

OUTCOMES:

At the end of the course, the student will be able to:

- Estimate the heavy metal quantity present in sample using Atomic Absorption Spectroscopy (AAS).
- To impart knowledge on the importance and applications of UV visible spectrophotometer analysis.
- Assess the skill of operating Gas Chromatography for the analysis of fluid samples.
- Assess the skill of operating 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.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18113	PROCESS MODELING AND SIMULATION LABORATORY	0	0	4	2

OBJECTIVES:

- To learn Process Modeling and Simulation of Chemical operations and processes.
- To understand Dynamic Behavior of processes.
- To understand Close loop control of processes.
- To learn Dynamic simulation of chemical processes.

List of Experiments

1. Thermodynamic property estimations using property estimation and property analysis in Aspen.
2. Simulate Mixer, splitter, heat exchangers, and reactive distillation column.
3. Apply sensitivity, design specification and case study tools in Aspen .
4. Solve linear and non-linear programming problems.
5. Controller tuning by Ziegler- Nichol's & Cohen- Coon methods
6. Stability analysis using Bode diagrams for control systems.
7. Simulation of Ideal Binary Distillation Column
8. Simulation of Heat/Mass Transfer coefficient in 3 phase fluidized bed column
9. Simulation studies of various unit operations using Aspen Plus
10. Modeling and Simulation of cyclone separator
11. CFD Simulation of flow over a flat plate
12. CFD Simulation of flow over a sphere.

	TOTAL: (L:0 + T:60): 60 PERIODS

OUTCOMES:

- Estimate thermodynamic property using property estimation and property analysis in Aspen.
- To impart knowledge on Simulation of Mixer, splitter, heat exchangers, reactors and distillation columns.
- Explore sensitivity, design specification and case study tools in Aspen Plus and HYSYS.
- Perform CFD Simulations for momentum transport problems - 3D flow.
- Develop MATLAB codes for Chemical Engineering problems.

TEXT BOOKS:

1.	Jana A.K., Process Simulation and control using Aspen, Prentice Hall of India Pvt. Ltd, 2009.
2.	Coughnowr, D., Process Systems Analysis and Control, 3rd Edn., McGraw Hill, New York, 2008.

REFERENCES:

1.	Kamal I.M. Al-Malah., Aspen Plus: Chemical Engineering Applications, Wiley and sons 2017.

SEMESTER II

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18201	ADVANCED TRANSPORT PHENOMENA	3	1	0	4

OBJECTIVES:

- To familiarize the student with basic concepts of transport phenomena and brief review of mathematics.
- To enable students to understand the equations of change for isothermal flow and for non-isothermal flow.
- To introduce them details of equations of change for multi component systems and to give them insight into properties of two-dimensional flows and aspects of dimensional analysis**.**

UNIT I		**12**

Equations of Change for Isothermal Systems: Equation of Continuity, Equation of Motion, Equation of Mechanical Energy, Equations of Change in terms of the Substantial Derivative, Use of the Equations to solve Flow Problems, Dimensional Analysis of the Equations of Change.

Velocity Distributions with more than one Independent Variable: Time Dependent Flow of Newtonian Fluids.		
UNIT II		**12**
Equations of Change for Non-Isothermal Systems: The Energy Equation, Special forms of the Energy Equation, The Boussinesq Equation of Motion for Forced and Free Convection, Use of the Equations of change to Solve Steady-State Problems, Dimensional Analysis of the Equations of Change for Non-Isothermal Systems. Temperature Distributions in Solids and in Laminar Flow: Temperature Distributions with more than One Independent Variable - Unsteady Heat Conduction in Solids, Steady Heat Conduction in Laminar, Incompressible Flow. Empirical Expressions for the Turbulent Heat Flux Temperature Distribution for Turbulent Flow in Tubes.		
UNIT III		**12**
Concentration Distributions with more than One Independent Variable: Time-Dependent Diffusion, Steady-State Transport in Binary Boundary Layers, Concentration Distributions in Turbulent Flow - Concentration Fluctuations and the Time-Smoothed Concentration, Time-Smoothing of the Equation of Continuity of A, Semi-Empirical Expressions for the Turbulent Mass Flux, Enhancement of Mass Transfer by a First-Order Reaction in Turbulent Flow.		
UNIT IV		**12**
Macroscopic Balances for Isothermal Systems: The Macroscopic Mass Balance, The Macroscopic Momentum Balance, The Macroscopic Mechanical Energy Balance, Estimation of the Viscous loss, Use of the Macroscopic Balances for Steady-State Problems, Derivation of the Macroscopic Mechanical Energy Balance. Macroscopic Balances For Non-Isothermal Systems: Macroscopic Energy Balance, Macroscopic Mechanical Energy Balance, Use Of The Macroscopic Balances To Solve Steady State Problems With Flat Velocity Profiles		
UNIT V		**12**
Interphase Transport in Multi-Component Systems: Definition of Transfer Coefficients inOne Phase, Analytical Expressions for Mass Transfer Coefficients, Correlation of Binary Transfer Coefficients in One Phase, Definition of Transfer Coefficients in Two Phases, Mass Transfer and Chemical Reactions. Macroscopic Balances For Multi-Component Systems: Macroscopic Mass		

Balances, Macroscopic Momentum, Use of the Macroscopic Balances to solve Steady-State Problems.

TOTAL: (L:45 + T:15): 60 PERIODS

OUTCOMES:

- Enumerate the mechanism of momentum, heat and mass transport for steady and unsteady flow.
- Develop momentum, energy and mass balances for a given system at macroscopic and microscopic scale.
- Estimate 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.

TEXT BOOKS:

1.	Bird R. B., Stewart W. E. and Light Foot E. N., Transport Phenomena, Revised 2nd Edition, John Wiley & Sons, 2007
2.	Thomson W. J., Transport Phenomena, Pearson education, Asia, 2001

REFERENCES:

1.	Geankopolis C. J., Transport Processes and Unit Operations, 4th Ed., Prentice Hall (India) Pvt. Ltd., New Delhi. 2004.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18202	ADVANCED CHEMICAL REACTION ENGINEERING	3	1	0	4

OBJECTIVES:

This course is essential for Design of Reactor especially heterogeneous reactors. Students will learn the energy balance, temperature and concentration profiles in different reactors, advance design aspects of multiple reactors, students will get insight of importance of population balance of particles. Role of Reaction Engineering in mitigation of Global warming will also be addressed.

UNIT I **12**

Non-elementary Kinetics Importance: Approximations for formulations of Rate laws,

Formulations of Kinetic model. Effect of flow on conversions in Reactors: Semibatch Reactors : Importance and examples of applications , Material Balance on Semibatch Reactor, Multiple reaction in Semibatch Reactors, Conversion Vs Rate in Reactors.		
UNIT II		**12**
Multiple Reactor systems with CSTR's: Exothermic and Endothermic Reaction with examples, CSTR with heat effects, Multiple reactions in CSTR and PFR with heat effects, Semi batch Reactors with heat exchange. Design of PFR and Packed Bed Tubular Reactors: Volume of reactors calculations for non-isothermal reactors. Optimal Design of Reactors for Reversible exothermic reactions: Heat effects in semi batch unsteady state operation. Auto thermal Plug flow reactors and packed tubular reactors.PFR with inter stage cooling. Examples of optimal design of PFR and Semibatch and CSTR Exothermic Reactions.		
UNIT III		**12**
Catalytic reactions: theory and modeling: Global rate of reaction, Types of Heterogeneous reactions Catalysis, Different steps in catalytic reactions, Theories of heterogeneous catalysis. Steady State approximation, formulations of rate law Rate laws derived from the PSSH, Rate controlling steps, Eiley-Rideal model, Reforming catalyst example: Finding mechanism consistent with experimental observations Evaluation of rate law parameters, packed beds : Transport and Reactions, Gradients in the reactors : temperature. Porous media reactors:		
UNIT IV		**12**
Fluidized bed reactor modeling: Fixed bed vs fluidized bed Why fluidized bed, important parameters pressure drop in fixed bed, Class I model Arbitrary Two Region Flow Models, Class II Chemical Reactor: Plug Flow or Mixed Flow Model.		
UNIT V		**12**
Application of Population Balance Equations for reactor modeling: Particle size distribution, Distribution Functions in Particle Measuring Techniques, Particle distribution model in colloidal particle synthesis in batch reactor, Moments of Distribution, Nucleation rate based on volumetric holdup versus crystal growth rate. Reaction engineering and mitigation of Global warming: CO_2 absorption in high pressure water, different techniques of mitigation of CO_2, methods of separations. Recent advancements, automotive monolith catalytic converter example, removal and		

utilization of CO_2 for thermal power plants.		
	TOTAL: (L:45 + T:15):60 PERIODS	

OUTCOMES:

- Evaluate heterogeneous reactor performance considering mass transfer limitations.
- Acquire knowledge on energy balance and obtain concentration profiles in multiphase reactors.
- Estimate the performance of multiphase reactors under non-isothermal conditions.
- Enumerate modern reactor technologies for mitigation of global warming.
- Model population balance equations for batch, continuous and catalytic reactor modeling.

TEXT BOOKS:

1.	K.G. Denbigh : Chemical Reactor Theory, Cambridge University Press, Second Edition, 1971.
2.	Levenspiel O., Chemical Reaction Engineering, Wiley, 1998.

REFERENCES:

1.	J.M. Smith : Chemical Engineering Kinetics, McGraw Hill, Third Edition, 1981.
2.	Foggler, H.S., Elements of Chemical Reaction Engineering, Prentice Hall of India, 2008.
3.	Fromment G.F. and Bischoff K.B., Chemical Reactor Analysis and Design, John Wiley, 2010.

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18203	**ADVANCED PROCESS CONTROL**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To introduce dynamic response of open and closed loop systems, control loop components.
- To analyze the stability of control systems along with instrumentation.
- To study multi-variable control strategies.

UNIT I	**Advanced Control Strategies**	**9**

Feed forward, cascade, dead time compensation, split range, selective and override control; automatic tuning and gain scheduling.

UNIT II	**Internal Model Control**	**9**
Model based control – IMC structure – development and design; IMC based PID control		
UNIT III	**Multi-variable 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: (L:45 + T:0): 45 PERIODS	

OUTCOMES:

- Describe 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.
- Acquire knowledge on control strategies and Discrete – Time Response of dynamic system.
- Design of digital feedback controllers and algorithms.

TEXT BOOKS:

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.

REFERENCES:

1.	Pradeep B. Deshpande, Raymond H. Ash , Elements of Computer Process Control with Advanced Control Applications , Instrument Society of America,1981.
2.	Stephanopolous, G., "Chemical Process Control", Prentice Hall of India, New Delhi, 2003.

SUB CODE	SUBJECT TITLE	L	T	P	C
MC18081	INTRODUCTION RESEARCH METHODOLOGY AND IPR	3	0	0	3

OBJECTIVES:

- To impart knowledge on formulation of research problem, research methodology, ethics involved in doing research and importance of IPR protection.

UNIT I	**RESEARCH METHODOLOGY**	**9**

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations. Effective literature studies approaches, analysis Plagiarism, Research ethics

UNIT II	**RESULTS AND ANALYSIS**	**9**

Importance and scientific methodology in recording results, importance of negative results, different ways of recording, industrial requirement, artifacts versus true results, types of analysis (analytical, objective, subjective) and cross verification, correlation with published results, discussion, outcome as new idea, hypothesis, concept, theory, model etc.

UNIT III	**TECHNICAL WRITING**	**9**

Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

UNIT IV	**INTELLECTUAL PROPERTY RIGHTS**	**9**

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT V	**PATENT RIGTS AND NEW DEVELOPMENTS IN IPR**	**9**

Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases.

Geographical Indications. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

TOTAL: (L:45 + T:0): 45 PERIODS

OUTCOMES:

- Critically evaluate any research article based upon research methodology.
- Correlate the results of any research and develop hypothesis, concept, theory and model.
- Developing a research proposal, research presentation and review article in the field of chemical engineering.
- Enumerate the importance of intellectual property right in research.
- Develop proposal for patent rights and identify the new developments in IPR

TEXT BOOKS:

1.	Ranjit Kumar, Research Methodology- A step by step guide for beginners, Pearson Education, Australia, 2005.
2.	Ann M. Korner, Guide to Publishing a Scientific paper, Bioscript Press 2004.
3.	T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

REFERENCES:

1.	Kothari, C. R. Research Methodology - Methods and Techniques, New Age International publishers, New Delhi, 2004.
2.	Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students', Juta & Company, 1996.
3.	Robert P. Merges, Peter S. Menell and Mark A. Lemley, "Intellectual Property in New Technological Age", Aspen Publishers, 2016.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18211	MINI PROJECT	0	0	4	2

OBJECTIVES:

At the end of the course, the student will be able to:

- Identify structural engineering problems reviewing available literature.
- Study different techniques used to analyze complex structural systems.
- work on the solutions given and present solution by using his/her technique applying

engineering principles.

Syllabus:

1) Mini Project will have mid semester presentation and end semester presentation.
2) Mid semester presentation will include identification of the problem based on the literature review on the topic referring to latest literature available.
3) End semester presentation should be done along with the report on identification of topic for the work and the methodology adopted involving scientific research, collection and analysis of data, determining solutions highlighting individuals' contribution.
4) Continuous assessment of Mini Project at Mid Sem and End Sem will be monitored by the departmental committee.

TOTAL (L:0 + T:60): 60 PERIODS

OUTCOMES:

- Students will able to solve the problem in chemical engineering
- Students will be able to work on an emerging area of chemical engineering

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18212	ADVANCED CHEMICAL REACTION ENGINEERING LABORATORY	0	0	4	2

OBJECTIVES:

- To provide through understanding of Reaction Engineering
- To design reactor and identity type of reactor by suiting chemical kinetics and using information from thermodynamics, heat and mass transfer economics.
- Characteristics of a fluidized bed reactor.
- Understanding of corrosion reaction and monolithic catalytic reactors.

List of Laboratory Experiments:

1. Analyze the characteristics of a fluidized bed reactor.
2. Kinetics of a (solid-liquid) Esterification reaction in a batch reactor.
3. Evaluate the performance of a process intensified Batch Reactive Distillation in catalytic

reactions.
4. Evaluate the performance of a process intensified micro reactor in catalytic reactions.
5. Interfacial (Liquid-Liquid) Nitration.
6. Gas-solid catalytic reactor analysis: Understanding of gas-solid catalytic reactor theory and dynamics analysis.
7. Gas-liquid-solid three-phase catalytic reactor analysis: Understanding gas-liquid-solid three phase catalytic reactor theory and dynamics analysis.
8. Reactor analysis: Understanding the principle and diffusion analysis of batch and flow reactors.
9. Corrosion reaction characteristics of a metal in a given electrolyte.
10. Reactions on Monolithic Catalytic Reactors.

	TOTAL: (L: 0+ T: 45): 45 PERIODS	

OUTCOMES:

- Acquire knowledge on the solid-liquid, liquid –liquid reactions.
- Enumerate the micro-reactor based process intensification.
- Assess solid-liquid catalytic reactions.
- Explore the performance of a process intensified Batch Reactive Distillation in catalytic reactions.
- Distinguish the corrosion reaction characteristics of a metal in different electrolytes.

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18213	**ADVANCED CHEMICAL ENGINEERING LABORATORY**	**0**	**0**	**4**	**2**

OBJECTIVES:

- Analyze characteristics of a fluidized bed dryer, compact heat exchangers, electrochemical phenomena such as corrosion
- Evaluate the performance of a process intensification in catalytic reactions, ultrasound assisted reactions, reactive distillation column, micro reactor and advanced flow reactor
- Design controller for a given process and Evaluate the performance of membrane

separation process for water purification
List of Laboratory Experiments:
1. Ultrasonic cavitation based reactions
2. Helical Coil heat exchanger
3. Plate Type Heat Exchanger
4. Kinetics for solid catalyzed esterification reaction in a batch reactor
5. Reactive distillation in Packed Column
6. Characteristics of a fluidized bed dryer
7. Advanced Flow Reactor
8. Membrane Separation for water purification
9. Corrosion characteristics of a metal in a given electrolyte
10. Control of liquid level in non-interacting systems.
11. Identification and control of a three tank system.
12. pH control in a process.
TOTAL: (L: + T: 45): 45 PERIODS
OUTCOMES:
• Evaluate the characteristics of a fluidized bed dryer, compact heat exchangers, electrochemical phenomena such as corrosion. • Evaluate the performance of process intensification in various reactors and reactive distillation column. • Design controller and determine the performance of membrane separation process for water purification. • Identify the use of PID for Control of liquid level in interacting and non-interacting systems • Distinguish the corrosion characteristics of a metal in different electrolytes.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18311	**PROJECT WORK PHASE -I**	**0**	**0**	**12**	**6**
OBJECTIVES:					

At the end of the course:

- Students will be exposed to self-learning various topics.
- Students will learn to survey the literature such as books, national/international refereed journals and contact resource persons for the selected topic of research.
- Students will learn to write technical reports.
- Students will develop oral and written communication skills to present and defend their work in front of technically qualified audience.

Syllabus:

1. The Project Work will start in semester III and should preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solution and must preferably bring out the individual contribution.
2. Seminar should be based on the area in which the candidate has undertaken the project work work as per the common instructions for all branches of M. Tech. The examination shall consist of the preparation of report consisting of a detailed problem statement and a literature review.
3. The preliminary results (if available) of the problem may also be discussed in the report. The work has to be presented in front of the examiners panel set by Head and PG coordinator. The candidate has to be in regular contact with his guide and the topic of project work must be mutually decided by the guide and student.

TOTAL: (L: + T:): PERIODS

OUTCOMES:

- Students will able to solve the unique problem in chemical engineering
- Students will be able to work on a emerging area of chemical engineering

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18411	**PROJECT WORK PHASE -II**	**0**	**0**	**24**	**12**

OBJECTIVES:

1. Students will be able to use different experimental techniques and
2. Students will be able to use different software/ computational/analytical tools.
3. Students will be able to design and develop an experimental set up/ equipment/test rig.
4. Students will be able to conduct tests on existing set ups/equipments and draw logical conclusions from the results after analyzing them.
5. Students will be able to either work in a research environment or in an industrial environment.
6. Students will be conversant with technical report writing.
7. Students will be able to present and convince their topic of study to the engineering community.

Syllabus:

1) It is a continuation of Project work started in semester III. He has to submit the report in prescribed format and also present a seminar.
2) The project work should be presented in standard format as provided by the department. The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) of solution and results and discussion.
3) The report must bring out the conclusions of the work and future scope for the study.
4) The work has to be presented in front of the examiners panel consisting of an approved external examiner, an internal examiner and a guide, co-guide etc. as decided by the Head and PG coordinator. The candidate has to be in regular contact with his guide.

TOTAL: (L: + T:): PERIODS

OUTCOMES:

- Students will able to solve the unique problem in chemical engineering
- Students will be able to work on a emerging area of chemical engineering

ELECTIVE I

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18001	**ELECTROCHEMICAL PROCESSES FOR CLEAN TECHNOLOGY**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To understand the different methods for electrode materials synthesis and effluent treatment.
- To know the basics of electrochemical membrane process
- To treat the various industrial effluents by electrochemical methods

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 Excell 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: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- To impart knowledge on the basic principles of electrochemistry and electrochemical properties of materials
- Model the mass transport in Electrochemical Systems using various mechanisms and theories of mass transfer
- Apply the principles of electrochemistry in mitigating the various types of corrosion
- Describe the various electro deposition techniques and electro chemical energy storage systems
- Establish the fundamental knowledge of electrodes used in different electrochemical industries and its design

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.

REFERENCES:

1.	Marcel Mulder, Basic Principles of Membrane Technology, 2nd edition, Kluwer Academic Publishers, 2003.
2.	Krishnan Rajeshwar, JORGE G. IBANEZ, Environmental Electrochemistry, Fundamentals and applications in Pollution Abatement, ACADEMIC PRESS, Inc,1997.

3.	K. Scott, Electrochemical reaction engineering, London, ACADEMIC PRESS, 1991.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18002	**SOLAR ENERGY ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- Students gain the knowledge on solar energy radiation, availability, solar power applicability.
- Students will understand the various methods and optimization techniques to harness solar power.

UNIT I		**9**

Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer-sunshine recorder.

UNIT II		**9**

Solar Non-Concentrating Collectors- Design considerations – Classificationair, liquid heating collectors –Derivation of efficiency and testing of flat plate collectors –Analysis of concentric tube collector - Solar green house.

UNIT III		**9**

Design – Classification– Concentrator mounting –Focusing solar concentratorsHeliostats. Solar powered absorption A/C system, water pump, chimney, drier, dehumidifier, still, cooker.

UNIT IV		**9**

Photo-voltaic cell – characteristics-cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-charge regulators, Construction concepts.

UNIT V		**9**

Energy Storage -Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber's salt-organic compounds. Solar ponds.

TOTAL: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

- To impart knowledge on solar radiation and its measurements
- Develop an efficient solar energy conversion system
- Design various applications powered by solar energy
- Perform the calculation, analyze and optimize various parameters associated with the solar energy for a specific geography
- Compare the different types of energy storage based on transport processes

TEXT BOOKS:

1.	D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003
2.	. Edward E. Anderson, "Fundamentals for solar energy conversion", Addison Wesley Publ. Co., 1983.

REFERENCES:

1.	Duffie J. A and Beckman, W .A., "Solar Engineering of Thermal Process", John Wiley, 1991.
2.	G. N. Tiwari and M. K. Ghosal, "Fundamentals of Renewable energy Sources", Narosa Publishing House, New Delhi, 2007
3.	Energy Studies, Second Edition, by W. Shepherd and D. W. Shepherd, Imperial College Press, London, 2004

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18003	**DOWNSTREAM PROCESSES IN PETROLEUM ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To illustrate the importance of crude oil as source of fuel and the size of refining industry
- To summarize the various refinery processes and the products along with their specifications
- To show the challenges involved in refining from viewpoint of economic considerations and environmental regulations.

UNIT I	**Overview of Production and Refining of Crude Oil**	**9**
Origin, formation, exploration and production of crude oil, Reserves and deposits in the world, Petroleum industry in India, Overall Refinery flow, Petroleum Products.		
UNIT II	**Composition and evaluation of Crude oil and its Products**	**9**
Classification of crude oil, Composition of crude oil, Crude Assay, ASTM/TBP/EFV curves, Specifications and Test methods for: LPG, Naphtha, Gasoline, Kerosene, Diesel, Lube oil, Waxes, Bitumen and Coke.		
UNIT III	**Refinery Process: Distillation, Cracking and Conversion**	**9**
Desalting of Crude, Preheating Train, Atmospheric Distillation of Crude oil, Vacuum Distillation, Catalytic Cracking, Hydrocracking, Catalytic Reforming, Alkylation, Isomerization, Hydroprocessing, Hydrotreating, Coking		
UNIT IV	**Manufacture of Lube oil and Bitumen**	**9**
Lube oil processing, Propane deasphalting, Solvent Extraction, Dewaxing, Finishing Processes, Lube oil additives, Properties of Bitumen, Methods of Manufacture of Bitumen		
UNIT V	**Supporting Process and Pollution Control in Refineries**	**9**
Product Blending, Hydrogen Production, Sulphur Recovery, Control of air and water pollution, solid waste management		
	TOTAL: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Demonstrate knowledge on the overall refinery flow and petroleum products.
- Classify crude oil on the basis of its properties and characterization methods.
- Identify the specifications required for good quality petroleum product
- Explain the process of purification and fractionation of crude oil
- Gain knowledge on the supporting processes and pollution control

TEXT BOOKS:

1. Gary, J.H and Handework, G.E., 'Petroleum Refining Technology and Economics', Fourth Edition, Marcel Dekker, Inc. 2001

2.	Ram Prasad, 'Petroleum Refining Technology', First Edition, Khanna Publishers. 2013
REFERENCES:	
1.	BhaskaraRao, B.K, 'Modern Petroleum Refining Processes', Fifth Edition, Oxford and IBH Publishing Co. Pvt. Ltd. 2007
2.	Fahim, M.A., Alsahhaf, T.A. and Elkilani, A. 'Fundamentals of Petroleum Refining', Elsevier, 2010
3.	Nelson, N.L. (1985) 'Petroleum Refinery Engineering', McGraw Hill Book Co

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18004	**ENVIRONMENTAL ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To introduce students to Environment friendly chemical processes, unit operations for abatement of water, air and solid pollution.
- To make students to understand waste recycles methodologies, towards a cleaner environment and also to recover useful products from wastes.

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: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

- Demonstrate knowledge on the environmental chemical engineering processes.
- Assess the unit operations required for treatment water, air and solid wastes.
- Perform hazard and risk analysis and to apply the appropriate recylcing methodology.
- Apply clean technology principles to produce the eco-friendly products from chemical industries.
- Apply the knowledge to apply the various concepts for the betterment of the environment

TEXT BOOKS:

1.	Rao, C.S Environmental Pollution control Engineering, Wiley- Eastern Ltd. 1991.
2.	Peavy H.S. Rowe D.R., and George Environmental Engineering, Mc Graw Hill Book Company, Ny, 1985

REFERENCES:

1.	Rao M.N and H.V.N. Rao. "Air pollution" ,Tata McGraw Hill Publishing Co. Ltd.1989.
2.	Theodore L and Buomlore A.J Air pollution control equipments. Prentice Hall Inc, NY. 1982.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18005	**WASTE WATER ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- **Objectives:** Impart the knowledge on the wastewater sources , treatment methods and residual Treatment

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: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

- Demonstrate knowledge and understanding of the chemical and biological principles behind unit processes used in wastewater treatment unit processes.
- Acquire knowledge on advanced methods of wastewater Treatment and to reuse
- Design the wastewater treatment plant.
- Explain the management of residuals from wastewater treatment
- Analyze different case studies to mitigate the problems arising in industries

TEXT BOOKS:

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.

REFERENCES:

1.	Nelson Leonard Nemerow, Industrial waste treatment - Contemporary practice and vision for the future. Elsevier, Singapore 2007..
2.	Metcalf & Eddy , George Tchobanoglous , Franklin L. Burton & H. David Stensel "Wastewater Engineering: Treatment and Reuse" Fourth Eddition, Tata McGraw Hill,2003

ELECTIVE II

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18006	**ELECTROCHEMICAL PROCESS FOR CHEMICAL ENGINEERS**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To understand Fundamentals of reaction kinetics and thermodynamics behavior of electrolytic processes
- To familiarize the energetic and energy balances for different reactors involved, and the concept of transport operations.

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	**MASS AND HEAT TRANSFER IN ELECTROLYTIC CELL**	**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 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: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Illustrate the various reaction kinetics, mass transfer and fluid flow of various electrolytic processes
- Infer the concepts in Mass Transfer operations with its applications
- Illustrate the different rate processes involved in electrochemical reaction
- Elaborate the procedure to design and scale up of the electrochemical reactors
- Elucidate the types of fluid flow in electrolytic processes.

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.

REFERENCES:

1.	Pletcher. D and Walsh F.C, Industrial electrochemistry, 2nd edition, Chapman and Hall, London, 1990.
2.	Hartmut Wendt, Gerhard Kreysa, Electrochemical engineering, Science and technology in Chemical and other industries, Springer, 1999.
3.	Krishnan Rajeshwar, JORGE G. IBANEZ, Environmental Electrochemistry, Fundamentals

	and applications in Pollution Abatement, ACADEMIC PRESS, Inc,1997.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18007	**PROCESS INTEGRATION**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To introduce to the students, the various opportunities in the process integration in chemical industries.
- To the make students familiar with the important concepts process integration for heat recovery/minimization.
- To get familiarized with case studies.

UNIT I		**6**

Introduction to process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram.

UNIT II		**12**

Pinch Technology-an overview: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology, Key steps of Pinch Technology: Concept of T_{min} , Data Extraction, Targeting, Designing, Optimization Super targeting, Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve.

UNIT III		**9**

Heat exchanger networks analysis, Maximum Energy Recovery (MER) networks formultiple utilities and multiple, Chemical Engineering Pre-requisites: Knowledge of basic process design of process equipment. Pinches, design of heat exchanger network.

UNIT IV		**9**

Heat integrated distillation columns, evaporators, dryers, and reactors.

UNIT V		**9**

Waste and waste water minimization, flue gas emission targeting, and heat and power integration. Case studies.

	TOTAL: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

- Compare and contrast the given process for the maximum heat recovery.
- Explain the opportunities for integration towards high-efficiency energy.
- Illustrate the various Energy-intensive thermal separation operations (distillation, evaporation) at an industrial process site.
- Evaluate the process integration measures with respect to energy efficiency, greenhousegas emissions and economic performance.
- Identifying the various opportunities for integration of high-efficiency energy

TEXT BOOKS:

1.	Shenoy U.V.;"Heat Exchanger Network Synthesis", Gulf Publishing company, 1995.
2.	Smith R.;"Chemical Process Design", McGraw-Hill, NewYork, 1995

REFERENCES:

1.	Linnhoff B., Townsend D. W.,Boland D, Hewitt G. F., Thomas B.E.A., Guy A. R., and Marsland R. H.;"A User Guide on Process Integration for the Efficient Uses of Energy", Inst. of Chemical Engineers.
2.	Douglas, J.M., "Conceptual Design of Chemical Process", McGraw Hill, New York,1988.

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18008	**GAS TRANSPORTATION**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To resolve key issues in oil and gas industry

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: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Choose the right type of transport processes for gases
- Elaborate the various types of pipes, pipeline protection techniques
- Design pipeline for gas transportation
- Enumerate the contribution for field development
- Illustrate the pipeline integrity and environmental, legal, safety considerations and implications.

TEXT BOOKS:

1.	Oilfield Processing: Crude Oil (Oilfield Processing of Petroleum R. Solvay, Pennwell Books 1995.
2.	Advances in Environmental Control Technology: Storage Tank Paul Cheremisinoff Gulf

	Professional Publishing; 1ST edition (May 9, 1996)
REFERENCES:	

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18009	**ENVIRONMENTAL POLICIES AND LEGISLATION**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To introduce the students to various national and international environmental policies and principles.
- To make students understand the water, air and environmental protection acts etc.

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, authorization – 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 of environmental abuse and protection.		
	TOTAL: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Illustrate the knowledge about the national environmental principles and policies, international environmental agreements
- Elaborate regulatory and legal aspects of Water act, air act and environment (protection) act
- Explain the relevant acts like Indian forest act, insurance act etc.
- Infer the role of different government policies towards environmental protection.
- Compare and contrast the different provisions and judgments towards environmental protection.

TEXT BOOKS:

1.	Shyam Divan and Armin Roseneranz "Environmental law and policy in India "Oxford University Press, New Delhi, 2001.

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.	Greger I. Megregor, "Environmental law and enforcement", Lewis Publishers, London, 1994.

SUB CODE	SUBJECT TITLE	L	T	P	C

CL18010	**BIOPROCESS ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To learn the principles of bioprocessing for traditional chemical engineering in the design and development of processes involving biocatalyst.
- To study engineering principles in the development of products based on living cells or subcomponents of such cells.
- To learn and develop quantitative models and approaches related to bioprocesses.
- To learn mechanistic models for enzyme catalyzed reactions for large scale production of bioproducts.

UNIT I	**INTRODUCTION**	**6**

Biotechnology and bioprocessing. An overview of biological basics. Basics of enzyme and microbial kinetics. Operating considerations for bioreactors: cultivation method, modifying batch and continuous reactors, immobilized cell systems, solid state fermentations.

UNIT II	**ADVANCE ENZYME KINETICS**	**10**

Models for complex enzyme kinetics, modeling of effect of pH and temperature, models for insoluble substrate, models for immobilized enzyme systems, diffusion limitations in immobilized enzyme system, electrostatic and steric effects.

UNIT III	**BIOREACTORS**	**10**

Selection, scale-up, operation and control of bioreactors: Scale-up and its difficulties, bioreactor instrumentation and control, sterilization of process fluids. Modifications of batch and continuous reactors, chemostat with recycle, multistage chemostat, fed-batch operation, perfusion system, active and passive immobilization of cells, diffusional limitations in the immobilized system, solid state fermenters.

UNIT IV	**HOMOGENEOUS & HETEROGENEOUS REACTIONS IN BIOPROCESS**	**10**

Reaction thermodynamics, growth kinetics with Plasmid instability, The Thiele Modulus and effectiveness factor, diffusion and reaction in waste treatment lagoon. Reactors and choice of reactors.

UNIT V	RECOVERY & PURIFICATION OF PRODUCTS	9
Strategies to recover and purify products, separation of insoluble products, cell disruption, separation of soluble products.		
	TOTAL: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

At the end of the course, the student will be able to

- Illustrate the details on different cells and their use in biochemical processes.
- Identifying the role of enzymes in kinetic analysis of biochemical reaction.
- Articulate bioreactors, upstream and downstream processes in production of bio-products
- Elaborate the mechanistic models for enzyme catalyzed reactions for large scale production of bio-products.
- Demonstrate the fermentation process and its products for the latest industrial revolution

TEXT BOOKS:

1.	Bailey J.E. and Ollis D.F., "Biochemical Engineering Fundamentals", McGraw-Hill, 2e, 2017
2.	Shuler M.L., Kargi F., "Bioprocess Engineering", Prentice –Hall, 1992

REFERENCES:

1.	Doran P.M., "Bioprocess Engineering Principles", Academic Press, 2e, 2012

ELECTIVE III

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18011	FUEL CELL TECHNOLOGY	3	0	0	3

OBJECTIVES:

- To teach students fundamental knowledge required in the development of fuel cell technology. Thermodynamics, chemical reaction engineering, transport processes and electrochemical engineering perspectives of fuel cell technology.
- To present a problem oriented in depth knowledge of fuel cell technology and to address the underlying concepts, methods and application of fuel cell technology.

UNIT I		9+3
Overview of fuel cells: Low and high temperature fuel cells; Fuel cell thermo dynamics - 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: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

- 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
- Apply the fundamentals of components of fuel cell power plants in automotive and portable applications

TEXT BOOKS:

1. Supramaniam Srinivasan , "Fuel cells : From fundamental to application, 1st Edition, Springer, 2006.
2. Viswanathan, B and M AuliceScibioh, Fuel Cells – Principles and Applications Universities Press (2006).

REFERENCES:

1.	Gregorhoogers, Fuel cell technology – Hand book, 1st Edition, CRC Press,2002.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18012	**CHEMICAL REACTOR ANALYSIS**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To learn the heterogeneous catalyzed reactions and the models involved in reactor design
- To study mass and heat transfer mechanisms in the different reactors
- To appreciate the importance of both external and internal transport effects in gas-solid and liquid-solid systems.
- To design isothermal and non-isothermal reactors for heterogeneous catalytic reactions.

UNIT I		**9**

Chemical factor affecting the choice of the reactor, fundamental mass, energy and momentum balance, Model for a semi-batch reactor, optimum operation policies and control strategies, optimal batch operation time, optimal temperature policies, stability of operation and transient behavior for mixed flow reactor.

UNIT II		**9**

Fixed bed catalytic reactor: The importance and scale of fixed bed catalytic processes, factors in preliminary design, modeling of fixed bed reactor. Pseudo-homogeneous model, the multibed adiabatic reactor, auto-thermal operation, non-steady-state model with axial mixing, two dimensional pseudo-homogeneous models.

UNIT III		**9**

Multiphase flow reactor: Types of multiphase flow reactors, packed columns, plate columns, empty columns, stirred vessel reactors. Development of rate equations for solid catalyzed fluid phase reactions; Estimation of kinetic parameters. External mass and heat transfer in catalyst particles. Stability and selectivity, Packed bed reactor, slurry reactor; Trickle bed reactor and fluidized bed reactor.

UNIT IV		**9**

Design model for multiphase flow reactors, gas and liquid phase in completely mixed and plug

flow, gas phase in plug flow and liquid phase in completely mixed flow, effective diffusion model, two zone model, specific design aspects, packed absorber, two-phase fixed bed reactor, plate column, spray tower, bubble reactor, stirred vessel reactor.		
UNIT V		**9**
Temperature effects in reactor: Introduction, well mixed system with steady feed, the stability and start-up of CSTR, limit cycles and oscillatory reactions, the plug flow reactors, tubular reactor.		
	TOTAL: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Develop design equations of semi-batch reactors for its optimum functionality
- Formulate mathematical models and design of fixed bed catalytic reactors
- Develop rate equations for solid catalyzed fluid phase reactions carried out in multi-phase reactors
- Perform design calculations of gas-liquid multi-phase flow reactors
- Explain the temperature effects during the operation of reactors

TEXT BOOKS:

1.	Froment G. F. and K.B.Bischoff, " Chemical Reactor Analysis and Design", John Wiley & sons
2.	Denbigh K. G. and J.C. Turner, " Chemical Reactor and Theory – an Introduction", 3rd edition, Cambridge University Press.

REFERENCES:

1.	Bruce Nauman, " Chemical Reactor Design", John Wiley & Sons
2.	Elements of Chemical Reaction Engineering by H. Scott Fogler
3.	Chemical Engineering Kinetics by J. M. Smith.
4.	Chemical Reactor Design and Operation by K. R. Westerterp, W. P. M. Van Swaaij and A. A. C. M. Beenackers.

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18013	**FLUIDIZATION ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To study the phenomenon of fluidization with industrial processing objective.

- To study the various regimes of fluidization and their mapping.
- To study the design of equipment based on fluidization technique.

UNIT I	**Introduction to fluidization and applications**	**9**

Phenomenon of fluidization, behaviour of fluidized bed, contacting modes, advantages and disadvantages of fluidization, fluidization quality, selection of contacting mode, Beds for Industrialapplications, coal gasification, synthesis reactions, physical operations, cracking of hydrocarbons.

UNIT II	**Mapping of fluidization regimes**	**9**

Characterization of particles, mechanics of flow around single particles, minimum fluidization velocity, pressure drop versus velocity diagram, The Geldart classification of solids, fluidization withcarryover of particles, terminal velocity of particles, distributor types, gas entry region of bed,pressure drop requirements, design of gas distributor, power consumption.

UNIT III	**Bubbling fluidized beds**	**9**

Davidson model for bubble in a fluidized bed, and its implications, the wake region and movementof solids at bubbles, coalescence and splitting of bubbles, bubble formation above a distributor, slugflow, Turbulent and fast fluidization - mechanics, flow regimes and design equations, Emulsionmovement, estimation of bed properties, bubble rise velocity, scale up aspects, flow models, twophase model, K-L model.

UNIT IV	**Solids movement and Gas dispersion**	**9**

Vertical and horizontal movement of solids, Dispersion model, large solids in beds of smaller particles, staging of fluidized bedsGas dispersion in beds, gas interchange between bubble and emulsion, estimation of gas interchangecoefficient, Heat and mass transfer in fluidized systems, Mixing in fluidized systems – measurementsand models.

UNIT V	**Fluidized bed reactors**	**9**

Entrainment and elutriation, Freeboard behavior, gas outlet, entrainment from tall vessel, freeboardentrainment model, high velocity fluidization, pressure drop in turbulent and fast fluidization,Slugging, Spouted beds, Circulating Fluidized Beds.Mathematical model of a homogeneous fluidized bed, Design of catalytic reactors, pilot plantreactors, information for

design, bench scale reactors, design decisions, deactivating catalysts, Designof noncatalytic reactors, kinetic models for conversion of solids, models for shrinking particles,conversion of solids of unchanging size.		
	TOTAL: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

At the end of the course, the student will be able to

- To impart knowledge on fluidization phenomena and its industrial applications
- Evaluate the characterization of particles in different fluidization regimes
- Develop the mathematical model of bubbling fluidized beds
- Apply the concepts of heat and mass transfer for solids movement and gas dispersion in fluidized beds.
- Perform design calculations of fluidized bed reactors

TEXT BOOKS:

1.	Levenspiel O. and Kunnii D., "Fluidization Engineering", John Wiley, 1972
2.	Liang-Shih Fan, "Gas-Liquid-Solid Fluidization Engineering", Butterworths, 1989

REFERENCES:

1.	Gibilaro, L. G., Fluidization - Dynamics, Butterworth - Heinemann (2001)
2.	Davidson, J. F., R. Clift and D. Harrison, Fluidization, 2nd Ed., Academic Press (1985).

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18014	**DESIGN OF EXPERIMENTS AND PARAMETER ESTIMATION**	**3**	**0**	**0**	**3**

OBJECTIVES:

- Use statistics in experimentation.
- Understand the important role of experimentation in new product design, manufacturing process development, and process improvement.
- Analyze the results from such investigations to obtain conclusions; become familiar methodologies that can be used in conjunction with experimental designs for robustness and optimization.

UNIT I	**DESIGN OF EXPERIMENTS FOUNDATION - I**	**9**
Design of experiments. Basic concepts, Bias and confounding, controlling bias, causation,		

Examples. Random Variables: Introduction to discrete and continuous random variables, quantify spread and central tendencies of discrete and continuous random variables.

UNIT II	**DESIGN OF EXPERIMENTS FOUNDATION - II**		**9**

Exploratory Data Analysis Variable types, Displaying the distribution, mean variance and typical spread, quartiles and unusual spread, multivariate data: finding relations. Probability Definition of a random variable, expectation, percentiles, common distributions such as the binomial, Poisson and normal distributions.

UNIT III	**DESIGN OF EXPERIMENTS FOUNDATION - III**		**12**

Point Estimation Estimators as random variables, sample mean and the central limit theorem, normal approximations, assessing normality. Interval Estimation Confidence intervals for the mean when the variance is known, confidence interval for the mean when the variance is unknown, confidence intervals for a single proportion, sample size, Student distribution. Hypothesis Testing Hypothesis testing for a mean or proportion, testing the equality of two means assuming equal variances, testing the equality of two means with unequal variances, comparison of two proportions.

UNIT IV	**REGRESSION ANALYSIS**		**9**

Linear Regression analysis: The linear regression model, Parameter estimation, accuracy of the coefficient estimates, checking the model, multiple linear regression, confidence and prediction intervals, potential issues, high leverage points, outliers. Matrix approach to linear regression, Variance-Covariance matrix, ANOVA in regression analysis, quantifying regression fits of experimental data, Extra sum of squares approach, confidence intervals on regression coefficients, lack of fit analysis.

UNIT V	**RESPONSE SURFACE METHODOLOGY**		**6**

Method of steepest ascent, first and second order models, identification of optimal process conditions

TOTAL: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

- Develop experiments for a critical comparison of outputs
- Perform exploratory data analysis and probability distribution analysis of random

variables

- Apply statistical approach to propose hypothesis from experimental data
- Perform regression analysis for quantifying regression fits of experimental data
- Discuss the application of response surface methodology in design of experiments and parameter estimation

TEXTBOOKS:

1.	Devore, Jay L., Probability and Statistics for Engineering and the Sciences, 5th edition, Brooks- Cole, 1999.
2.	Hicks & Turner, "Fundamental Concepts in the Design of Experiments, 5th edition, Oxford University Press, 1999.
3.	Metcalf & Eddy, "Wastewater Engineering: Treatment and Reuse" Volume 1,McGraw-Hill, 2013.

REFERENCES:

1.	G E P Box and K B Wilson, J. R. Stat. Soc. Ser. B (Method.), 13 (1951) 1.D C Montgomery,
2.	Design and Analysis of Experiments, 3rdEdn (New York: Wiley, 1991) 270.
3.	Saunders, Mark, Brown, Reva Berman. "Dealing with Statistics: What You Need to Know". McGraw-Hill Education,

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18015	**MICRO AND NANO FLUIDICS**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To introduce to the students, the various opportunities in the emerging field of micro and nano fluids.
- To the make students familiar with the important concepts applicable to small micro and nano fluidic devices, their fabrication, characterization and application.
- To get familiarize with the new concepts of real-time nano manipulation & assembly.

UNIT I	**INTRODUCTION**	**9**

Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions-Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscale Couette

flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility. Pressure Driven Liquid Microflow: apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro - flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis.		
UNIT II	**LAMINAR FLOW**	**9**
Hagen-Poiseullie eqn, basic fluid ideas, Special considerations of flow in small channels, mixing, microvalves & micropumps, Approaches toward combining living cells, microfluidics and 'the body' on a chip, Chemotaxis, cell motility. Case Studies in Microfluidic Devices. Ionic transport: Polymer transport – microtubule transport in nanotuble channels driven by Electric Fields and by Kinesin Biomolecular Motors - Electrophoresis of individual nanotubules in microfluidic channels.		
UNIT III	**FABRICATION TECHNIQUES FOR NANOFLUIDIC CHANNELS**	**9**
Biomolecules separation using Nanochannels - Biomolecules Concentration using Nanochannels – Confinement of Biomolecules using Nanochannels. Hydrodynamics: Particle moving in flow fields – Potential Functions in Low Renoylds Number Flow – Arrays of Obstacles and how particles Move in them: Puzzles and Paradoxes in Low Re Flow.		
UNIT IV	**MICROFLUIDICS AND LAB-ON-A-CHIP**	**9**
Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods – Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of Proteins Strategies printing types- methods and characterization- Cell nanostructure interactions-networks for neuronal cells. Applications in Automatic DNA sequencing, DNA and Protein microarrays.		
UNIT V	BIOMEMS (MICRO-ELECTRO-MECHANICAL SYSTEMS)	**9**
Introduction and Overview, Biosignal Transduction Mechanisms: Electromagnetic Transducers Mechanical Transducers, Chemical Transducers, Optical Transducers – Sensing and Actuating mechanisms (for all types). Case Studies in Biomagnetic Sensors, Applications of optical and		

chemical transducers. Ultimate Limits of Fabrication and Measurement, Recent Developments in BioMEMS and BioNEMS - An alternative approach to traditional surgery, Specific targeting of tumors and other organs for drug delivery, Micro-visualization and manipulation, Implantation of microsensors, microactuators and other components of a larger implanted device or external system (synthetic organs).

	TOTAL: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

At the end of the course, the student will be able to

- Explain the concepts of pressure driven and electro-kinetically driven micro-flows
- Analyze fluid flow in micro and nano-size devices using physical principles
- Illustrate the fabrication techniques of nanofluidic channels and its hydrodynamics
- Elucidate the applications of microfluidic devices and its fabrication methods
- Enumerate the transduction mechanisms in Bio-Micro-Electro-Mechanical Systems

TEXT BOOKS:

1.	Joshua Edel "Nanofluidics" RCS publishing, 2009
2.	Patric Tabeling "Introduction to Microfluids" Oxford U. Press, New York 2005
3.	K. Sarit "Nano Fluids; Science and Technology", RCS Publishing, 2007

REFERENCES:

1.	M. Madou, Fundamentals of Microfabrication, CRC Press, 1997
2.	G. Kovacs, Micromachined Transducers, McGraw-Hill, 1998
3.	Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006

ELECTIVE IV

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18016	**ELECTROCHEMICAL ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To understand the basic electrochemistry concepts, principles of electrochemical devices, electro active materials
- To familiarize in the aspects diffusion controlled and mass transfer coefficient
- To provide fundamental understanding on materials science relevant to corrosion phenomena and identify practices for the prevention and remediation of corrosion.
- To differentiate between the metal finishing techniques and make the student to understand

the kinetics of electrochemical engineering.		
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		**9**
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 corrosioncorrosioncontrol measures- industrial boiler water corrosion control – protective coatings – Vapor phase inhibitors – cathodic protection, sacrificial anodes –Paint removers.		
UNIT IV		**9**
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: (L: 45+ T: 0): 45 PERIODS	
OUTCOMES:		
• Identify the basic principles of electrochemistry applied in electrochemical engineering		

- Apply mass transfer principles in electrochemical reactions.
- Develop electrochemical technique for corresion prevention.
- Design electrodes and operating conditions with favorable performance for specific applications.
- Identify types of electrode required by different electrochemical industry.

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.	

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18017	**ENERGY MANAGEMENT**	**3**	**0**	**0**	**3**

OBJECTIVES:

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

UNIT I		**9**

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

UNIT II		**9**

Forecasting techniques, energy demand, magnitude and pattern, input and output analysis, energy modeling and optimal mix of energy sources. Energy - various forms, energy storage, structural properties of environment.

UNIT III		**9**
Bio-geo-chemical cycles; society and environment population and technology. Energy and evolution, growth and change, patterns of consumption in developing and advances countries, commercial generation of power requirements and benefit.		
UNIT IV		**9**
Chemical industries, classification, conservation in unit operation such as separation, cooling tower,drying, conservation applied to refineries, petrochemical, fertilizers, cement, pulp and paper, food industries, chloro alkali industries, conservation using optimization techniques.		
UNIT V		**9**
Sources of continuous power, wind and water, geothermal, tidal and solar power, MHD, fuel cells, hydrogen as fuel. Cost analysis, capacity; production rate, system rate, system cost analysis, corporate models, production analysis and production using fuel inventories, input-output analysis, economics, tariffs.		
	TOTAL: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Ability to categorize and access energy resources
- Forecast and analyze energy demand and resource
- Identify the patterns of energy consumption and generation
- Apply energy conservation and energy management techniques in chemical Industries
- Design and develop economical process to harvest non conventional, renewable energy resources.

TEXT BOOKS:

1.	Gramlay, G. M., Energy , Macmillan Publishing Co., New York, 1975.
2.	Krentz, J. H., Energy Conservation and Utilization, Allyn and Bacur Inc., 1976.

REFERENCES:

1.	Loftiness, R.L. – Energy Hand Book, Van Nostrand Reinhold Company, New York, 1978.
2.	Rused, C. K., Elements of Energy Conservation , McGraw-Hill Book Co., 1985.

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18018	**HSE IN PETROLEUM INDUSTRIES**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To provide an overview of safety and environmental issue in petroleum industry
- To resolve key issues in oil and gas industry
- To identify and assess hazard in any stage of operation

UNIT I		**9**

Environmental impact and management, Impact of oil and gas industry in marine environment, Oil hydrocarbons in marine environment, Chemical disposal of offshore industry and environmental management, Dispersion models and atmospheric pollution

UNIT II		**9**

HSE and culture: - Introduction - HSE and culture Characteristics of a sound HSE culture -Sources for understanding one's own HSE culture - Factors which can affect the HSE culture - Management and culture.

UNIT III		**9**

Toxicity, physiological, asphyxiation, respiratory, skin effect of petroleum hydrocarbons and their mixture- Sour gases with their threshold limits- Guidelines for occupational health monitoring in oil and gas industry. Corrosion in petroleum industry- Additives during acidizing, sand control and fracturing.

UNIT IV		**9**

Dose assessment, safety regulations, Toxic releases- models and methods, Chemical risk analysis, Chemical exposure index (CEI), Case studies in oil industries, Quantitative risk assessment, Fire and explosion models, Flammability diagrams, Exposure models.

UNIT V		**9**

Classification of fires- The fire triangle- Distinction between fires and explosions- Flammability characteristics of liquids and vapors- Well blowout fires and their control- Fire fight equipment- Suppression of hydrocarbons fires, Fire and explosion: prevention methods, Event tree and fault tree analyses.

	TOTAL: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Identify environmental impact due to industrial pollution and management technique
- Improving safety culture in order to optimize the effectiveness of control measures,
- Identify occupational hazard and occupational health monitoring
- Develop models and assessment of industrial risk associated with accidental release and fire explosions.
- Identify types of fire, fire prevention and fire protection methodology.

TEXT BOOKS:

1.	Environmental Control in Petroleum Engineering, John C. Reis, Gulf Publishing Company, 1996.
2.	Application of HAZOP and What if Reviews to the Petroleum, Petrochemical and Chemical Process Industries, Dennis P. Nolan, Noyes Publications, 1994.

REFERENCES:

1.	Oil Industry Safety Directorate (OISD) Guidelines, Ministry of Petroleum & Natural Gas, Government of India and Oil Mines Regulations-1984, Directorate General of Mines Safety, Ministry of Labor and Employment, Government of India.
2.	Guidelines for Process Safety Fundamentals in General Plant Operations Centre for Chemical Process Safety, American Institute of Chemical Engineers, 1995.
3.	Guidelines for Fire Protection in Chemical, Petrochemical and Hydrocarbon Processing Facilities, Centre for Chemical Process Safety, American Institute of Chemical Engineers, 2003.

SUB CODE	**SUBJECT TITLE**	**L**	**T**	**P**	**C**
CL18019	**ENVIRONMENTAL SUSTAINABILITY**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To introduce students to environmental problems like acid rain, global warming and also environmental sustainability.
- To make students understand sustainable development by analyzing population problems, natural resources available and overall economic growth.

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**
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: (L: 45+ T: 0): 45 PERIODS	

OUTCOMES:

- Apply the concepts of sustainable development, valuing the environment
- Relate population growth and conservation of resources.
- Assess the effect of air pollution in environmental sustainability.
- Identify effect of water pollution and global warming.
- Discuss socio economic factors affecting environmental sustainability.

TEXT BOOKS:

1.	Stephen Doven, Environment and Sustainability Policy: Creation, Implementation, Evaluation, The Federation Press, 2005

REFERENCES:

1.	Andrew Hoffman, Competitive Environmental Strategy -A Guide for the Changing Business

	Landscape, Island Press

SUB CODE	SUBJECT TITLE	L	T	P	C
CL18020	**PROCESS DESIGN AND SYNTHESIS**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To understand the systematic approaches for the development of conceptual chemical process designs.
- To learn the advances in problem formulation and software capabilities which offer the promise of a new generation of practical process synthesis techniques based directly on structural optimization.
- Learning chemical process synthesis, analysis, and optimization principles.
- Product design and development procedure and Process life cycle assessment.

UNIT I	**INTRODUCTION**	**9**

Introduction to fundamental concepts and principles of process synthesis and design and use of flow sheet simulators to assist process design. Process Flowsheet Models: An Introduction to Design, Chemical process synthesis, analysis and optimization. Introduction to commercial process design software such as HYSYS, Aspen plus etc., Chemical Process (reactor, heat exchanger, distillation etc) analysis using commercial software.

UNIT II	**PRODUCT DESIGN AND DEVELOPMENTS**	**9**

Process engineering economics and project evaluation Life Cycle Assessments of process: From design to product development, Engineering Economic Analysis of Chemical Processes, Project costing and performance analysis, Environmental concerns, Green engineering, Engineering ethics, Health and safety.

UNIT III	**NETWORKS**	**9**

Geometry of mixing and basic reactor types, The Attainable Region (AR) approach, AR in higher dimensions & for other processes, Reactive Separation processes, Fundamental behavior and problems, Separation through reactions. Reactive Residue Curve Maps.

UNIT IV	**SYNTHESIS OF SEPARATION TRAINS**	**9**

Criteria for selection of separation methods, select ion of equipment**:** Absorption, Liquid-liquid extraction Membrane separation, adsorption, leaching, drying, crystallization, Ideal distillation - Column and sequence fundamentals, Sharp splits & sequencing Phase diagrams for 2, 3 and 4

Components, Feasibility and vapor flow rates for single columns, Residue curve basics, Non-ideal Distillation - Azeotropic systems; detecting binary azeotropes, Residue curve maps for azeotropic systems, Topological analysis, Feasibility for single azeotropic columns ,Binary VLLE and pressure swing separation, Non-ideal distillation synthesis. Equipment sequencing: VLE + VLLE, Detailed Residue Curve Maps, Residue curve maps: Interior structure.

UNIT V	**HEAT EXCHANGER NETWORK SYNTHESIS**	**9**

Minimum heating and cooling requirements, Minimum Energy Heat Exchanger Network, Loops and Paths, Reducing Number of Exchangers, HENS basics & graphics, The pinch point approach, Stream Splitting, Performance targets, trade-off & utilities, Heat & power integration, HENS as mathematical programming.

TOTAL: (L: 45+ T: 0): 45 PERIODS

OUTCOMES:

- Apply fundamental concepts and principles of process synthesis and design
- Develop process engineering economics and life cycle assessment of process.
- Design reactor network and analyze.
- Demonstrate the synthesis of separation trains.
- Complete collaboratively a preliminary process design within a given time frame.

TEXT BOOKS:

1.	Douglas, J. "Conceptual Design of Chemical Processes", New York, NY: McGraw-Hill Science /Engineering/Math, 1988. ISBN: 0070177627.
2.	Seider, W. D., J. D. Seader, and D. R. Lewin. "Product and Process Design Principles: Synthesis, Analysis, and Evaluation",. *2*nd ed. New York, NY: Wiley, 2004.

REFERENCES:

1.	Richard Turton, Richard C. Bailie, Wallace B. Whiting, Joseph A. Shaeiwitz., "Analysis, Synthesis, and Design of Chemical Processes", 2nd Edition, 2002, Prentice Hall .
2.	Biegler L.T., Grossmann I.E. and Westerberg A.W., "Systematic Methods of Chemical Process Design", Prentice Hall, 1997.