BHARATI VIDYAPEETH
(DEEMED TO BE UNIVERSITY), PUNE

Faculty of Engineering And Technology
M. Tech. Chemical
New Syllabus

BHARATI VIDYAPEETH (TO BE DEEMED UNIVERSITY)

COLLEGE OF ENGINEERING PUNE

CHEMICAL ENGINEERING DEPARTMENT

M. Tech. Chemical Programme (Revised 2019 Course)

Program Educational Objectives (PEOs)

1. Pursue career and/or higher studies in chemical engineering and allied thrust areas
2. Undertake fundamental and applied scientific research in chemical engineering, multidisciplinary, and emerging fie
3. Inculcate leadership and entrepreneurial skills to implement innovative and sustainable technologies in the context of environmental and societal needs

Programme Outcomes (POs)

1. Independently carry out research/investigation and development work to solve practical problems.
2. Write and present a substantial technical report /document.
3. Demonstrate a degree of mastery over the area as per the specialization of the chemical engineering programme. The mastery should be at a level higher than the requirements in the appropriate bachelor programme.
4. Apply the knowledge of advances in chemical engineering for the execution of projects related to chemical and allied areas.
5. Practice chemical engineering by applying professional ethics with due consideration to environmental, societal and safety aspects.
6. Engage in life-long learning to sustain and enhance practice of chemical engineering

M.TECH STRUCTURE (Chemical Engineering)
Choice Based Credit System
SEMESTER-I

Semester I — **Total Duration: 20 hrs/week** | **Total Marks : 500** | **Total Credits: 18**

Subject Code	Subject	Teaching Scheme (Hrs) Hrs./Week		Examination Scheme (Marks)						Examination Scheme (Credits)		Total Credits
		L	P	Theory	Unit Test	Attendance	Tutorial/ assignments	TW /PR	TW /OR	TH	TW/ Oral /PR	
K10501	Applied Mathematics for Chemical Engineering	04	02	60	20	10	10	50	-	04	01	05
K10502	Advanced Momentum and Heat Transfer	04	--	60	20	10	10	-	-	04	-	04
K10503	Thermodynamics of Phase Equilibria	04	--	60	20	10	10	-	-	04	-	04
K10504	Multiphase Reactors	04	02	60	20	10	10	-	50	04	01	05
	Total	**16**	**04**	**240**	**80**	**40**	**40**	**50**	**50**	**16**	**02**	**18**

Teaching Scheme		Examination Scheme					Total
Lectures	Practical	Theory	**Unit Test**	**Attendance**	**Tutorials/ Assignments**	**T.W./PR Oral**	
16	04	240	**80**	**40**	**40**	**100**	**500**

SEMESTER-II

Semester II									**Total Duration: 20 hrs/week** **Total Marks : 500** **Total Credits: 18**		
Subject Code	**Subject**	**Teaching Scheme (Hrs) Hrs./Week**		**Examination Scheme (Marks)**					**Examination Scheme (Credits)**		**Total Credits**
		L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/assignments**	**TW / Oral**	**TH**	**TW/ Oral / PR**	
K10505	Modeling & Simulation of Chemical Processes	04	02	60	20	10	10	50	04	01	05
K10506	Chemical Reactor Analysis and Design	04	--	60	20	10	10	-	04	--	04
K10507	Synthesis & Design of Chemical Processes	04	--	60	20	10	10	-	04	--	04
K10508	Advanced Mass Transfer	04	02	60	20	10	10	50	04	01	05
	Total	**16**	**04**	**240**	**80**	**40**	**40**	**100**	**16**	**02**	**18**

Teaching Scheme		Examination Scheme					Total
Lectures	Practical	Theory	**Unit Test**	**Attendance**	**Tutorials/ Assignments**	**T.W./ Oral**	
16	04	240	**80**	**40**	**40**	**100**	**500**

SEMESTER-III

Semester III									**Total Duration: 28 hrs/week** **Total Marks : 475** **Total Credits: 40**		
Subject Code	**Subject**	**Teaching Scheme (Hrs) Hrs./Week**		**Examination Scheme**					**Examination Scheme (Credits)**		**Total Credits**
		L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/ assignments**	**TW / Oral**	**TH**	**TW/ Oral/ PR**	
K10601	Elective –I	04	02	60	20	10	10	50	04	01	05
K10602	Elective –II	04	02	60	20	10	10	50	04	01	05
	**Self-Study Paper-I	* 04	--	60	20	10	10	-	04	-	04
K10604	Dissertation Stage –I	-	07	-	-	---	--	25		21	21
K10603	Seminar	-	05	-	-	--	--	50	-	05	05
	Total	**12**	**16**	**180**	**60**	**30**	**30**	**175**	**12**	**28**	**40**

Teaching Scheme		Examination Scheme					Total
Lectures	Practical	Theory	**Unit Test**	**Attendance**	**Tutorials/ Assignments**	**T.W./ Oral**	
12	16	180	**60**	**30**	**30**	**175**	**475**

Elective – I	**Elective - II**
• Advanced Process Control • Industrial waste water treatment • Heterogeneous Catalysis • Multicomponent Separation • Fluidization Engineering	• Non Conventional Energy Sources • Catalyst Materials • Membrane Separation • Bio-process Engineering • Food Process Engineering

SEMESTER-IV

Semester IV									**Total Duration: 14 hrs/week** **Total Marks : 325** **Total Credits: 34**		
Subject Code	**Subject**	**Teaching Scheme (Hrs) Hrs./Week**		**Examination Scheme**					**Examination Scheme (Credits)**		**Total Credits**
		L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/ assignments**	**TW / Oral**	**TH**	**TW/PR/OR**	
	**Self-Study Paper-II	* 04	--	60	20	10	10	-	04	-	04
K10605	Dissertation Stage –II	-	10	-	-	--	-	225		30	30
	Total	**04**	**10**	**60**	**20**	**10**	**10**	**225**	**04**	**30**	**34**

Teaching Scheme		Examination Scheme					Total
Lectures	Practical	Theory	Unit Test	Attendance	Tutorials/ Assignments	T.W./ Oral	
4	10	60	20	10	10	225	325

Sr.No.	**SELF STUDY PAPER- I (SEM-III)**	**SELF STUDY PAPER- II (SEM-IV)**
1	Optimization Techniques in Process design	Technology Transfer Practices –Bridge to Industry
2	Non Conventional Energy System	Polymer Engineering
3	Mechanical Aspects in Chemical Engineering	Food Technology
4	Green Chemistry & Technology	Modeling & Simulation of Processes
5	Cavitation Techniques	Nanoscience
6	Safety Engineering in Industries	Petrochemical Engineering
7	Petroleum Engineering	Physical Concepts of Unit Operations
8	Fluid Particle Technology	Multiphase Reactor Engineering

9	Multicomponent separation	Fluidization engineering
10		Membrane Separation

M. Tech (Chemical) –SEMESTER-I

K10501 APPLIED MATHEMATICS FOR CHEMICAL ENGINEERING		
Designation: Professional Core.		
Course Pre-requisites: Chemical Engineering Mathematics		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures : 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical : 2 Hour /Week	Unit Test: 20 Marks	Practical: 01
Total : 6 Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Estimate the error in mathematical analysis
2.	Evaluate the value of root of the equation by various methods
3.	Analyze the problem and fit the curve through linear and polynomial regression
4.	Solve chemical engineering problems with numerical integration
5.	Interpret the results with various methods of solving the ordinary differential equations
6.	Analyze the experimental data to formulate the mathematical model

Topics covered

UNIT - I	**Introduction:** Approximation and round-off errors, significant figures, accuracy and precision, error definitions, truncation errors. Taylor series, error propagation, total numerical error, formulation errors and data uncertainty. Tests of significance. Analysis of variance.	**(08 Hours)**
UNIT - II	**Numerical solution of linear & nonlinear algebraic equations:** Linear systems of equations, solutions by Creamer's Rule, Matrix methods, Gaussian, Gauss-Jordan, Jacobean, Gauss-Seidel and Relation methods. Non-linear equations: Bisection, Regular-falsi, Secant and Newton- Raphson methods.	**(08 Hours)**
UNIT - III	**Curve fitting:** Least square regression: Linear regression, polynomial regression. Interpolation: Newton's divided–difference interpolating polynomials, Lagrange interpolating polynomials, coefficient of an interpolating polynomial. Fourier approximation.	**(08 Hours)**
UNIT - IV	**Numerical integration and differentiation:** Newton-cotes integration of equations. Integration of equations: Romberg integration, Gauss Quadrature. **Partial differential equations:**	**(08 Hours)**

	Finite difference: Elliptic equations, parabolic equations, finite element method. Diffusion/convection form of partial differential equations in chemical engineering. Characteristics and partial differential equation types and their analytical solution.	
UNIT - V	**Numerical solution of ordinary differential equations:** Formulation of linear and non-linear first and second order ordinary differential equations, higher order linear, differential equations for systems involving momentum, heat and mass transfer with and without chemical reactions and their analytical solutions. Ordinary differential equations: Runge- Kutta, Euler's and Milne's predictor corrector methods. Boundary–value and eigen value problems, general methods of boundary-value problems.	**(08 Hours)**
UNIT - VI	**Mathematical analysis and engineering problem-solving:** Design and analysis of experiments: data analysis, treatment, generalization and interpretation on engineering data. Formulation of physical problems: mathematical statement of the problem, representation of problems, problem solving with appropriate mathematical method, analysis of results with statistical tests.	**(08 Hours)**

Termwork: Oral examination will consist of assessment of the term work (duly certified by the teacher and HOD) and oral exam based on the term work/practical. The term work shall consist of the following: Minimum 8 practical based on solving numerical methods mentioned in the syllabus using C, C++ language, or TK solver software, or any chemical Engineering Software.

Assignment: : Each student will submit assignments based on different topics in consultation with faculty, in the area of application of mathematics in chemical engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, 6th Ed., McGraw Hill, 2010.
2.	S. C. Chapra, Applied Numerical Methods with MATLAB: for Engineers and Scientists, 2nd Ed., Tata McGraw Hill, New Delhi, 2010.
3.	S. K. Gupta, "Numerical Techniques for Engineers", Wiley Eastern, 1995.
4.	M.K. Jain, S.R.K. Iyengar and R. K. Jain, "Numerical Methods for Scientific and Engineering Computations", 1992.
5.	Kreyszig, Erwin: Advanced Engineering Mathematics, 8th Edition, Wiley Eastern, New Delhi, 2002.
6.	H.S.Mickley, T.K. Sherwood and C.E. Reid, “Applied Mathematics in Chemical Engineering”, II Ed., Tata McGraw Hill, New Delhi, 1978.
7.	Teukolsky S.A., W.H. Press, “Numerical Recipes in ‘C’ ”, Cambridge University press
8.	Constantinides A., “Applied Numerical Methods with Personal computer”, McGraw Hill publishers

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10502 ADVANCED MOMENTUM AND HEAT TRANFER		
Designation: Professional Core.		
Course Pre-requisites: Fluid flow operation and Heat transfer		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination: 60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test : 20 Marks	Total Credits : 04
	Attendance : 10 Marks	
	Assignment :10 Marks	
	Total: 100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Estimate the momentum flux and velocity distributions for various flow systems
2.	Develop and apply the differential equations of fluid flow
3.	Estimate the friction factors for fluid flow in closed conduits and construct the macroscopic material balances for steady-state problems
4.	Estimate the temperature distributions in solids and in laminar flow
5.	Illustrate the unsteady heat conduction in solids and estimate the temperature distribution in turbulent flow
6.	Evaluate the heat transfer coefficients for interphase transport in non-isothermal system

Topics covered		
UNIT - I	**Shear stress in laminar flow:** Newtonian and non Newtonian fluids; Rheological models; theories of transport properties of gases and liquids; effect of pressure and temperature. **One dimensional momentum transport in laminar flow (shell balance):** General method of shell balance approach to momentum transfer problems; momentum flux and velocity distribution for flow of Newtonian and non-Newtonian fluids in pipes, planes, slits and annulus; Fluid flow of two immiscible fluids.	**(08 Hours)**
UNIT - II	**Differential equations of fluid flow:** Control volume approach; Differential continuity equation; Navier-Stokes Equation and Bernoulli's equation; Applications of differential equations of fluid flow **Effect of turbulence on momentum transfer:** Description of turbulence; Turbulent shearing stresses; The mixing length hypothesis, velocity distribution from the mixing length theory; The universal velocity distribution; The turbulent boundary layer on a flat plate	**(08 Hours)**
UNIT - III	**Fluid flow in closed Conduits:** Friction factors for fully developed laminar, turbulent and transition flow in circular conduits; Friction factors for flow in the entrance to a circular conduit; Friction factors for packed columns. **Macroscopic momentum balances:** The macroscopic mass, momentum and mechanical energy balances; Use of macroscopic balances for steady-state problems; Use of macroscopic balances for unsteady-state	**(08 Hours)**

	problems.	
UNIT - IV	**Mechanism of energy transport:** Fourier's law of heat conduction; Thermal conductivity of liquids and solids; Effective thermal conductivity of composite solids. **Temperature distribution in solids and in laminar flow:** Heat conduction through composite walls; Heat conduction in a cooling Fin; Forced convection; Free convection.	**(08 Hours)**
UNIT - V	**The equation of change for non isothermal systems:** The equation of energy; The equation of motion for forced and free convection; Use of equations of change to solve the steady-state problems **Unsteady Heat Conduction in Solids:** Heating of a semi-infinite slab; Heating of a finite slab; Unsteady heat conduction near the wall with sinusoidal heat flux **Temperature distribution in turbulent flow**: Time smoothed equation of change for incompressible non isothermal flow; Time smoothed temperature profile near a wall; Empirical expressions for the turbulent heat flux; Temperature distribution for turbulent flow in tubes	**(08 Hours)**
UNIT - VI	**Interphase transport in non-isothermal systems:** Heat transfer coefficients for forced convection in tubes and through packed beds; Heat transfer coefficients for free and mixed convection; Heat transfer coefficients for condensation of pure vapors on solid surfaces. **Analogies of momentum and heat transfer:** Reynolds and Chilton Colburn analogy	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of advanced momentum and heat transfer, keeping track of the recent technological trends and developments.

Text Books/References:

1.	W. E. Stewart, E. N. Lightfoot, R. B. Bird, "Transport Phenomena", John Wiley & Sons
2.	J. R. Welty, C. W. Wicks, R. E. Wilson, G. Rorrer, "Fundamentals of momentum, heat and mass transfer, Wiley INDIA
3.	J.C. Slattery, "Advanced transport phenomena", Cambridge University Press
4.	J. G. Knudsen, D. L. Kaz, "Fluid Dynamics and Heat Transfer", McGraw Hill

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10503 THERMODYAMICS OF PHASE EQUILIBRIA

Designation: Professional Core.

Course Pre-requisites: Process calculations, Basic concepts of residual and excess properties

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures : 4 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test : 20 Marks	Total Credits : 04
	Assignment : 10 Marks	
	Attendance :10 Marks	
	Total :100 Marks	

Course Outcomes

After completion of the course the student will be able to:

1.	Determine residual and excess properties to quantify deviation from an ideality
2.	Apply modified Raoults law for VLE and estimate activity coefficient using various models.
3..	Apply concept of fugacity for solid fluid equilibria
4.	Determine Gibbs free energy for homogeneous and heterogeneous reactions.
5..	Apply thermodynamic principles to interfacial phase equilibria
6.	Apply thermodynamic principles to acid and alkali, and corresponding reactions.

Topics covered

UNIT-I	**Thermodynamics of Multi-component mixtures:** Ideal mixtures and excess mixture properties, Fugacity of species in gaseous, liquid and solid mixtures, Criteria for phase equilibrium in multi-component systems, Modified Roult's law and its significance, Gibbs Duhem equation, Hydrogen bonding and charge transfer complexing Equilibrium	**(08 Hours)**
UNIT-II	**Vapor liquid Equilibrium of mixtures** Vapor Liquid equilibrium (VLE) of ideal mixtures, Low pressure VLE in non-ideal mixtures, High pressure VLE using equation of states, Solubility of gas in liquid, Liquid-Liquid Equilibrium, Vapor Liquid-Liquid Equilibrium, Models for activity coefficient, UNIFAC method, UNIQUAC equation, Osmotic pressure, osmotic equilibrium	**(08 Hours)**
UNIT-III	**Mixture phase equilibrium involving solids** Solubility of solid in liquid and supercritical fluid, Solid Liquid Equilibrium, Partitioning of solid between two liquid phases, distribution coefficient, Freezing point depression of solvent due to presence of solute, freezing point of liquid mixtures in presence of solid.	**(08 Hours)**
UNIT-IV	**Chemical Reaction Equilibria:** Chemical equilibrium in single phase system, Heterogeneous chemical reactions, Chemical equilibrium when several reaction occurs in single phase, Combined chemical and phase equilibrium. Phase rule and Duhem's theorem for reacting systems, Degree of freedom analysis for non-reacting and reacting systems	**(08 Hours)**
UNIT-V	**Surfaces, Interfaces and Adsorption** Thermodynamics of interfaces, Gibbs surface model and surface tension,	**(08 Hours)**

	Surface energy of solids, Surface effects on heterogeneous phase equilibrium, effect of particle size on vapor pressure, effect of bubble size on the boiling temperature of pure substances, solubility and nucleation, effect of particle size on melting temperature, Gibbs adsorption equation	
UNIT-VI	**Thermodynamics of acid, alkali interaction, Energy analysis** Acidity of solutions, ionization of chemicals, solubilties of weak acids, weak bases, pharmaceuticals as function of pH, Gibbs-Donnan equilibrium. Defining Energy, Control Volume Energy Rate Balance, Exergetic Efficiency, Introduction to Energy Costing	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of thermodynamics of phase Equilibria, keeping track of the recent technological trends and developments

Text Books/References:

1.	J. M. Smith & H. C. Van Ness, "Introduction to Chemical Engineering Thermodynamics"
2.	Stanley I. Sandler, "Chemical, Biochemical and Engineering Thermodynamics"
3.	Savein Stolen, Tor Grande, Neil Allan, "Chemical Thermodynamics of Materials"
4.	K.V.Narayanan," Chemical Engineering Thermodynamics"
5.	Kenneth Denbigh, "Principles of Chemical Equilibrium"
6.	Y. V. C. Rao, "Chemical Engineering thermodynamics"
7.	B. F. Dodge, "Chemical Engineering Thermodynamics"
8.	T. E. Daubert, " Chemical Engineering Thermodynamics"
9.	Glasstone S., "Thermodynamics for Chemists"
10.	B. G. Kyle, "Chemical and Process Thermodynamics

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10504 MULTIPHASE REACTORS

Designation: Professional Core.

Course Pre-requisites: Thermodynamics and Transport Processes

TEACHING SCHEME:		**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures	: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical	:2 Hours/Week	Unit Test	: 20 Marks	TW/PR/OR	: 01
Total	: 6Hours/Week	Assignment	: 10 Marks	Total credits	: 05
		Attendance	:10 Marks		
		TW	:25 Marks		
		Oral	:25 Marks		
		Total	:150 Marks		

Course Outcomes

After completion of the course the student will be able to:

1.	Enumerate the industrial significance of multiphase reactors
2.	Estimate Gibbs free energy and intrinsic kinetics for multiphase reaction
3	Enumerate hydrodynamic characteristics of multiphase reactors
4.	Quantify phase mixing in multiphase reactors as function of system, operating, and geometrical parameters
5.	Determine heat and mass transfer coefficients in multiphase reactors as function of system, operating, and geometrical parameters
6.	Standardize multiphase reactors.

Topics covered

UNIT-I	**Introduction to Multiphase Reactor Engineering: Types**, Classification, Application of Industrial Importance.	**(08 Hours)**
UNIT-II	**Thermodynamics and kinetics:** Notable industrial heterogeneous systems and thermodynamic role. Application of equilibrium criteria to chemical reactions. The Gibbs energy change and equilibrium constant. Estimation of equilibrium constant for heterogeneous system by defining standard state of the phases involved. Determination of rate controlling step: intrinsic kinetics for heterogeneous systems	**(08 Hours)**
UNIT-III	**Hydrodynamic Characteristics:** Hydrodynamic characteristics of different multiphase reactors: Mechanically Agitated Contactors (MAC), Bubble Columns, Slurry Reactors, Fluidized Beds, Loop Reactors and Modified Versions.	**(08 Hours)**
UNIT-IV	**Mixing Studies :** Effect of geometrical, system, and operating parameters on phase mixing in multiphase reactors. Quantification of phase mixing. Development of a mathematical model.	**(08 Hours)**
UNIT-V	**Heat Transfer and Mass Transfer Studies :** Effect of geometrical, system, and operating parameters on heat transfer coefficient in multiphase reactors. Quantification of heat transfer coefficient. Application of correlations available to different multiphase reactors. Experimental techniques used for estimation of mass transfer coefficient and selection of suitable technique for a multiphase reactor. Effect of geometrical, system, and operating parameters on mass transfer coefficient in multiphase reactors. Quantification of mass transfer coefficient. Application of correlations available to different multiphase reactors.	**(08 Hours)**

UNIT-VI	**Design Aspects of Multiphase Reactors:** Pressure drop, Fractional phase hold- up, mass and heat transfer coefficient, extent of mixing, etc.	**(08 Hours)**

Term-work: based on the term work/practical. The term work shall consist of the following:

- Assignments given by concerned subject teacher throughout the semester.
- Seminar presented and duly report prepared on any topic given from syllabus.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of multiphase reactors, keeping track of the recent technological trends and developments.

Text Books/References:

1.	L. K. Doraiswamy and M. M. Sharma, "Heterogeneous Reactions", 2nd Edition, Volume I and II.
2.	G. B. Tatterson, "Fluid Mixing and Gas Dispersion in Stirred Reactors", 10th Edition, Academic Press, London, 1994
3.	W. D. Deckwer, "Bubble Column Reactors", Cambridge University Press, New York, 2000.
4.	Diazo Kunji and O. Levenspiel, "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
5.	J. F. Devidson and Harrison, " Fluidization", 10th Edition, Academic Press, London, 1994.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

M.Tech (Chemical) –SEMESTER-II

K10505 MODELLING AND SIMULATION OF CHEMICAL PROCESSES		
Designation: Professional Core.		
Course Pre-requisites: Numerical methods for Chemical Engineering, Heat and Mass Transfer		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Illustrate various fundamental laws used in the formulation of models
2.	Develop simple steady state and dynamic mathematical models
3.	Propose a mathematical model for heat and mass transfer equipments; and reactors
4.	Explain the basics of simulation
5.	Estimate the parameters of a model and accomplish parameter sensitivity analysis
6.	Implement the modern approaches of simulation

Topics covered

UNIT-I	**Basics of phenomenological modeling** Introduction to modeling, systematic approach to model building, fundamentals of mathematical modeling-principles of formulations, fundamental laws: continuity equations, energy equation, equation of motion, transport equations, equation of state, equilibrium, chemical kinetics, advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes, classification of models-simple vs. rigorous, lumped parameter vs. distributed parameter, Steady state vs. dynamic, concept of degree of freedom for steady state and unsteady state systems.	**(08 Hours)**
UNIT-II	**Empirical modeling building and analysis** Development of steady state and dynamic lumped and distributed parameter models based on first principles, analysis of ill-conditioned systems, development of grey box models, empirical model building, statistical model calibration and validation, population balance models; Examples: simple hydraulic tank, variable hydraulic tank, mixing Vessel, mixing with reaction, steam jacked vessel	**(08 Hours)**
UNIT-III	Mathematical models of heat-transfer equipments: shell & tube heat exchangers, evaporators, partial condensers; Mathematical models of mass-transfer equipments: batch and continuous distillation columns, reactive distillation columns, packed absorption columns; Mathematical models of reactors: batch reactors, continuous-stirred tank reactors, plug-flow reactors, reactor with axial dispersion, etc.	**(08 Hours)**
UNIT-IV	**Basics of simulation** Fundamentals of simulations – Ab-initio methods, basis sets, Hartree-Fock theory,	**(08 Hours)**

	density functional theory, geometry optimization, vibrational analysis; elementary, classical statistical mechanics, elementary concepts of temperature, ensembles and fluctuations, partition function, ensemble averaging, ergodicity; molecular dynamics methodology − force field, integrating algorithms, periodic box and minimum image convention, long range forces, non bonded interactions, temperature control, pressure control, estimation of pure component properties, radial distribution function; molecular dynamics packages.	
UNIT-V	**Parameter estimation and sensitivity analysis** Parameter estimation, parameter sensitivity analysis, statistical validity, discrimination between two models, solution strategies for lumped parameter models, stiff differential equations, solution methods for initial value and boundary value problems, solving the problems using *MATLAB or other chemical engineering software,* solution strategies for distributed parameter models..	**(08 Hours)**
UNIT-VI	**Modern approaches** Broad overview of tools, deterministic and stochastic approaches, statistical decision theory, Markov processes, queuing theory, renewal theory, reliability theory, Non-traditional techniques: Simulated annealing, ant colony method or ANN, particle swarm method, neural networks, genetic programming, genetic algorithm, fuzzy logic, Wavelet, principal component analysis, etc.	**(08 Hours)**

Term Work: Oral examination will consist of assessment of the termwork (duly certified by the teacher and HOD) and oral exam based on the term work/practical. The term work shall consist of the following:
Minimum 6 practical based on solving various models mentioned in the syllabus using MATLAB/SCILAB, or TK solver software, or any chemical Engineering Software.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of modeling and simulation of chemical processes, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Franks R. E. G., "Modeling and Simulation in Chemical Engineering", Wiley Interscience, NY
2.	John Ingam, Irving J. Dunn, "Chemical Engineering Dynamic Modeling with PC Simulation", VCH Publishers
3.	William L. Luyben, "Process Modeling Simulation and Control for Chemical Engineers", McGraw Hill International Edition Publishing Company
4.	Himmelblau D., K. B. Bischoff, " Process Analysis and Simulation", John Wiely & Sons
5.	Wayne Blackwell, "Chemical Process Design on a Programmable Calculator", McGraw Hill
6.	Wayne Bequette, " Process Dynamics, Modeling, Analysis and Simulation", Prentice Hall
7.	S. S. Tambe, B. D. Kulkarni, P. B. Deshpande, Elements of Artificial Neural Networks with Selected Applications in Chemical Engineering, and Chemical & Biological Sciences, 1st Ed., Louisville: Simulations & Advanced Controls Inc., KY 1996.
8	C.D.Holland, Fundamentals and Modeling of Separation Processes, Prentice-Hall Internal Publications
9	Asghar Hussain, Chemical Process Simulation, Wiley Eastern Ltd., New Delhi (1986).
10.	M.E.Davis, Modeling and Numerical Methods in Chemical Engineering, John Wiley & Sons, 1984.
11.	B.Carnahan, H.A. Luther and J.O.Wilkes, Applied Numerical Methods, McGraw-Hill, New York (1969).
12.	K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press, 2001.
13.	Singiresu S. Rao, "Applied Numerical Methods for Engineers and Scientists" Prentice Hall, Upper Saddle River, NJ, 2001
14.	W. F. Ramirez, "Computational Methods for Process Simulation", 2nd ed., Butterworths, 1997
15.	Modeling and analysis of dynamic systems, by C.M .Close, D.H. Fredrick and J. C. Newell, John Wiley & Sons, 2002

16.	Bruce A. Finlayson, Introduction to Chemical Engineering Computing, Wiley, 2010.
Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10506 CHEMICAL REACTOR ANALYSIS AND DESIGN

Designation: Professional Core.

Course Pre-requisites: Chemical Reaction Engineering I and Chemical Reaction Engineering-II

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination:60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test :20 Marks	Total Credits : 04
	Attendance :10 Marks	
	Assignment :10 Marks	
	Total :100 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Analyze the operation policies and control strategies for chemical processes.
2.	Learn the design of multiphase reactors.
3.	Discuss the design of reactor at different conditions.
4.	Learn the design of reactors at unsteady state condition.
5.	Learn the design of fixed bed reactor at different conditions.
6.	Discuss the design aspects of reactors with non ideal flow.

Topics covered

UNIT - I	Chemical factor affecting the choice of the reactor, Model for batch reactor optimum operation policies and control strategies, optimal batch operation time, optimal temperature policies.	**(08 Hours)**
UNIT - II	Transient and steady state analysis, Optimal design of reactors, Multiphase reactors: fluidized, trickle bed, slurry etc	**(08 Hours)**
UNIT - III	Steady state non isothermal reactor design, the energy balance, adiabatic operation, tubular rector with heat exchange, equilibrium conversion, CSTR with heat effects, multiple steady states	**(08 Hours)**
UNIT - IV	Unsteady state non isothermal reactor design. Energy balance on batch reactor, Adiabatic operation of batch reactor, Batch reactor with interrupted isothermal operation, Semi batch reactors with a heat exchanger, Unsteady operation of CSTR, Unsteady operation of plug flow reactors	**(08 Hours)**
UNIT - V	Design of fixed bed catalytic reactors, isothermal ,adiabatic ,non isothermal	**(08 Hours)**
UNIT - VI	Non ideal flow in reactors, Estimation of dispersion/back mixing, design aspects of reactors with non ideal flow, micro and meso mixing in reactors.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of chemical reactor analysis and design, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Froment G. F. and K. B. Bischoff, " Chemical Reactor Analysis and Design", John Wiley & Sons
2.	Fogler H. S., "Elements of Chemical Reaction Engineering", Prentice - Hall, 1986
3.	Smith J. M., " Chemical Engineering Kinetics ", McGraw Hill, 1981
4.	Denbigh K. G. and J. C. Turner, "Chemical Reactor and Theory – An Introduction",3rd edition Cambridge University Press.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10507 SYNTHESIS AND DESIGN OF CHEMICAL PROCESSES		
Designation: Professional Core.		
Course Pre-requisites: Chemical Reaction Engineering I and Chemical Reaction Engineering-II		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination:60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test :20 Marks	Total Credits : 04
	Attendance :10 Marks	
	Assignment :10 Marks	
	Total :100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Learn the importance and different aspects of process design.
2.	Discuss about the synthesis tree and process operations.
3.	Analyze the parameters like separation system, distillation column sequencing residue curve mapping.
4.	Illustrate pinch technology for energy recovery.
5.	Discuss the industrial safety and risk management.
6.	Analyze the methods used for scale up of the process.

Topics covered		
UNIT - I	**Introduction to SDCP** Significance of SDCP in chemical process industry, Hierarchy of chemical process design: Hierarchy, approach to process design, performance. Preliminary Process Synthesis, Synthesis of reaction: Function of process recycle, vapor cycles and purges, vapor verses liquid cycles, batch processes, process yield	**(08 Hours)**
UNIT - II	Choice of reactor: Reaction path, types of reaction systems, reactor Continuous or Batch Processing, Chemical state, Process Operations, Synthesis Steps, Synthesis Tree, Heuristics, Algorithmic Methods.	**(08 Hours)**
UNIT - III	Recycle structure, Recycle material balances, Reactor heat effects, Equilibrium limitations, Reactor design, Separation system, vapor recovery system, Liquid separation system, Distillation column sequencing, azeotropic systems, Residue Curves for Heterogeneous Systems.	**(08 Hours)**
UNIT - IV	**Heat exchanger networks** Pinch Methodology: Problem representation, temperature enthalpy diagram, simple match matrix. Heat content diagram, Temperature interval diagram. Pinch Design and Optimization: Networks for maximum energy recovery, Pinch design method, Flexibility criteria of the pinch, case studies	**(08 Hours)**
UNIT - V	**Industrial Safety and risk management** Hazards: Chemical hazards classification. site selection and plant layout. Industrial lighting and ventilation. Occupational diseases and prevention	**(08 Hours)**

	methods. Instrumentation and control for safe operation. Personal protective equipments. Management and Risk Analysis: Case studies pertaining to chemical industries. Legislations and economics: Factory Act. Environmental Act. Provisions under various acts.	
UNIT - VI	Introduction to scale-up methods, pilot plants, models and principles of similarity. Industrial applications. Computer–Aided Design application in chemical process industries, complete plant simulation	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of synthesis and design of chemical processes, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Robin Smith, "Chemical Process Design", McGraw Hill
2.	Hartmann K., K. Kaplick, "Analysis and Synthesis of Chemical Process System", Elsevier, Amsterdam
3.	Jordan D.G., "Chemical Process Development – Part I", Robert K. Krieger Publishing Company
4.	James M.Douglas, "Conceptual Design of Chemical Processes" McGraw Hill.
5.	Warren D.Seider,J.D.Seader,Daniel R. Lewin, "Process Design Principles Synthesis ,Analysis and Evaluation," John Wiley & Sons Inc.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10508 ADVANCED MASS TRANSFER

Designation: Professional Core.

Course Pre-requisites: Mass transfer I and Mass Transfer II

TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Understand diffusion with and without chemical reactions and unsteady state diffusion.
2.	Learn ionic separation and its controlling factors.
3.	Learn different adsorption techniques and equipments.
4.	Solve multicomponent separation problems.
5.	Understand membrane separation operation completely.
6.	Learn different novel separation techniques.

Topics covered

UNIT - I	**Diffusion:** Steady State diffusion with heterogeneous chemical reaction, Steady state diffusion accompanied by homogeneous Chemical reaction. Unsteady state molecular diffusion in isotropic media, unsteady state diffusion for typical cases of mass transfer in infinite, semi-infinite and finite plane media and in spherical and cylindrical media.	**(08 Hours)**
UNIT - II	**Ionic Separations :** Controlling factors, applications, Theory mechanism and equipments for electrophoresis, dielectrophoresis and electro dialysis, commercial applications and design considerations.	**(08 Hours)**
UNIT - III	**Adsorption Techniques :** Mechanism, Thermal-Swing Adsorption, Pressure-Swing Adsorption, Continuous, Countercurrent Adsorption Systems, Slurry Adsorption , Fixed-Bed Adsorption (Percolation), Simulated-Moving-Bed Systems, affinity chromatography and immune chromatography, types of equipment and commercial processes, recent advances and process economics.	**(08 Hours)**
UNIT - IV	**Multicomponent Distillation:** Tray by Tray calculation, feed plate location, operating reflux and plates, recent advances in column design and operation-Petlyuk, divided wall, kaibel, pre fractionators, post fractinator. Azeotropic distillation,	**(08 Hours)**

	Extractive distillation, Molecular distillation, Reactive distillation.	
UNIT - V	**Membrane Separations :** Classification of membrane processes; Liquid permeation membrane processes or dialysis – Series resistance in membrane processes, Dialysis processes, Types of equipment for dialysis; Gas permeation membrane processes – Types of membranes and permeability for separation of gases, Types of equipment for gas permeation membrane processes (flat membranes, spiral-wound membranes, hollow-fibre membranes); Types of flow in gas permeation; Complete-mixing model, cross-flow model and countercurrent flow model for gas separation by membranes; Effect of processing variables on gas separation by membranes.	**(08 Hours)**
UNIT - VI	**Novel Separation Techniques :** Supercritical fluid extraction, Reactive extraction, Zone melting, separation based on thermal diffusion, separation based on surface science, adductive crystallization.	**(08 Hours)**

Term Work :

Oral examination will consist of assessment of the term work (duly certified by the teacher and HOD) and oral exam based on the term work/practical. The term work shall consist of the following.
Seminar presented and duly report prepared on any topic given from syllabus.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of advanced mass transfer, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Phillip C. Wankat , Separation Process Engineering (2nd Edition), Printice Hall,2007
2.	Marcel Mulder, Introduction to Membrane Science and Technology, Marcel Dekker, 1992.
3.	Rousseau, R. W., Handbook of Separation Process Technology, John Wiley, New York, 2009.
4.	Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
5.	King, C. J., Separation Processes , Tata McGraw Hill Co., Ltd., 1982.
6.	T.K.Sherwood, R.L.Pigford and C.R.Wilke, Mass Transfer, McGraw-Hill, New York (1975).
7.	R.E.Treybal, Mass-Transfer Operations, McGraw-Hill, New York (1980).
8.	Anthony L Hines , Robert N Maddox , Mass Transfer Fundamentals and Applications.
9.	Sherwood, T. K., Pigford, R. L. & Wilke, C. R, Mass Transfer Mc Graw Hill, 1975
10.	Skelland, A. H. P. : Diffusional Mass Transfer, John Wiley & Sons, 1974.
11.	Crank J, The Mathematics of Diffusion, Oxford University Press London 1956

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and III
Unit Test -2	UNIT –IV,V and VI

M.Tech (Chemical) –SEMESTER-III

K10601 ELECTIVE - I ADVANCED PROCESS CONTROL		
Designation: Elective		
Course Pre-requisites: Process instrumentation and control		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
Practical: 2 Hours/Week	Unit Test : 20 Marks	Practical : 01
Total : 6 Hours/Week	Assignment : 10 Marks	Total : 05
	Attendance :10 Marks	
	Term Work : 25 Marks	
	Practical/Oral : 25 Marks	
	Total :150 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Learn different forcing functions and respective responses.
2.	Learn the feed forward and feedback control system.
3.	Learn the advanced control system: adaptive and inferential.
4.	Check the stability of the control system and do response analysis.
5.	Understand the dynamics of various systems.
6.	Learn control systems applied to various operations and processes.

Topics covered

UNIT - I	**Response of Control Loop Components and Transfer Functions:** Open loop response, most useful forcing functions, step function, sinusoidal function and the pulse function, respective responses of the forcing functions. Response of a more complex system to forcing functions.	**(08 Hours)**
UNIT - II	**Types of Controls:** Feed forward control: Advantages and drawbacks, typical examples. Feedback control: Advantages and drawbacks, typical examples.	**(08 Hours)**
UNIT - III	**Adaptive and Inferential Control Systems:** Adaptive - Feed forward, feedback Inferential - Need for a model Examples for illustration.	**(08 Hours)**
UNIT - IV	**Response Analysis:** Stability and Testing Step response analysis Frequency response analysis Bode criterion, Nyquist Diagram, Root-Locus, Routh-Hertzwitz criterion. Pulse function Laplace transforms, transfer function of various system.	**(08 Hours)**
UNIT - V	**Dynamics of Various Systems:** Dead time, distance-velocity lag, inverse response systems, dynamic analysis, Qualitative characteristics, Distributed parameter systems.	**(08 Hours)**

UNIT - VI	**Control Strategies for various unit operations and processes:** Distillation, Drying, Absorption column, Stirred tanks. Processes: Process Design, Product quality control. Computer control: Direct Digital Control (DDC), Supervisory Digital Control, Economic justification for supervisory digital control.	**(08 Hours)**

Term Work: based on the term work/practical. The term work shall consist of the following.

- Ability of the student to explain the theory and related course material.
- The process control modules are now extensively used in industry. The student should demonstrate their working principles and the utility citing at least 4 chemical industries.
- The controllers used in chemical industry need careful monitoring.
- Students should briefly describe the type of maintenance for controllers.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of advanced process control, keeping track of the recent technological trends and developments.

Text Books/References:

1. George Stephanopoulos, "Chemical Process Control - An Introduction to Theory and Practice"
2. Coulson and Richardson, "Chemical Engineering Vol 3"

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and III
Unit Test -2	UNIT –IV,V and VI

K10601 ELECTIVE I: INDUSTRIAL WASTE WATER TREATMENT			
Designation: Elective			
Course Pre-requisites: Mass Transfer, Chemical Reaction Engineering, Process design			
TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory : 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical : 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total : 05
	Attendance	:10 Marks	
	Term Work	: 25 Marks	
	Practical/Oral	: 25 Marks	
	Total	:150 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Analyze the measurement techniques for waste water treatment.
2.	Learn the design of different physical unit operations.
3.	Discuss the design principles of conventional waste water treatment.
4.	Learn the aerobic and anaerobic treatments for sludge disposal.
5.	Discuss the advanced waste water treatments.
6.	Analyze the treatments used for solid waste disposal.

Topics covered

UNIT - I	Introduction, Source of Industrial waste water, Physical, Chemical & Biological characteristics Of Industrial Waste Water. Measurement of polluting strength of Ind. Waste water (physical, chemical & biological)	**(08 Hours)**
UNIT - II	Physical Unit operations: Sedimentation & Design of Settling Chambers. Filtration & Design of Filters. Coagulation, Flocculator, Froth Flotation	**(08 Hours)**
UNIT - III	**Conventional Waste Water Treatment:** Primary Treatment (Physical).Design Principles of Grit chambers & screens. Principles of Aeration .Secondary treatments (Biological), Kinetics of Growth & Food utilization, Design Principles of A.S.P. Trickling Filters, oxidation ponds, stabilization ponds, Aerobic, anaerobic Lagoons	**(08 Hours)**
UNIT - IV	**Sludge Treatment & Disposal:** Anaerobic digestion, Aerobic Digestion, Sludge disposal, composting	**(08 Hours)**
UNIT - V	**Advanced Waste Water Treatment:-** Carbon adsorption, Ion exchange, membrane processes. Nitrogen removal, Phosphorous removal, Chemical oxidation, Recovery of materials from process effluents	**(08 Hours)**
UNIT - VI	**Solid Waste Management:** Characteristics, Solid waste collection & transport, Solid Waste Processing &recovery, Disposal of Solid waste. Hazardous waste management & Risk assessment. Types of hazardous waste, health Effects, Treatment methods & Final disposal	**(08 Hours)**

Term Work: The term work shall consist of the following.
Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of wastewater treatment, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Metcalf & Eddy, "Waste Water Engineering" Treatment & Reuse, Tata Mc Graw-Hill. Fourth Edition 2003
2.	C.S.Rao., "Environmental Pollution Control Engineering", Wiley Eastern Ltd. New Age International, Second print 1994
3.	A. P. Sincero, G. A. Sincero, "Environmental Engg.", A design approach, Prentice Hall of India Pvt.Ltd. New Delhi 1996

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10601 ELECTIVE I: HETEROGENEOUS CATALYSIS

Designation: Elective

Course Pre-requisites: Mass Transfer, Chemical Reaction Engineering

TEACHING SCHEME:	EXAMINATION SCHEME:		CREDITS ALLOTTED:	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Analyze the process of adsorption and desorption.
2.	Discuss the important factors related to pore structure of catalyst.
3.	Learn the importance of lattice in heterogeneous catalysis.
4.	Explore the dynamics of selective and polyfunctional catalyst.
5.	Explain all the factors related to Fisher Tropsch synthesis process.
6.	Discuss mass and heat transfer in solid catalyst beds.

Topics covered

UNIT - I	**Adsorption, Desorption:** Definition, rates of adsorption and desorption, surface areas for physical adsorption. Experimental aspects of adsorption and allied phenomena on catalyst surfaces	**(08 Hours)**
UNIT - II	**Significance of Pore Structure and Surface Area in Heterogeneous Catalysis:** Importance of pore structure and surface area, experimental methods to determine surface area, methods of ascertaining pore volume and diameter .Kelvin equation, pore size distribution by gas adsorption, pressure porosimeter, density measurement. Pore structure of adsorbents and catalysts: Hysterisis and shape of capillaries, surface area from hysteresis loops, modes for characterizing pore structures. Reaction rates in pores catalysts: Mass transfer, concentration profiles, reaction rates, pressure and temperature gradients, catalyst deactivation	**(08 Hours)**
UNIT - III	**Role of Lattice Imperfections in Heterogeneous Catalysis:** Classification of lattice imperfections, role of point dislocations and point defects, lattice imperfections and polymerization catalysts, role of geometric and electronic factors in catalytic activity.	**(08 Hours)**
UNIT - IV	**Dynamics of Selective and Poly-functional Catalysis:** Catalyst selectivity, selective formation of intermediate products, effect	**(08 Hours)**

	of pore size on electivity, mass transport of intermediate product in non-trivial poly-step reactions, selectivity of poly-functional catalysts Zeolites in catalysis: Structural aspects and synthesis of zeolites, modification of zeolites, diffusion in zeolites, applications	
UNIT - V	**Fischer-Tropsch synthesis: Synthesis and Decomposition of Ammonia** Catalyst cracking: catalyst composition and chemical properties, mechanism of cracking reactions. Catalysis of electrode reactions. Kinetics of catalytic reactions: Rate of chemical reaction, overall reaction rate, mass transfer through gas phase, mass transfer in pores.	**(08 Hours)**
UNIT - VI	Mass and heat transfer in solid catalyst beds. Design calculations: Isothermal conditions, adiabatic conditions, non-adiabatic conditions. Thermal selectivity of packed bed reactors. Fluidized bed reactors. Optimum design: Continuous variation of parameter along the reaction path, temperature profiles for reversible and consecutive reactions, optimum catalyst concentration in bi-functional catalyst systems	**(08 Hours)**

Term Work: The term work shall consist of the following.
Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of heterogeneous catalysis, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Thomas J. M., Thomas W. J., "Introduction to The Principles of Heterogeneous catalysis", Academic Press
2.	Srivastav R. D., "Heterogeneous catalytic Science", CRC Press
3.	Thomas S. J., Webb G., "Heterogeneous Catalysis", Oliver & Boyd Ltd.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10601 ELECTIVE II: NON CONVENTIONAL ENERGY SOURCES

Designation: Elective

Course Pre-requisites: Conventional and non conventional energy sources.

TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Analyze the operation policies of Non conventional energy sources.
2.	Learn the design of solar panels.
3.	Discuss the design of tidal energy.
4.	Learn the design of bioreactors for energy production.
5.	Learn the design and sources of wind energy.
6.	Discuss the application of various non conventional energy sources.

Topics covered

UNIT - I	**Renewable Sources of Energy**: Solar energy: Thermodynamic and heat transfer aspects of solar collection; Energy storage; Solar distillation; Solar drying; Wind energy; Tidal, Wave and ocean thermal energy; Geothermal energy.	**(08 Hours)**
UNIT - II	**Fuel Cells:** Introduction, Principles; Types of fuel cells; phosphoric acid, molten salt, solid oxide and other types of fuel cells; Anodes and cathodes; Fuel cells as alternative energy source.	**(08 Hours)**
UNIT - III	**Biomass and biofuels:** Introduction, Biofuel classification; Biomass production for energy farming; Direct combustion for heat; Pyrolysis (destructive distillation); Thermochemical processes; Alcoholic fermentation; Anaerobic digestion for biogas; Vegetable oils and biodiesel; Economics of bio-mass energy systems	**(08 Hours)**
UNIT - IV	**Hydro-power:** Introduction, Principles, Assessing the resource for small installations, An impulse turbine, Reaction turbines, Hydroelectric systems, The hydraulic ram pump, Social and environmental aspects	**(08 Hours)**
UNIT - V	**Tidal power:** Introduction, The cause of tides, Enhancement of tides, Tidal current/stream power, Tidal range power, World range power sites 447 **Ocean thermal energy conversion (OTEC):**.Introduction, Principles, Heat exchangers, Pumping requirements, Practical considerations	**(08 Hours)**
UNIT - VI	**Utilization of Wastes:** Utilization of fly ash, blast furnace slag in cement and concrete, Wastes	**(08 Hours)**

	and residues	

Term Work: The term work shall consist of the following.
Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of catalyst material, keeping track of the recent technological trends and developments.

Text Books/References:

1	John Twidell & Tony Weir, Renewable Energy Resources, Second edition, Taylor & Francis, 2006
2	Douglas C., Energy Technology Handbook, Tata McGraw Hill Publishers
3	Rao C. S., Environmental Pollution Control Engineering, Wiley Eastern
4	Majumdar B., A Textbook of Energy Technology, APH Publications
5	J. T. Mcmullan, R. Morgan and R. B. Murray, Energy Resources and Supply, John Wiley & Sons, London, 1976
6	K.C. Khandelwal, S.S.Mahdi, Biogas Technology, Tata MGH
7	G.D. Rai, Solar Energy Utilization, Khanna Publishers, Delhi
8	A.W. Culp, Principles of energy conservation, Tata MGH

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10601 ELECTIVE II: CATALYST MATERIALS

Designation: Elective

Course Pre-requisites: Mass Transfer, Chemical Reaction Engineering

TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Discuss the properties and applications of bimetallic catalyst.
2.	Analyze the properties and application of oxides used as catalyst.
3.	Learn the properties and application of biological catalyst.
4.	Learn the factors related to catalyst distribution at different conditions.
5.	Discuss about optimization of catalyst distribution in a reactor.
6.	Explore the properties and applications of membrane catalytic reactor.

Topics covered

UNIT - I	**Bimetallic Catalysts:** Introduction, nature, method of preparation and characterization, catalytic properties of bimetallic systems. Supported bimetallic catalyst, chemical nature, factors affecting efficiency and uniformity of co clustering, structure, surface composition, catalytic properties.	**(08 Hours)**
UNIT - II	**Perovskite Related Oxides:** Solid state properties, Zeolite, crystal structure, non-stoichiometry, magnetic and electrical properties, ferro electric and acoustic properties,applications. Crystal chemistry and catalytic properties of oxides with scheelite structure, crystal chemistry, olefin oxidation, and mechanism. Catalytic properties of synthetic layered silicates and alumino silicate, synthetic mica-montmorillonite and nickel reducibility, layered metalsilicate catalyst.	**(08 Hours)**
UNIT - III	**Biological Catalyst:** Enzymes, incentives for using enzymes, methodology, chemical and physical properties, activity, pH-activity behavior, stability, application.	**(08 Hours)**
UNIT - IV	**Catalyst Design:** Optimization of catalyst distribution in a single pellet, the case of single and multiple reaction, isothermal and non-isothermal conditions, complex reaction system, factors affecting catalytic dispersion, optimal distribution of catalytic loading.	**(08 Hours)**
UNIT - V	**Optimization of Catalyst Distribution in a Reactor:**	**(08 Hours)**

	Single reaction and multiple reaction, isothermal and non-isothermal conditions. Catalytic deactivation, non-selective and selective poisoning..	
UNIT - VI	**Membrane Reactor:** Membrane reactor with non-uniform catalytic distribution, optimal catalyst distribution in pellets for an inert membrane reactor and catalytic membrane reactor, preparation of catalytic membrane.	**(08 Hours)**

Term Work: The term work shall consist of the following.
Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of catalyst material, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Burton J. J. and Garton R. L., "Advanced materials in catalysis", Academic press, London, 1977.Ÿ
2.	Morbidelli M., Gavriilidis A. and Varma A., "Catalyst design: Optimal distribution of catalyst in pellets, reactorts and membrane", Cambridge university press, Cambridge,2001.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10602 ELECTIVE II: BIOPROCESS ENGINEERING

Designation: Elective

Course Pre-requisites: Mass Transfer, Chemical Reaction Engineering, heat transfer

TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Learn about the growth kinetics and growth cycle of the microorganisms.
2.	Discuss about enzyme kinetics.
3.	Learn the scale up of bioreactors.
4.	Discuss about the purification and recovery of the insoluble products.
5.	Illustrate industrial production of different chemicals.
6.	Elaborate the different applications of bioprocess engineering.

Topics covered

UNIT - I	Introduction, Biotechnology & Bioprocess Engineering types & structure of cells ,Growth kinetics, Growth cycle phase, effect of substrate concentration, cell concentration and death rate on growth of M.O.	**(08 Hours)**
UNIT - II	Simple Enzyme Kinetics, Michaelis-Menten Kinetics, evaluation of M.M equation parameters,line weaver, Burk plot, Eadie-Hofstee plot, factors influencing enzyme activity, immobilized enzyme technology immobilized kinetics	**(08 Hours)**
UNIT - III	Selection, Scale-up & Control of Bioreactors Ideal, on-ideal Bioreactors, Fed Batch reactor, sterilization reactor, Aeration & Agitation & mass transport in cellular system. Scale up difficulties, Bioreactor instrumentation & control.	**(08 Hours)**
UNIT - IV	Recovery & Purification of Product Separation of insoluble products. Cell disruption, separation of soluble products, finishing steps for purification, integration of reaction & separation	**(08 Hours)**
UNIT - V	Industrial Production of Chemicals Ethanol, Acetic acid, Citric acid, Gluconic acid. Solvents such as Glycerol, acetone, butanol. Anti-biotics such as penicilline, streptomycine, tetracycline. Production of High Fructose Corn Syrup (HFCS), production of Bakers Yeast Single Cell Protein	**(08 Hours)**
UNIT - VI	Medical & other applications of Bioprocess Engg. introduction, Tissue Engineering, Gene Therapy, Stem cell, Use of microbes in mineral beneficiation & oil recovery, Biofertilizers & Biopesticides, Biopolymer	**(08 Hours)**

	Biological treatment of Industrial Waste	

Term Work: The term work shall consist of the following.
Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of bioprocess engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Thomas J. M., Thomas W. J., "Introduction to The Principles of Heterogeneous catalysis", Academic Press
2.	Srivastav R. D., "Heterogeneous catalytic Science", CRC Press
3.	Thomas S. J., Webb G., "Heterogeneous Catalysis", Oliver & Boyd Ltd.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

K10602 ELECTIVE II: FOOD PROCESS ENGINEERING

Designation: Elective

Course Pre-requisites: Various types of food and their characteristics

TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Understand various types of food available and their characteristics.
2.	Learn the design of food dryers.
3.	Discuss the design of food concentrators.
4.	Learn the design of food processing equipments.
5.	Learn the design of food preservation systems.
6.	Discuss the various food packaging and transportation systems.

Topics covered

UNIT - I	Introduction: Characteristics and nutritional properties of food texture, taste, flavor and aroma. Geometric, physical and functional properties of food material. Preparation for food processing, energy conservation, material and energy balance	**(08 Hours)**
UNIT - II	Processing Methods: Heating : Balancing and pasteurization, freezing, dehydration, canning, additives. Fermentation: Extrusion cooking, hydrostatic pressure cooking. Dielectric heating microwave processing and aspetic processing, infrared radiation processing, concept and equipment used	**(08 Hours)**
UNIT - III	Drying: Moisture content: Definition, method of determination, direct and indirect methods. Equilibrium moisture content: Hysterisis Effect. Psychometric of air water vapour mixture, Drying mechanism, constant rate period and falling rate period , Method and equipments used, factor affecting rate of drying	**(08 Hours)**
UNIT - IV	Food conservation Operation: Sieve reduction, fibrous foods, dry foods and liquid foods. Theory and equipment, membrane	**(08 Hours)**
UNIT - V	Material handling: types of candling and conveying system food products, and their design, belt conveyors, screw conveyors, bucket elevator and pneumatic conveyor.	**(08 Hours)**
UNIT - VI	Preservation of food material: Preservation by drying, preservation by low temperature, chemical preservation .Thermal death time curve	**(08 Hours)**

Term Work:

The term work shall consist of the following. Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.	
Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of multicomponent separation, keeping track of the recent technological trends and developments.	
Text Books/References:	
1.	Smith B. D., "Design of Equilibrium Stage Processes", McGraw Hill Book Company Ltd.
2.	King C. J., "Separation Processes", McGraw Hill Book Company Ltd.
3.	Treybal R. E., "Mass Transfer Operation", McGraw Hill
4.	Treybal R. E., "Liquid Extraction", McGraw Hill Book Company Ltd.
5.	Phillip C. Wankat, "Equilibrium Staged Separations", Prentice Hall
Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and III
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER I: OPTIMIZATION TECHNIQUES IN PROCESS DESIGN		
Designation: Self Study		
Course Pre-requisites: Mass transfer, Separation Technology, Chemical Reaction Engineering, Modeling Simulation, Chemical Processes, Stoichiometry, Thermodynamics, Heat Transfer		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination:60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test :20 Marks	Total Credits : 04
	Attendance :10 Marks	
	Assignment :10 Marks	
	Total :100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Explain basics of optimization and model design
2.	Classify optimization techniques and choose right one in given constraints
3.	Define and use proper method for solution of linear equation to obtain optimum solutions
4.	Select proper method and solve the non-linear equations to obtain optimum solution
5.	Design and the optimization strategy and obtain optimum solution via programming
6.	Perform the optimization in given situation as per requirement

Topics covered		
UNIT - I	**Introduction to optimization** Scope and Hierarchy of optimization, Essential features of optimization Problems, General Procedure for solving optimization problems, obstacles to optimization, Developing Models for optimization, Classification of Models, How to build Model, Selecting functions to fit empirical data, degree of Freedom, Formulation of objective function .	**(08 Hours)**
UNIT - II	Classification of Optimization Techniques, Single variable, Multivariable optimization with no constraints, equality constraints, inequality constraints	**(08 Hours)**
UNIT - III	**Linear Programming** Simplex method, Geometry of LPP, solution to linear simultaneous equations, Pivotal reduction of a general system of equations, sensitivity Analysis	**(08 Hours)**
UNIT - IV	**Non Linear Programming** One dimensional minimization method, unimodal function, Dichotomous search, Fibonacci Method, Golden section Method, Interpolation Method, Scanning and bracketing Method	**(08 Hours)**
UNIT - V	Non linear Programming unconstrained optimization & constrained Optimization, Direct Search Method, Random Search method, Descent Method, Conjugate Gradient Method, Introduction to NLP constrained optimization Direct and Indirect Methods	**(08 Hours)**
UNIT - VI	Examples and case study for different engineering applications	**(08 Hours)**
Assignment: Each student will submit assignments based on different topics in consultation with		

faculty, in the area of optimization techniques, keeping track of the recent technological trends and developments.	
Text Books/References:	
1.	Edgar T F , Himmelblau D N , "Optimization of Chemical Processes", MC Graw Hill Publication
2.	S S Rao, Optimization theory and Application, Wiley Eastern Publication

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER I: NON CONVENTIONAL ENERGY SYSTEMS		
Designation: Self Study		
Course Pre-requisites: Conventional and non conventional energy sources		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination:60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test :20 Marks	Total Credits : 04
	Attendance :10 Marks	
	Assignment :10 Marks	
	Total :100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Analyze the operation policies of Non conventional energy sources.
2.	Learn the design of solar panels.
3.	Discuss the design of tidal energy.
4.	Learn the design of bioreactors for energy production.
5.	Learn the design and sources of wind energy.
6.	Discuss the application of various non conventional energy sources.

Topics covered		
UNIT - I	**Renewable Sources Of Energy** Renewable sources of energy such as hydro, solar, wind, biomass, tidal and geothermal – their availability and limitation. Energy crisis and energy demand projection..	**(08 Hours)**
UNIT - II	**Solar Energy** Solar radiation, photovoltaic cell, pyranometer, solar thermal collectors, solar air heaters, solar constant, solar cell, applications of solar energy.	**(08 Hours)**
UNIT - III	**Wind Energy** Wind map of India, mean wind speed and wind density during different months in specific areas. Types of wind mills, their assembly and application as electric converters, pumping motors. Concept of wind farms, its applications.	**(08 Hours)**
UNIT - IV	**Bio-Mass Energy** Bio-mass as a source of energy, energy plantation, pyrolysis classification and anaerobic fermentation, types of biogas plant, their comparative status, design and application.	**(08 Hours)**
UNIT - V	**Other Alternate Sources Of Energy** Tidal power, sites for tidal power plants in India, micro-hydel power station,geothermal energy, limitations and applications of such power plants.	**(08 Hours)**
UNIT - VI	**Energy Conversation And Auditing** Conservation of energy in – domestic application and industries, use of fuel efficiently in vehicles, waste recycling fuel gas and heat recovery, energy demand management, energy accounting and auditing	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of optimization techniques, keeping track of the recent technological trends and developments.	
Text Books/References:	
1.	Edgar T F , Himmelblau D N , "Optimization of Chemical Processes", MC Graw Hill Publication
2.	S S Rao, Optimization theory and Application, Wiley Eastern Publication

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER I: MULTICOMPONENT SEPERATION

Designation: Self Study Paper I

Course Pre-requisites: Mass transfer I and Mass Transfer II

TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Analyze different separation techniques and factors affecting them.
2.	Understand different multicomponent separations implemented.
3.	Solve multicomponent distillation problems.
4.	Understand and solve azeotropic and extractive distillation problems.
5.	Learn extraction calculations.
6.	Learn multicomponent absorption calculations.

Topics covered

UNIT - I	Characteristics and selection of separation process: Importance and variety of separation, economic significance, characteristics, inherent separation factor, selection, factors influencing the choice of separation process, solvent selection, selection of equipment.	**(08 Hours)**
UNIT - II	Multicomponent separation: General short-cut equation, Edmister method,distillation, absorption, extraction, alternate short-cut method, Fenske and Underwood equation.	**(08 Hours)**
UNIT - III	Multicomponent separation: Distillation, Rigorous method, Lewis-Matheson method, Thiele-Geddes method, Amundson-Pontinen method.	**(08 Hours)**
UNIT - IV	Azeotropic and extractive distillation: Activity coefficient, equilibrium relationship, binary and ternary azeotropes, selection of solvent, calculations.	**(08 Hours)**
UNIT - V	Multicomponent separation: Extraction, Rigorous method, stripping factor equation, material balance, single and cross-current multiple contact, calculations.	**(08 Hours)**
UNIT - VI	Multicomponent separation: Absorption, Rigorous method for absorption, calculations.	**(08 Hours)**

Term Work:

The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the

subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.	
Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of multicomponent separation, keeping track of the recent technological trends and developments.	
Text Books/References:	
1.	Smith B. D., "Design of Equilibrium Stage Processes", McGraw Hill Book Company Ltd.
2.	King C. J., "Separation Processes", McGraw Hill Book Company Ltd.
3.	Treybal R. E., "Mass Transfer Operation", McGraw Hill
4.	Treybal R. E., "Liquid Extraction", McGraw Hill Book Company Ltd.
5.	Phillip C. Wankat, "Equilibrium Staged Separations", Prentice Hall
Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and III
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER -I: MECHANICAL ASPECTS IN CHEMICAL ENGINEERING		
Designation: Self Study		
Course Pre-requisites: Unit operations		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination: 60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test : 20 Marks	Total Credits : 04
	Attendance : 10 Marks	
	Assignment :10 Marks	
	Total : 100 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Analyze the piping design and layout.
2.	Design the mechanical aspects of chemical process equipments.
3.	Estimate the power requirement for steam turbines.
4.	Explain energy conservation for various heat pumps.
5.	Discuss alternative routes in process engineering.
6.	Distinguish general purpose tools and special purposes tools and machines.

Topics covered

UNIT - I	Mechanical aspects of piping design and layout, Pipe and its representation, pipe fittings, methods of pipe joining, piping insulation, Piping insulation, piping symbols, design of piping systems, piping isometrics, plot plan and Pipe racks.	**(08 Hours)**
UNIT - II	Chemical equipment design - mechanical aspects, Design of Support for process vessels, basic theory for vertical vessels, design of skirt support, Bracket or lug support, leg support, ring support, horizontal support, saddle support, leg support, Ring support, engineering materials, classification and commercial applications.	**(08 Hours)**
UNIT - III	Principles of mechanical engineering in chemical engineering, Power conversion devices such as steam turbines, IC engines, different types of pumps, Air conditioning and refrigeration, ON-OFF valves, Non return and other type of valves.	**(08 Hours)**
UNIT - IV	Energy conservation and heat pumps, Energy conservation in India and World, mechanical vapor compression, heat pumps, various thermodynamic cycles, actual vapor compression heat pumps with liquid sub cooling, various types of heat pumps.	**(08 Hours)**
UNIT - V	Mechanical aspects in chemical process engineering, Alternative routes in process engineering , general approach to plant design, process research and pilot studies, process design and development , preparation of operating manual instructions, cost cutting machines, trouble shooting , green engineering and	**(08 Hours)**

	process intensification.	
UNIT - VI	Mechanical engineering aspects in chemical engineering and technology, Study of general purpose tools and special purposes tools and machines, lathes, milling, drilling and accessories. EDM , TWEDM, hobbling, electroplating, ECM, arc welding, gas welding, brazing, soldering, riveting, TIC, MIG welding processes, equipment used and applications, drop forging, press forging , role forging, and industrial applications.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of mechanical aspects in chemical engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Coulson and Richardson, Chemical Engineering, Volume 2, Paragon press Oxford, New York.
2.	Treybal R.E., Mass transfer Operation Operations, third edition, Mc Hill International Publishers.
3.	Smith R, Chemical Process Design , McGraw Hill International Publishers
4.	Dodge B. F., Chemical Engineering Thermodynamics, McGraw Hill International Publishers.
5.	Thakori S B and Bhatt B I, Introduction to Process engineering and Design, Mcgraw Hill Companies
6.	Brownwell L, E, and Young E H, Process equipment design, John Willey and Sons, Inc. New York.
7.	Shingles ,J and MischkaC, Mechanical Engineering Design, McGraw Hill Edition
8.	Vijayrangan S, and Rajendran I, Materials and Mechanical Engineering Narosa Publishing Company New Delhi, Chenai, Mumbai and Kolkata
9.	Arora C P, Refrigeration and Air-conditioning, TataMcgraw Publishing Companies Ltd. New-Delhi.
10.	Agarawal B, Agarawal C, M, Basic Mechanical Engineering, Wiley India Publishers and Editions.
11.	Myer Kutz ,Mechanical Engineers Hand Book John Willey and Sons (New York)
12.	Perry R, and Green D, Perrys Chemical Engineers Hand Book Sixth Edition, International Students Edition

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER -I: GREEN CHEMISTRY AND TECHNOLOGY					
Designation: Self Study					
Course Pre-requisites: Environmental Engineering, Chemical conversions					
TEACHING SCHEME:		**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures	: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 4Hours/Week	Unit Test	: 20 Marks	Total credits	: 04
		Assignment	: 10 Marks		
		Attendance	:10 Marks		
		Total	:100 Marks		

Course Outcomes:	
After completion of the course students will be able to	
1.	Explain twelve basic principles of green chemistry and inherently safer chemistry for accident prevention.
2.	Identify and explain green synthetic methods and materials for green chemistry and technology
3.	Identify and select suitable biochemical /chemical conversion processfor food processing.
4.	Select eco/green technologies for addressing the problems of Water, Energy, Health, Agriculture and Biodiversity-WEHAB.
5.	Explain the global warming, future energy systems and international agreements/conventions on energy and sustainability.
6.	Explain the green energy management and green product management.

Topics covered		
UNIT-I	Introduction: Definition, the twelve basic principles of green chemistry. Use of Renewable Feedstock, Reduction of Derivatives, Catalysis, Design for Degradation, Real-time Analysis for Pollution Prevention, Inherently Safer Chemistry for Accident Prevention.	**(08 Hours)**
UNIT-II	Green synthetic methods: Microwave synthesis, electro-organic synthesis, Design and development of environmentally friendly chemical pathways: challenges and opportunities. Materials for green chemistry and technology: Catalysis, environmental friendly catalysts, Bio-catalysis, biodegradable polymers, alternative solvents.	**(08 Hours)**
UNIT-III	Biochemical conversion: anaerobic digestion, alcohol production from biomass; Chemical conversion process: hydrolysis and hydrogenation; Biophotolysis: Hydrogen generation from algae biological pathways; Storage and transportation; Applications.	**(08 Hours)**
UNIT-IV	Green innovation & sustainability: Criteria for choosing appropriate green energy technologies, life cycle cost; the emerging trends – process/product innovation-, Eco/green technologies for addressing the problems of Water, Energy, Health, Agriculture and Biodiversity- WEHAB (eco-restoration/ phyto-remediation, ecological sanitation, renewable energy technologies.	**(08 Hours)**
UNIT-V	Global warming; greenhouse gas emissions, impacts, mitigation and adaptation; future energy Systems- clean/green energy technologies; International agreements/conventions on energy and sustainability - United Nations Framework Convention on Climate Change (UNFCC); sustainable development.	**(08 Hours)**
UNIT-VI	Environmental reporting and ISO 14001; climate change business and ISO 14064;	**(08 Hours)**

	green financing; financial initiative by United Nations Environment Programme (UNEP); green energy management; green product management , green tax incentives and rebates (to green projects and companies); green project management in action; business redesign; eco-commerce models.	

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of green chemistry and technology, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Philip G. Jessop, Chao-Jun Li ,Peter Wasserscheid , Annegret Stark, Handbook of Green Chemistry, 3 Volume Set, Green Solvents, Viley-VCH.
2.	Paul T. Anastas, Istvan T. Horvath, Green Chemistry for a Sustainable Future.
3.	V. K. Ahluwalia, M. Kidwai, New Trends in Green Chemistry, Kulwer Academic Publisher.
4.	Paul T, John C., Green Chemistry: Theory and Practice,Oxford University Press, USA.
5.	Baird, C. and Cann, M.,Environmental Chemistry, 4thEdition, W.H. Freeman and Company, New York, 2008.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER I- CAVITATION TECHNIQUES

Designation: Self Study

Course Pre-requisites: Basic knowledge of Chemistry and Sonochemistry

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:-- Hours/Week	Unit Test: 20 Marks	
Total : 4 Hours/Week	Assignment: 10 Marks	Total Credits: 04
	Attendance:10 Marks	
	Total :100 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Illustrate the basics of cavitation processes
2.	Classify the sonochemical reactions and analyze the controlling factors.
3.	Synthesize various inorganic materials using cavitation based processes
4.	Create various inorganic materials using cavitation based processes
5.	Apply the cavitation based advanced oxidation processes for the environmental protection and remediation
6.	Apply the cavitation based techniques for the synthesis and degradation of polymers

Topics covered

UNIT-I	**Introduction** The physical phenomenon , Definition, Vapor pressure, The main forms of vapor cavities, Cavitation regimes, Typical situations favorable to cavitation , The main effects of cavitation in hydraulics , Specific features of cavitating flow, Pressure and pressure gradient, Liquid-vapor interfaces, Thermal effects, some typical orders of magnitude, Non-dimensional parameters: Cavitation number, Cavitation number at inception, Relative under pressure of a cavity.	**(08 Hours)**
UNIT-II	**Acoustic Cavitation** Cavitation Bubble Temperature, Classification of Acoustic Cavitation, Sonoluminescence, Sonochemistry, Experimental Factors that Control Sonochemistry, Sites where Sonochemical Reactions Occur, The Classification of Sonochemical Reactions.	**(08 Hours)**
UNIT-III	**Synthesis of Inorganic Materials** Ultrafine powders and nanostructured materials, metal oxides, metal powders, supported nano powders etc.	**(08 Hours)**
UNIT-IV	**Synthesis of organic Materials** Homogeneous reactions, heterogeneous sono chemistry, Synthesis using alkylation reactions, addition reactions, reduction and oxidation reactions etc.	**(08 Hours)**

UNIT-V	**Environmental protection and remediation** Degradation of organic pollutants, Water purification, application of cavitation alone, combined application of cavitation and ozone, combined application of cavitation and ultraviolet light, combined application of cavitation and advanced oxidation processes(AOPs)	**(08 Hours)**
UNIT-VI	**Other applications of cavitation** Polymers: Degradation of polymers, factors affecting polymer degradation, polymer synthesis, ultrasonic processing of polymers. Sonoelectrochemistry: Electroplating in presence of ultrasound, zinc, iron, copper , nickel etc. Sonoelectro - organic synthesis.	**(08 Hours)**
Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of Cavitation techniques, keeping track of the recent technological trends and developments.		

Text Books/References:

1.	Jean-Pierre Franc, Jean-Marie Michel, "Fundamentals of Cavitation", Kluwer Academic Publishers, Dordrecht.
2.	"Sonochemistry- Kirk-Othmer Encyclopedia of Chemical Technology", John Wiley & Sons, Inc.
3.	T. J. Mason and J. P. Lorimer, "Applied sonochemistry: Uses of power ultrasound in chemistry and processing", Wiley-VCH publishers.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER-I: SAFETY ENGINEERING IN INDUSTRIES			
Designation: Self Study			
Course Pre-requisites: Process Design			
TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination:	60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test	:20 Marks	Total Credits : 04
	Attendance	:10 Marks	
	Assignment	:10 Marks	
	Total	:100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Discuss the different hazards in industries.
2.	Learn the parameters related to process and plant selection and operation.
3.	Elaborate pollution in industries and handling of toxic materials.
4.	Analyze the different safety programmes used in industries.
5.	Learn about the government rules about safety in industries.
6.	Discuss about the relief system used in industry.

Topics covered		
UNIT - I	Types of chemical Process Industries, various hazards in industries, handling of Hazardous chemicals, case study (one or two), chemical composition of hazards, case Study (one or two), first aid measures, fire fighting measures, accidental release Measures, personal protection and storage.	**(08 Hours)**
UNIT - II	Process Selection, plant operation, plant selection, construction, process system Engineering	**(08 Hours)**
UNIT - III	Industrial pollution, pollution control aspects, pollution control acts, various Toxic materials, handling of toxic materials, and industrial gases	**(08 Hours)**
UNIT - IV	Safety program, engineering ethics, accident and loss statistics, acceptable Risk, nature of accidental process, one or two case studies	**(08 Hours)**
UNIT - V	Government regulations, identification, MSD sheets, evaluation and control.	**(08 Hours)**
UNIT - VI	Relief concept, definitions, location of relief, relief types, relief scenario, Data for sizing relief, relief systems, design considerations and recommendations	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of safety engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Environmental Engineering,Howard S Peavy, Donald R Rowe and George Tchobanogloglons, Mc Graw Hill Book company
2.	Shreve s Chemical Process IndustriesG,eorge T Austin, Mc Graw Hill International Edition.
3.	Pollution Control in Chemical Process Industries, Mahajan S B, Tata Mc Graw Hill edition (P) Ltd.

4.	Introduction to process Engineering and Design, Thakore S.B and Bhatt B. I. Mc Graw Hill Publishing Company Ltd. New Delhi

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER -I: PETROLEUM ENGINEERING		
Designation: Self Study		
Course Pre-requisites: Chemical Reaction Engineering ,Mass Transfer, Heat Transfer		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination:60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test :20 Marks	Total Credits : 04
	Attendance :10 Marks	
	Assignment :10 Marks	
	Total :100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Learn about distribution of oil reserves spread in all over the world.
2.	Discuss about the formation of hydrocarbons.
3.	Elucidate the properties of fluids from the reservoir rocks.
4.	Analyze the drilling techniques used for petroleum production.
5.	Illustrate the safety aspects and the processes such as catalytic cracking and hydrosulphurization.
6.	Learn the new trends in hydrocarbon processing.

Topics covered		
UNIT - I	Distribution of Reserves Worldwide distribution of oil and gas reserves, Subsurface data sampling and data interpretation, Measurement scaling	**(08 Hours)**
UNIT - II	Origin of Hydrocarbons , accumulation and migration of hydrocarbons, Reservoir traps	**(08 Hours)**
UNIT - III	Properties of reservoir rocks and fluids, Rock – fluid interface, Reservoir description by direct and indirect methods, Oil and Gas in place. Chemical, physical and thermodynamic properties of petroleum and reservoir fluids	**(08 Hours)**
UNIT - IV	Drilling of oil and gas wells, Classification of wells, Drilling operating systems, Drilling fluids. New trends in drilling engineering	**(08 Hours)**
UNIT - V	Hazard and safety measures in handling of natural gas, transportation and storage of oil and gas ,Storage of oil and gas , Types of storage tanks, underground storage of natural gas Catalytic cracking, Catalytic reforming, Hydrodesulfurization, Hydrocraking	**(08 Hours)**
UNIT - VI	Recent developments in Hydrocarbon production techniques, Hydrocarbon recovery mechanisms, Non-conventional hydrocarbon energy sources, International trading in oil and gas.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of petroleum engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Bradley, “Petroleum Engineering Handbook”, SPE
2.	Mian, M. A., “Petroleum Engineering Handbook for Practicing Engineer”, Vol. I and II,

	Pennwell Publication.
3.	Deshpande, B.G., "World of Petroleum", Wiley.
4.	. John, F., Cook, M., and Graham, M., "Hydrocarbon Exploration and Production", Elsevier.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER-I: FLUID PARTICLE TECHNOLOGY

Designation: Self Study

Course Pre-requisites: Thermodynamics and Transport Processes

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures : 4 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test : 20 Marks	Total Credits : 04
	Assignment : 10 Marks	
	Attendance :10 Marks	
	Total :100 Marks	

Course Outcomes

After completion of the course the student will be able to:

1.	Enumerate the industrial significance of fluidized bed reactors
2.	Determine pressure drop in fluidized bed system
3.	Quantify phase mixing in multiphase reactors as function of system, operating, and geometrical parameters
4.	Determine heat and mass transfer coefficients in multiphase reactors as function of system, operating, and geometrical parameters
5.	Differentiate between conventional and circulating fluidized bed with respect to hydrodynamic characteristics
6.	Standardize fluidized bed reactor system

Topics covered

UNIT-I	**Applications of fluidized beds** Introduction. Industrial application of fluidized beds. Physical operations and reactions.	**(08 Hours)**
UNIT-II	**Fluidization and analysis of phases** Fluidization and analysis of phases for gas-solid, liquid-solid, and gas-liquid-solid fluidized beds. Hydrodynamic characteristics: pressure drop, velocity mapping, and fractional hold- up.	**(08 Hours)**
UNIT-III	**Mixing studies in fluidized beds** Effect of geometrical, system, and operating parameters on phase mixing in fluidized beds. Quantification of phase mixing. Development of a mathematical model.	**(08 Hours)**
UNIT-IV	**Heat and mass transfer in fluidized beds** Mass and heat transfer between fluid and particles. Effect of geometrical, system, and operating parameters on heat and mass transfer coefficients. Application of correlations available for estimating heat and mass transfer coefficients.	**(08 Hours)**
UNIT-V	**Circulating Fluidized Beds** Fluid and particle distribution in a fluidized bed. Introduction to circulating fluidized bed and its application. Hydrodynamic aspects of circulating fluidized beds. Standardization of circulating fluidized beds.	**(08 Hours)**
UNIT-VI	**Design of fluidized bed systems**	**(08 Hours)**

	Design of fluidization system for physical operations, catalytic and non-catalytic reactions, three phase fluidization and its standardization with regards to pressure drop, fractional phase hold- up, mass and heat transfer coefficient, extent of mixing, etc.	

Term-work: based on the term work/practical. The term work shall consist of the following:

- Assignments given by concerned subject teacher throughout the semester.
- Seminar presented and duly report prepared on any topic given from syllabus.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of fluid particle technology, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Diazo Kunji and O. Levenspiel "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
2.	J. F. Devidson and Harrison " Fluidization", 10th Edition, Academic Press, London, 1994.
3.	Jackson "The Dynamics of Fluidized Particles", Cambridge University Press, New York, 2000.
4.	Fan, L. S. And C. Zhu, "Principles of Gas- Solid Flows", Cambridge University Press, New York, 1998.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

M.Tech (Chemical) –SEMESTER-IV

SELF STUDY PAPER-II-TECHNOLOGY TRANSFER PRACTICES –BRIDGE TO INDUSTRY		
Designation: Self Study		
Course Pre-requisites: Plant design and Project management.		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination: 60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test : 20 Marks	Total Credits : 04
	Attendance : 10 Marks	
	Assignment :10 Marks	
	Total: 100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Discuss types of innovations.
2.	Analyze about commercialization of technology.
3.	Elaborate the product innovation strategy.
4.	Discuss the systems of innovation.
5.	Analyze the SWOT analysis of product.
6.	Learn about competences, strategic gaps and market implementation.

Topics covered		
UNIT - I	Innovation and the dynamics of technological change. The interactive and nonlinear nature of Innovation, Defining the Innovation Need**,** Dynamics of Technological Change and Systems of Innovation	**(08 Hours)**
UNIT - II	Theory and practice of processes of technology transfer and diffusion: Commercialization of technology; intellectual property rights. Product innovation: impact of product innovation, Product Innovation within OEM (case studies)	**(08 Hours)**
UNIT - III	Success factors for product innovation; developing a product innovation strategy: Interactive learning and networks of innovation: technology Platforms; firms taxonomy	**(08 Hours)**
UNIT - IV	Systems of Innovation and the corporate value chain: fostering clustering effects. Regional innovation strategies	**(08 Hours)**
UNIT - V	SWOT Analyses of company and product, Product Portfolio Analyses: Product Life Cycle (PLC) Product Innovation and Design consultancies (case studies), New Product-Service-System development	**(08 Hours)**
UNIT - VI	External trends (PESTED) and company core competences, Strategic Gap, Selection of ideas, Market implementation	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of technology transfer, keeping track of the recent technological trends and developments.

Text Books/References:	
1.	Mytelk, L. K. a nd Smith, K. (2003), "Interactions Between Policy Learning and Innovation Theory", in "Innovation, Competence Building, And Social Cohesion In Europe: Towards a Learning Society", Editors: Pedro Conceição,Manuel V. Heitor and Bengt-Åke Lundvall, Edward Elgar
2.	Lundval, B.-A., and Christensen, J.L. (2003), "Broadening the Analysis of Innovation Systems – Competition, Organisational Change and Employment Dynamics in the Danish System", in "Innovation, Competence Building, and Social Cohesion In Europe: Towards a Learning Society", Editors: Pedro Conceicao, Manuel V. Heitor and Bengt-Åke Lundvall, Edward Elgar
3.	Edquist, C. (1997). "Systems of innovation a introduction" (Chapter 1), in: "Systems of Innovation", ed. C. Edquist,

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER-II : FLUIDIZATION ENGINEERING		
Designation: Self Study Paper-II		
Course Pre-requisites: Thermodynamics and Transport Processes		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures : 4 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
Practical : 2 Hours/Week	Unit Test : 20 Marks	Practical : 01
Total : 6 Hours/Week	Assignment : 10 Marks	Total : 05
	Attendance :10 Marks	
	Term Work : 25 Marks	
	Practical/Oral : 25 Marks	
	Total :150 Marks	

Course Outcomes

After completion of the course the student will be able to:

1.	Estimate pressure drop in fluidized bed system
2.	Analyze fluidization regimes and models underlying
3.	Quantify design parameters like phase dispersion coefficient, HTC, and MTC
4.	Determine intrinsic kinetics of catalytic reactions to enumerate application of fluidized bed system.
5.	Enumerate models for entrainment from fluidized bed and their applications.
6.	Apply fluidized bed system for industrial relevant reactions like catalytic cracking, gasification, etc.

Topics covered

UNIT-I	Introduction and Application: Phenomenon of Fluidization, Liquid like behavior of a fluidized bed, comparison with other methods, Advantages and Disadvantages, Types of Fluidization. Gas behavior of Fluidized bed: Fixed beds, minimum fluidization velocity, Terminal velocity, and pressure drop, importance of distributor, voidage, TDH, viscosity and fluidity of fluidized beds.	**(08 Hours)**
UNIT-II	Bubbles and Emulsion phase in Dense bubbling beds: Single rising bubble, Stream of bubbles from single source, Ordinary Bubbling bed. Experimental findings. Bubbling bed model for Emulsion phase.	**(08 Hours)**
UNIT-III	Flow pattern of gas through fluidized bed: Experimental findings, Bubbling bed model for gas interchange. Evaluation of inter change coefficient. Radial and Axial dispersion of gas. Mass and heat transfer b/w fluid and solid	**(08 Hours)**
UNIT-IV	Conversion of gas in bubbling beds: Two region model, Model using distribution. Catalytic conversion, reaction rate, contacting efficiency, application to successive reactions, control of bubble size, baffling and scale-up	**(08 Hours)**
UNIT-V	Entrainment and Elutriation: Entrainment at or above TDH, Entrainment below TDH. Model for entrainment from dense fluidized bed and its applications.	**(08 Hours)**
UNIT-VI	Application in physical operations: Synthesis reactions, cracking and	**(08 Hours)**

	reforming of hydrocarbons, carbonization and gasification. Gas solid reactions.	

Practical: Practical examination will consist of assessment of the term-work (duly certified by the teacher and HoD) and the oral/seminar based on the term work/practical.

Term-work: based on the term work/practical. The term work shall consist of the following:

- Assignments given by concerned subject teacher throughout the semester.

Seminar presented and duly report prepared on any topic given from syllabus.

Text Books/References:

1.	Diazo Kunji and O. Levenspiel "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
2.	J. F. Devidson and Harrison " Fluidization", 10th Edition, Academic Press, London, 1994.
3.	Jackson "The Dynamics of Fluidized Particles", Cambridge University Press, New York, 2000.
4.	Fan, L. S. And C. Zhu, "Principles of Gas- Solid Flows", Cambridge University Press, New York, 1998.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER-II: MEMBRANE SEPARATION

Designation: Self Study Paper-II

Course Pre-requisites: Mass transfer, Separation Technology, Chemical Interaction

TEACHING SCHEME:	**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Practical: 2 Hours/Week	Unit Test	: 20 Marks	Practical	: 01
Total : 6 Hours/Week	Assignment	: 10 Marks	Total	: 05
	Attendance	:10 Marks		
	Term Work	: 25 Marks		
	Practical/Oral	: 25 Marks		
	Total	:150 Marks		

Course Outcomes:

After completion of the course the student will be able to:

1.	Explain basics of membrane separation with principles behind
2.	Select proper material depending upon application
3.	Prepare the membranes with desired property for given application
4.	Choose proper method for membrane characterization
5.	Explain the transport properties of membranes ant their applicability
6.	Select and design proper membrane processes for desired application

Topics covered

UNIT - I	Introduction- Separation Processes, Introduction to membrane processes, Definition of Membrane, Merits of the Processes. Classification of the membrane separation process.	**(08 Hours)**
UNIT - II	Materials & Materials Properties-: Membrane Polymers, Molecular weight, Porous & Porous membrane, Thermal, Chemical & Mechanical Properties of Inorganic membranes, Biological membranes. Retention & rejection co-efficient. Factor affecting the separation processes. Effect of polymeric structure on Tg Glass transition temperature depression.	**(08 Hours)**
UNIT - III	Preparation of Synthetic Membranes:- Phase inversion membranes, Preparation by evaporation, Precipitation from the vapor phase. Precipitation by controlled evaporation, Thermal & immersion precipitation. Flat membranes, Tubular membranes, Zeolite membranes, Dense membrane. Preparation Technique for Composite Membrane, Inorganic Membranes.	**(08 Hours)**
UNIT - IV	Characteristics of porous membrane, Bubble Point Method, Mercury intrusion method, Permeability Method, Ultra filtration, Gas-adsorption desorption, Characterization of ionic membranes, characterization of non-porous membrane.	**(08 Hours)**
UNIT - V	Transport in membrane, Knudsen flow, Friction Model, Transport through non-porous membrane. Determination of diffusion co-efficient & solubility co-efficient. Transport in ion exchange membranes.	**(08 Hours)**
UNIT - VI	Membrane Processes, M.F, U.F, R.O, Nanofiltration Dialysis, Electro	**(08 Hours)**

	dialysis, Piezodialysis, Diffusion Dialysis, Membrane reactors & membrane bioreactors, Polarization & Fouling Phenomena in Membranes, C.P in electro dialysis, Temperature Polarization, Membrane Fouling, Method to reduce Fouling.	

Term Work: The term work shall consist of the following.
Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of membrane separation, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Osada Yoshohito, Nakagawa T."Membrane Science and Technology", Marcel Dekker Inc.
2.	Marcel Mulder, "Basic Principles of Membrane Technology", Kluwer Academic Publishers. Netherlands.1998.
3.	C. J. King,"Separation Processes". Tata Mc Graw-Hill.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER II: POLYMER ENGINEERING		
Designation: Self Study		
Course Pre-requisites: Basic Chemical Sciences, Chemical Reaction Engineering, Thermodynamics		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	Theory : 60 Marks	Theory : 04
Practical : 02 Hours / Week	Unit Test : 20 Marks	Total Credits : 04
Total : 06 Hours / Week	Assignment :10 Marks	
	Attendance : 10 Marks	
	Total : 100 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Explain basics of polymerization and polymerization reactions
2.	Explain the synthesis of important polymers and monomers
3.	Select the proper reactor for polymerization and explain its design basis
4.	Choose method for characterization and interpret the obtained data
5.	Select the desired processing method for given polymers
6.	Explain the applicability of polymers in specialized applications and the issues of polymer waste management

Topics covered

UNIT - I	Introduction to polymer technology – types of polymerization, effect of temperature and pressure on polymerization, degree of polymerization , molecular weight determination	**(08 Hours)**
UNIT - II	Polymerization process – Manufacturing process of pthalic anhydride, propylene, acrylonitrile, adipic acid, tetrapthalic acid, LDPE, HDPE, PVC, PP, PC, polystyrene, polyurethanes, PTFE, polyester via terepthalic acid, nylon-6.	**(08 Hours)**
UNIT - III	Polymerization reactors – Batch, continuous, plug flow, CSTR, Design consideration of batch reactor, design consideration in high pressure LDPE reactors, LLDPE & HDPE Fluid bed reactor. Types of agitators for polymerization reactors, polymer drying.	**(08 Hours)**
UNIT - IV	Polymer characterization & rheology. Mechanical properties of polymer, crystallinity, glass transition temperature (Tg), heat distribution temperature, mathematical models of viscoelastic behavior of plastic, viscosity determination of polymer.	**(08 Hours)**
UNIT - V	Plastic processing – injection molding, compression molding, rotational molding, transfer molding, coating polymer blends, & composites – polymer alloys, reinforced plastics.	**(08 Hours)**
UNIT - VI	Polymer adhesives technology - Different types of adhesive, polyvinyl alcohol, rubber cement, polymer applications, identification and waste management.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of polymer engineering, keeping track of the recent technological trends and

developments.	
Text Books/References:	
1.	"Introduction to polymer science & technology" by Dr S.D Dawande, Denett & Co 1st edition 2006.
2.	Gowarikar V.R , Vishvanathan N.V., Sridhar J., Polymer Science, New Age International Pvt. Ltd., Dariyaganj, New Delhi.
3.	Bhatnagar M.S., Text book of Polymer Vol. I, II, III, S. Chand & Co. Ltd., New Delhi – 55.
4.	Raonatti S., Design formula for plastic engineering, Hanser Publication, Munich Vienna, New York (1991).
5.	Pattan W. J., Plastic Technology, Theory, Design, and Manufacture, Ruston Publishing Co. Mumbai – 01
6.	Athalye A. S., Plastic Material Handbook Vol. 1 & 2, Multitech Publishing Co. Ghatkopar Mumbai – 77.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER -II: FOOD TECHNOLOGY

Designation: Self Study

Course Pre-requisites: Basics of Food Processing, Separation Technology, Chemical Conversions.

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures : 4 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test : 20 Marks	Total credits : 04
	Assignment : 10 Marks	
	Attendance : 10 Marks	
	Total : 100 Marks	

Course Outcomes:

After completion of the course students will be able to

1.	Explain the principles of food processing.
2.	Identify and select the method of processing for conductive and convective foods.
3.	Explain balancing and freezing of foods.
4.	Select membrane processes for food processing as per desired application.
5.	Explain osmotic dehydration of food.
6.	Explain extrusion cooking and packaging of foods.

Topics covered

UNIT-I	Principle of food processing: Rheology of solid, semi-solid and liquid foods. Heat transfer and thermal death times, Schmidt plot procedure.	**(08 Hours)**
UNIT-II	Canning of food: Thermal processing, determining time of heat sterilization process. Conductive and convective foods.	**(08 Hours)**
UNIT-III	Balancing and freezing of foods: Balancing processes, freezing, Ultra-high temperature thermal processing, food sterilization, probability of non-sterile unit, Convective drying of food, rate of drying, time of drying.	**(08 Hours)**
UNIT-IV	Membrane processing of liquid foods: Principles, membrane configuration, types, evaporation concentration of liquid food, evaporator load calculation.	**(08 Hours)**
UNIT-V	Osmotic dehydration of food: Mechanism of osmotic dehydration, kinetics. Microwave heating of food, Frying of food, heat and mass transfer in frying.	**(08 Hours)**
UNIT-VI	Extrusion cooking of foods: extrusion process, role of moisture content. Packaging of foods, packaging materials, shelf life, water transmission rate, prediction of packaging time. Process control in food manufacturing.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of food technology, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Frazier, W.C., and Westhoff, D.C., (1995). Food Microbiology. 4th ed. New Delhi: Tata McGraw-Hill publishing Company Limited.
2.	Basic Food Microbiology; Bannett, Chapman and Hall
3.	**Potter**, Norman N., **Hotchkiss,** Joseph H., Food Science, fifth edition.
4.	Frazier, Food Microbiology, Tata McGraw Hill, (2007).
5.	Norman W. Desrosier, James N. Desrosier, The technology of food preservation, 4th ed. Westport, Conn. : AVI Pub. Co., c1977.
6.	Fennema Karrel, Principles of Food Science, Vol-I, Marcel Dekker publisher.

7.	Food Science by Mudambi Robinson RK; 1996; Modern Dairy Technology, Vol 1 & 2; Elsevier Applied Science Pub.
8.	Charm SE, The Fundamentals of Food Engineering; 1963, AVI Pub.
9.	Sharan K., Mulvaney S. J., Rizvi S. H., Food process engineering, Wiley Interscience Publication

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER-II- MODELING AND SIMULATION OF PROCESSES

Designation: Self Study

Course Pre-requisites: Basic knowledge of simulation techniques and numerical methods

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:-- Hours/Week	Unit Test: 20 Marks	TW/PR/OR: --
Total : 4 Hours/Week	Assignment: 10 Marks	Total credits: 04
	Attendance:10 Marks	
	Total :100 Marks	

Course Outcomes:

After completion of the course the student will be able to:

1.	Compare and analyze the controls used in various processes
2.	Develop a steady state and dynamic models for simple systems
3.	Compute the frequency response analysis
4.	Accomplish the process identification
5.	Estimate the building blocks of artificial neural network (ANN)
6.	Apply the simulation techniques to solve the industrial application based models

Topics covered

UNIT-I	**Introduction:** Models, Open loop systems, Feedback controls, cascade controls, System analysis from models, The control engineers role.	**(08 Hours)**
UNIT-II	**Modeling of dynamic systems:** Modeling principles, Modeling physical components, Obtaining a transfer function for Analysis or Simulation with SIMULINK. Modeling of various systems.	**(08 Hours)**
UNIT-III	**Frequency response analysis:** Mathematical basis, Application of frequency response diagram, using MATLAB to obtain gain margin (GM) and phase margin (PM).using MATLAB to produce a Nichols Chart, comparison of various methods.	**(08 Hours)**
UNIT-IV	**Process identification:** Purpose, Direct methods, time domain fitting of step test data, direct sine wave testing, digital evaluation of Fourier transformation, auto tuning, approximate transfer functions.	**(08 Hours)**
UNIT-V	**Building blocks of feed forward neural network:** Building blocks of ANN, processing elements, connections, weights, activation and transfer functions, learning rules	**(08 Hours)**
UNIT-VI	Computer Simulation for various industrial applications.	**(08 Hours)**

Assignment:
Each student will submit assignments based on different topics in consultation with faculty, in the area of modeling and simulation of processes, keeping track of the recent technological trends and developments

Text Books/References:

1.	Franks R. E. G., "Modeling and Simulation in Chemical Engineering", Wiley Interscience, NY
2.	John Ingam, Irving J. Dunn, "Chemical Engineering Dynamic Modeling with PC Simulation", VCH Publishers
3.	William L. Luyben, "Process Modeling Simulation and Control for Chemical Engineers", McGraw Hill International Edition Publishing Company
4.	Himmelblau D., K. B. Bischoff, " Process Analysis and Simulation", John Wiely & Sons
5.	Wayne Bequette, " Process Dynamics, Modeling, Analysis and Simulation", Prentice Hall
6.	K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press, 2001.
7.	Singiresu S. Rao, "Applied Numerical Methods for Engineers and Scientists" Prentice Hall, Upper Saddle River, NJ, 2001
8.	W. F. Ramirez, "Computational Methods for Process Simulation", 2nd ed., Butterworths, 1997
9.	Modeling and analysis of dynamic systems, by C.M .Close, D.H. Fredrick and J. C. Newell, John Wiley & Sons, 2002

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -II: PETROCHEMICAL ENGINEERING		
Designation: Self Study		
Course Pre-requisites: Chemical Reaction Engineering ,Mass Transfer, Heat Transfer, Petroleum Engineering		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination: 60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test : 20 Marks	Total Credits : 04
	Attendance : 10 Marks	
	Assignment :10 Marks	
	Total: 100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Analyze today's feedstock scenario for fossil fuel.
2.	Discuss about coal bed methane process and Potential, and Technologies for exploitation of resources for fuel.
3.	Learn about coal gasification process in detail.
4.	Discuss the pathways for manufacturing of chemicals from Alco chemicals.
5.	Elaborate about the processing hydrocarbons.
6.	Analyze the industrial application in petrochemical industry.

Topics covered		
UNIT - I	Existing Feedstock Scenario Fossil fuel feedstock, Coal, Natural Gas and Petroleum, Reserves, Present and Future ,Production Trends, Statics for India and World, Distribution and utilization pattern of existing fossil reserves, Demand supply scenario, Cycle of oil prices, Need for alternative feedstocks	**(08 Hours)**
UNIT - II	Non conventional Fossil Fuels ,Coal Bed Methane, Coal Gasification, Shale Oil, Hydrates, Reserves, Potential, and Technologies for exploitation of these resources, Cost factor	**(08 Hours)**
UNIT - III	Coal Gasification Chemistry and Technology for coal gasification and Syngas production, Fischer Tropsch Synthesis, Chemistry, Catalyst and Process Technology, Other outlets for Syngas	**(08 Hours)**
UNIT - IV	Alco Chemicals -Pathways and technologies for chemicals from ethanol, isopropyl alcohol, n-butanol, isobutanol, Lube oil additives, Octane boosters	**(08 Hours)**
UNIT - V	Fundamentals of natural gas engineering, chemical composition of natural gas, Processing of Petroleum and Hydrocarbons	**(08 Hours)**
UNIT - VI	Industrial Applications in Petrochemical Industry	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of petrochemical engineering, keeping track of the recent technological trends and developments.

Text Books/References:	
1.	Satterfield C. N., "Heterogeneous Catalysis in Industrial Practice", Second Edition, McGraw Hill, 1993
2.	Smith J. M., "Chemical Engineering Kinetics", Third Edition, McGraw Hill.
3.	Froment G. F. and Bischoff, K. B. "Chemical Reactor Analysis and Design", John Wiley & Sons.
4.	John, F., Cook, M., and Graham, M., "Hydrocarbon Exploration and Production",Elsevier.

Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and II
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER -II: PHYSICAL CONCEPTS OF UNIT OPERATIONS		
Designation: Self Study		
Course Pre-requisites: Basic knowledge of Phase Equilibrium, Material and Energy balances, Fluid flow operation and Heat Transfer.		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTED**
Lectures: 04 Hours / Week	End Semester Examination:60 Marks	Theory : 04
Total : 04 Hours / Week	Unit Test :20 Marks	Total Credits : 04
	Attendance :10 Marks	
	Assignment :10 Marks	
	Total :100 Marks	

Course Outcomes:	
After completion of the course the student will be able to:	
1.	Identify and solve distillation based problems.
2.	Learn and understand extraction operations and equipments.
3.	Learn and understand crystallization mechanism.
4.	Understand the adsorption phenomenon and Isotherms.
5.	Understand the leaching operation and equipments.
6.	Understanding the drying operation and equipments.

Topics covered		
UNIT - I	Vapor-Liquid Equilibrium, relative volatility, boiling point diagram, Raolts law, Mc Cabe-Thiele method, Lewis-Sorel method, reflux ratio, partial condenser, H-X diagram,Azeotropes, steam distillation, different types of columns and analysis.	**(08 Hours)**
UNIT - II	Applications of liquid-liquid extraction, difference between distillation and extraction, Distribution coefficient, ternary systems, selection of solvent, different stages of operation, Various types of extraction equipments.	**(08 Hours)**
UNIT - III	Equilibrium data, solubility curves, crystallization theory, classification of crystallization Equipments, types of crystallizers, mechanism of crystallisation.	**(08 Hours)**
UNIT - IV	Application of adsorption, nature of adsorption, types of adsorption, adsorption Isotherms, different stages of adsorption, breakthrough curves.	**(08 Hours)**
UNIT - V	Introduction to leaching operation, equilibrium diagram, various stages of operation, Countercurrent leaching operation, leaching of fine solids, dorr agitator.	**(08 Hours)**
UNIT - VI	General definitions of drying, equilibrium in drying, rate of drying curve, General classification and types of dryers.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of physical concepts of unit operations, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Coulson J,M. and Richardson Chemical Engineering Volume 2
2.	Pergaon Press, Oxford, New York (USA) King C, J.Separation ProcessesMc Graw – Hill

	Publications.
Syllabus for Unit Test:	
Unit Test -1	UNIT – I,II and III
Unit Test -2	UNIT –IV,V and VI

SELF STUDY PAPER II: MULTIPHASE REACTION ENGINEERING

Designation: Self Study.

Course Pre-requisites: Thermodynamics and Transport Processes

TEACHING SCHEME:		**EXAMINATION SCHEME:**		**CREDITS ALLOTTED:**	
Lectures	: 4 Hours/Week	End Semester Examination	: 60 Marks	Theory	: 04
Total	: 4 Hours/Week	Unit Test	: 20 Marks	Total Credits	: 04
		Assignment	: 10 Marks		
		Attendance	: 10 Marks		
		Total	: 100 Marks		

Course Outcomes

After completion of the course the student will be able to:

1.	Enumerate the industrial significance of multiphase reactors
2.	Estimate Gibbs free energy and intrinsic kinetics for multiphase reaction
3.	Enumerate hydrodynamic characteristics of multiphase reactors
4.	Quantify phase mixing in multiphase reactors as function of system, operating, and geometrical parameters
5.	Determine heat and mass transfer coefficients in multiphase reactors as function of system, operating, and geometrical parameters
6.	Standardize multiphase reactor system

Topics covered

UNIT-I	**Introduction to Multiphase Reactor Engineering: Types**, Classification, Application of Industrial Importance.	**(08 Hours)**
UNIT-II	**Thermodynamics and kinetics:** Notable industrial heterogeneous systems and thermodynamic role. Application of equilibrium criteria to chemical reactions. The Gibbs energy change and equilibrium constant. Estimation of equilibrium constant for heterogeneous system by defining standard state of the phases involved. Determination of rate controlling step: intrinsic kinetics for heterogeneous systems	**(08 Hours)**
UNIT-III	**Hydrodynamic Characteristics:** Hydrodynamic characteristics of different multiphase reactors: Mechanically Agitated Contactors (MAC), Bubble Columns, Slurry Reactors, Fluidized Beds, Loop Reactors and Modified Versions.	**(08 Hours)**
UNIT-IV	**Mixing Studies :** Effect of geometrical, system, and operating parameters on phase mixing in multiphase reactors. Quantification of phase mixing. Development of a mathematical model.	**(08 Hours)**
UNIT-V	**Heat Transfer and Mass Transfer Studies :** Effect of geometrical, system, and operating parameters on heat transfer coefficient in multiphase reactors. Quantification of heat transfer coefficient. Application of correlations available to different multiphase reactors. Experimental techniques used for estimation of mass transfer coefficient and selection of suitable technique for a multiphase reactor. Effect of geometrical,	**(08 Hours)**

	system, and operating parameters on mass transfer coefficient in multiphase reactors. Quantification of mass transfer coefficient. Application of correlations available to different multiphase reactors.	
UNIT-VI	**Design Aspects of Multiphase Reactors:** Pressure drop, Fractional phase hold- up, mass and heat transfer coefficient, extent of mixing, etc.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of fluid particle technology, keeping track of the recent technological trends and developments

Text Books/References:

1.	L. K. Doraiswamy and M. M. Sharma, "Heterogeneous Reactions", 2nd Edition, Volume I and II.
2.	G. B. Tatterson, "Fluid Mixing and Gas Dispersion in Stirred Reactors", 10th Edition, Academic Press, London, 1994
3.	W. D. Deckwer, "Bubble Column Reactors", Cambridge University Press, New York, 2000.
4.	Diazo Kunji and O. Levenspiel, "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
5.	J. F. Devidson and Harrison, " Fluidization", 10th Edition, Academic Press, London, 1994.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER II: NANOSCIENCE		
Designation: Self Study.		
Course Pre-requisites: Basic Chemistry and Physics		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures : 4 Hours/Week	End Semester Examination : 60 Marks	Theory : 04
Total : 4 Hours/Week	Unit Test : 20 Marks	Total credits : 04
	Assignment : 10 Marks	
	Attendance : 10 Marks	
	Total : 100 Marks	

Course Outcomes

After completion of the course the student will be able to:

1. Define the concept of nanomaterials and Nanotechnology
2. Distinguish between the synthesis techniques for nanomaterials and apply the appropriate synthesis technique.
3. Recognize the properties of nanomaterials and effect on them due to nanoscale.
4. Recognize the forms of nanomaterials based on dimensions.
5. Elaborate the effect of Nano structuring on properties nanostructured materials.
6. Express various types of nanomaterials and characterization techniques

Topics covered

UNIT-I	Introduction, Scientific Revolutions; Types of nanomachines and nanotechnology; periodic table; Atomic structure molecules and phase Energy, Molecular and Atomic size, Surfaces and dimensional space; Top down and bottom up.	**(08 Hours)**
UNIT-II	Nano material synthesis methods, Introduction to Nano scale materials - Synthesis and processing, method of nano structured materials preparation – mechanical grinding, wet chemical synthesis – sol-gel processing, gas phase synthesis, gas condensation processing, chemical vapor condensation – nano composite synthesis – processing.	**(08 Hours)**
UNIT-III	Nanomaterials properties Opportunity at the nano scale - Length and time scale in structures -energy landscapes-Inter dynamic aspects of inter molecular forces	**(08 Hours)**
UNIT-IV	Quantum dots - Nano wires-Nano tubes; 2D and 3D films; Nano and mesopores, micelles, nano machines-biological membranes	**(08 Hours)**
UNIT-V	Physical properties of nanostructured materials, Influence of Nano structuring on Mechanical - Optical, electronic, magnetic and chemical properties – gramsize effects on strength of metals optical properties of quantum dots and quantum wires carbon nano tubes -magnetic behavior	**(08 Hours)**
UNIT-VI	Nanostructures-surface chemistry of tailored monolayer -self assembling; Characterization Techniques: X-ray Diffraction, Scanning Electron Microscopy (SEM), Transmission Electron microscopy (TEM), Optical Spectroscopy, Atomic Force Micrograph (AFM), Particle Size Analyzer.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the

area of fluid particle technology, keeping track of the recent technological trends and developments	
Text Books/References:	
1.	L. K. Doraiswamy and M. M. Sharma, "Heterogeneous Reactions", 2nd Edition, Volume I and II.
2.	G. B. Tatterson, "Fluid Mixing and Gas Dispersion in Stirred Reactors", 10th Edition, Academic Press, London, 1994
3.	W. D. Deckwer, "Bubble Column Reactors", Cambridge University Press, New York, 2000.
4.	Diazo Kunji and O. Levenspiel, "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
5.	J. F. Devidson and Harrison, " Fluidization", 10th Edition, Academic Press, London, 1994.
Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

BHARATI VIDYAPEETH
(DEEMED TO BE UNIVERSITY), PUNE

Faculty of Engineering And Technology
M. Tech. Chemical
Old Syllabus

BHARATI VIDYAPEETH UNIVERSITY COLLEGE OF ENGINEERING

CHEMICAL ENGINEERING DEPARTMENT

M.TECH CHEMICAL (CBCS -2015 COURSE)

M.TECH STRUCTURE (CHEMICAL)
Choice Based Credit System

SEMESTER-I

Semester I **Total Duration: 20 hrs/week**

Total Marks : 500

Total Credits: 18

Subject Code	Subject	Teaching Scheme (Hrs) Hrs./Week		Examination Scheme (Marks)						Examination Scheme (Credits)		Total Credits
		L	P	Theory	Unit Test	Attendance	Tutorial/assignments	TW	Pract/ Oral	TH	TW/PR/OR	
K10501	Applied Mathematics for Chemical Engineering	04	02	60	20	10	10	25	25	04	01	05
K10502	Advanced Momentum and Heat Transfer	04	--	60	20	10	10	-	--	04	-	04
K10503	Thermodynamics of Phase Equilibria	04	--	60	20	10	10	-	-	04	-	04
K10504	Multiphase Reactors	04	02	60	20	10	10	25	25	04	01	05
	Total	**16**	**04**	**240**	**80**	**40**	**40**	**50**	**50**	**16**	**02**	**18**

SEMESTER-II

Semester II **Total Duration: 20 hrs/week**

Total Marks : 500

Total Credits: 18

Subject Code	Subject	Teaching Scheme (Hrs) Hrs./Week		Examination Scheme (Marks)						Examination Scheme (Credits)		Total Credits
		L	P	Theory	Unit Test	Attendance	Tutorial /assignments	TW	Pract/ Oral	TH	TW/ PR/OR	
K10505	Modeling & Simulation of Chemical Processes	04	02	60	20	10	10	25	25	04	01	05
K10506	Chemical Reactor Analysis and Design	04	--	60	20	10	10	--	--	04	--	04
K10507	Synthesis & Design of Chemical Processes	04	--	60	20	10	10	--	--	04	--	04
K10508	Advanced Mass Transfer	04	02	60	20	10	10	25	25	04	01	05
	Total	**16**	**04**	**240**	**80**	**40**	**40**	**50**	**50**	**16**	**02**	**18**

SEMESTER-III

Semester III												**Total Duration: 28 hrs/week** **Total Marks : 475** **Total Credits: 40**
Subject Code	**Subject**	**Teaching Scheme (Hrs)** **Hrs./Week**		**Examination Scheme**						**Examination Scheme** **(Credits)**		**Total Credits**
		L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/ assignments**	**TW**	**Pract/ Oral**	**TH**	**TW/PR /OR**	
K10601	Elective –I	04	02	60	20	10	10	25	25	04	01	05
K10602	Elective –II	04	02	60	20	10	10	25	25	04	01	05
	**Self-Study Paper-I	* 04	--	60	20	10	10	-	-	04	-	04
K10604	Dissertation Stage –I	-	07	-	-	---	--	25	--		21	21
K10603	Seminar	-	05	-	-	**--**	**--**	25	25	-	05	05
	Total	**12**	**16**	**180**	**60**	**30**	**30**	**100**	**75**	**12**	**28**	**40**

Elective – I	**Elective - II**
• Advanced Process Control • Non Conventional Energy Sources • Industrial Waste Water Treatment • Heterogeneous Catalysis • Catalyst Materials	• Membrane Separation • Bio-process Engineering • Multicomponent Separation • Food Process Engineering • Fluidization Engineering

SEMESTER-IV

Semester IV												**Total Duration: 14 hrs/week** **Total Marks : 325** **Total Credits: 34**
Subject Code	**Subject**	**Teaching Scheme (Hrs)** **Hrs./Week**		**Examination Scheme**						**Examination Scheme** **(Credits)**		**Total Credits**
		L	**P**	**Theory**	**Unit Test**	**Attendance**	**Tutorial/ assignments**	**TW**	**Pract/ Oral**	**TH**	**TW/PR /OR**	
	**Self-Study Paper-II	* 04	--	60	20	10	10	-	-	04	-	04
K10605	Dissertation Stage –II	-	10	-	-	--	-	150	75		30	30
	Total	**04**	**10**	**60**	**20**	**10**	**10**	**150**	**75**	**04**	**30**	**34**

Sr.No.	**SELF STUDY PAPER- I** **(SEM-III)**	**SELF STUDY PAPER- II** **(SEM-IV)**
1	Optimization Techniques in Process design	Technology Transfer Practices –Bridge to Industry
2	Non Conventional Energy System	Polymer Engineering
3	Mechanical Aspects in Chemical Engineering	Food Technology
4	Green Chemistry & Technology	Modeling & Simulation of Processes
5	Cavitation Techniques	Nanoscience
6	Safety Engineering in Industries	Petrochemical Engineering
7	Petroleum Engineering	Physical Concepts of Unit Operations
8	Fluid Particle Technology	Multiphase Reactor Engineering

SEMSETER-I

K10501 APPLIED MATHEMATICS FOR CHEMICAL ENGINEERING		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures : 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical : 2 Hour /Week	Unit Test: 20 Marks	Practical: 01
Total : 6 Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered		
UNIT-I	**Introduction:** Approximation and round-off errors, significant figures, accuracy and precision, error definitions, truncation errors. Taylor series, error propagation, total numerical error, formulation errors and data uncertainty. Tests of significance. Analysis of variance.	**(08 Hours)**
UNIT-II	**Numerical solution of linear & nonlinear algebraic equations:** Linear systems of equations, solutions by Creamer's Rule, Matrix methods, Gaussian, Gauss-Jordan, Jacobean, Gauss-Seidel and Relation methods. Non-linear equations: Bisection, Regula-falsi, Secant and Newton- Raphson methods.	**(08 Hours)**
UNIT-III	**Curve fitting:** Least square regression: Linear regression, polynomial regression. Interpolation: Newton's divided–difference interpolating polynomials, Lagrange interpolating polynomials, coefficient of an interpolating polynomial. Fourier approximation.	**(08 Hours)**
UNIT-IV	**Numerical integration and differentiation:** Newton-cotes integration of equations. Integration of equations: Romberg integration, Gauss Quadrature. **Partial differential equations:** Finite difference: Elliptic equations, parabolic equations, finite element method. Diffusion/convection form of partial differential equations in chemical engineering. Characteristics and partial differential equation types and their analytical solution.	**(08 Hours)**
UNIT-V	**Numerical solution of ordinary differential equations:** Formulation of linear and non-linear first and second order ordinary differential equations, higher order linear, differential equations for systems involving momentum, heat and mass transfer with and without chemical reactions and their analytical solutions. Ordinary differential equations: Runge-Kutta, Euler's and Milne's predictor corrector methods. Boundary–value and eigenvalue problems,general methods of boundary-value problems.	**(08 Hours)**
UNIT-VI	**Mathematical analysis and engineering problem-solving:** Design and analysis of experiments: data analysis, treatment, generalization and interpretation on engineering data. Formulation of physical problems: mathematical statement of the problem, representation of problems, problem solving with appropriate mathematical method, analysis of results with statical tests.	**(08 Hours)**

Term Work:

Oral examination will consist of assessment of the termwork (duly certified by the teacher and HOD) and oral exam based on the term work/practical. The term work shall consist of the following:

Minimum 8 practical based on solving numerical methods mentioned in the syllabus using C, C++ language, or TK solver software, or any chemical Engineering Software.

Assignment: : Each student will submit assignments based on different topics in consultation with faculty, in the area of application of mathematics in chemical engineering, keeping track of the recent technological trends and developments..

Text Books/References:

1.	S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, 6th Ed., McGraw Hill, 2010.
2.	S. C. Chapra, Applied Numerical Methods with MATLAB: for Engineers and Scientists, 2nd Ed., Tata McGraw Hill, New Delhi, 2010.
3.	S. K. Gupta, "Numerical Techniques for Engineers", Wiley Eastern, 1995.
4.	M.K. Jain, S.R.K. Iyengar and R. K. Jain, "Numerical Methods for Scientific and Engineering Computations", 1992.
5.	Kreyszig, Erwin: Advanced Engineering Mathematics, 8th Edition, Wiley Eastern, New Delhi, 2002.
6.	H.S.Mickley, T.K. Sherwood and C.E. Reid, “Applied Mathematics in Chemical Engineering”, II Edn., Tata McGraw Hill, New Delhi, 1978.
7.	Teukolsky S.A., W.H. Press, “Numerical Recipes in ‘C’ ”, Cambridge University press
8.	Constantinides A., “Applied Numerical Methods with Personal computer”, McGraw Hill publishers

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10502 ADVANCED MOMENTUM AND HEAT TRANFER		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered		
UNIT-I	**Shear stress in laminar flow:** Newtonian and non Newtonian fluids; Rheological models; theories of transport properties of gases and liquids; effect of pressure and temperature. **One dimensional momentum transport in laminar flow (shell balance):** General method of shell balance approach to momentum transfer problems; momentum flux and velocity distribution for flow of Newtonian and non-Newtonian fluids in pipes, planes, slits and annulus; Fluid flow of two immiscible fluids.	**(08 Hours)**
UNIT-II	**Differential equations of fluid flow:** Control volume approach; Differential continuity equation; Navier-Stokes Equation and Bernoulli's equation; Applications of differential equations of fluid flow **Effect of turbulence on momentum transfer:** Description of turbulence; Turbulent shearing stresses; The mixing length hypothesis, velocity distribution from the mixing length theory; The universal velocity distribution; The turbulent boundary layer on a flat plate	**(08 Hours)**
UNIT-III	**Fluid flow in closed Conduits:** Friction factors for fully developed laminar, turbulent and transition flow in circular conduits; Friction factors for flow in the entrance to a circular conduit; Friction factors for packed columns. **Macroscopic momentum balances:** The macroscopic mass, momentum and mechanical energy balances; Use of macroscopic balances for steady-state problems; Use of macroscopic balances for unsteady-state problems.	**(08 Hours)**
UNIT-IV	**Mechanism of energy transport:** Fourier's law of heat conduction; Thermal conductivity of liquids and solids; Effective thermal conductivity of composite solids. **Temperature distribution in solids and in laminar flow:** Heat conduction through composite walls; Heat conduction in a cooling Fin; Forced convection; Free convection.	**(08 Hours)**
UNIT-V	**The equation of change for non isothermal systems:** The equation of energy; The equation of motion for forced and free convection; Use of equations of change to solve the steady-state problems **Unsteady Heat Conduction in Solids:** Heating of a semi-infinite slab; Heating of a finite slab; Unsteady heat conduction near the wall with sinusoidal heat flux **Temperature distribution in turbulent flow**: Time smoothed equation of change for incompressible non isothermal flow; Time smoothed temperature profile near a wall; Empirical expressions for the turbulent heat flux; Temperature distribution for turbulent flow in tubes	**(08 Hours)**
UNIT-VI	**Interphase transport in non-isothermal systems:** Heat transfer coefficients for forced convection in tubes and through packed beds; Heat transfer coefficients for free and mixed convection; Heat transfer coefficients for condensation of pure vapors	**(08 Hours)**

	on solid surfaces. **Analogies of momentum and heat transfer:** Reynolds and Chilton Colburn analogy	

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of advanced momentum and heat transfer, keeping track of the recent technological trends and developments.

Text Books/References:

1.	W. E. Stewart, E. N. Lightfoot, R. B. Bird, "Transport Phenomena", John Wiley & Sons
2.	J. R. Welty, C. W. Wicks, R. E. Wilson, G. Rorrer, "Fundamentals of momentum, heat and mass transfer, Wiley INDIA
3.	J.C. Slattery, "Advanced transport phenomena", Cambridge University Press
4.	J. G. Knudsen, D. L. Kaz, "Fluid Dynamics and Heat Transfer", McGraw Hill

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10503 THERMODYAMICS OF PHASE EQUILIBRIA

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered

UNIT-I	**Thermodynamics of Multicomponent mixtures:** Ideal mixtures and excess mixture properties, Fugacity of species in gaseous, liquid and solid mixtures, Criteria for phase equilibrium in multicomponent systems, Modified Roult's law and its significance, Gibbs Duhem equation, Hydrogen bonding and charge transfer complexing Equilibrium	**(08 Hours)**
UNIT-II	**Vapor liquid Equilibrium of mixtures** Vapor Liquid equilibrium (VLE) of ideal mixtures, Low pressure VLE in non-ideal mixtures, High pressure VLE using equation of states, Solubility of gas in liquid, Liquid-Liquid Equilibrium, Vapor Liquid-Liquid Equilibrium, Models for activity coefficient, UNIFAC method, UNIQUAC equation, Osmotic pressure, osmotic equilibrium	**(08 Hours)**
UNIT-III	**Mixture phase equilibrium involving solids** Solubility of solid in liquid and supercritical fluid, Solid Liquid Equilibrium, Partitioning of solid between two liquid phases, distribution coefficient, Freezing point depression of solvent due to presence of solute, freezing point of liquid mixtures in presence of solid.	**(08 Hours)**
UNIT-IV	**Chemical Reaction Equilibria:** Chemical equilibrium in single phase system, Heterogeneous chemical reactions, Chemical equilibrium when several reaction occurs in single phase, Combined chemical and phase equilibrium. Phase rule and Duhem's theorem for reacting systems, Degree of freedom analysis for non-reacting and reacting systems	**(08 Hours)**
UNIT-V	**Surfaces, Interfaces and Adsorption** Thermodynamics of interfaces, Gibbs surface model and surface tension, Surface energy of solids, Surface effects on heterogeneous phase equilibrium, effect of particle size on vapor pressure, effect of bubble size on the boiling temperature of pure substances, solubility and nucleation, effect of particle size on melting temperature, Gibbs adsorption equation	**(08 Hours)**
UNIT-VI	**Thermodynamics of acid, alkali interaction, Energy analysis** Acidity of solutions, ionization of chemicals, solubilties of weak acids, weak bases, pharmaceuticals as function of pH, Gibbs-Donnan equilibrium. Defining Energy, Control Volume Energy Rate Balance, Exergetic Efficiency, Introduction to Energy Costing .	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of thermodynamics of phase equilibria, keeping track of the recent technological trends and developments.

Text Books/References:

1.	J. M. Smith & H. C. Van Ness, “Introduction to Chemical Engineering Thermodynamics”
2.	Stanley I. Sandler, “Chemical, Biochemical and Engineering Thermodynamics”
3.	Savein Stolen, Tor Grande, Neil Allan, “Chemical Thermodynamics of Materials”
4.	K.V.Narayanan,” Chemical Engineering Thermodynamics”
5.	Kenneth Denbigh, “Principles of Chemical Equilibrium”
6.	Y. V. C. Rao, “Chemical Engineering thermodynamics”
7.	B. F. Dodge, “Chemical Engineering Thermodynamics”
8.	T. E. Daubert, ” Chemical Engineering Thermodynamics“
9.	Glasstone S., “Thermodynamics for Chemists”
10.	B. G. Kyle, “Chemical and Process Thermodynamics

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10504 MULTIPHASE REACTORS

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	**Introduction to Multiphase Reactor Engineering: Types**, Classification, Application of Industrial Importance.	**(08 Hours)**
UNIT-II	**Thermodynamics and kinetics:** Notable industrial heterogeneous systems and thermodynamic role. Application of equilibrium criteria to chemical reactions. The Gibbs energy change and equilibrium constant. Estimation of equilibrium constant for heterogeneous system by defining standard state of the phases involved. Determination of rate controlling step: intrinsic kinetics for heterogeneous systems.	**(08 Hours)**
UNIT-III	**Hydrodynamic Characteristics:** Hydrodynamic characteristics of different multiphase reactors: Mechanically Agitated Contactors (MAC), Bubble Columns, Slurry Reactors, Fluidized Beds, Loop Reactors and Modified Versions.	**(08 Hours)**
UNIT-IV	**Mixing Studies :** Effect of geometrical, system, and operating parameters on phase mixing in multiphase reactors. Quantification of phase mixing. Development of a mathematical model.	**(08 Hours)**
UNIT-V	**Heat Transfer and Mass Transfer Studies :** Effect of geometrical, system, and operating parameters on heat transfer coefficient in multiphase reactors. Quantification of heat transfer coefficient. Application of correlations available to different multiphase reactors. Experimental techniques used for estimation of mass transfer coefficient and selection of suitable technique for a multiphase reactor. Effect of geometrical, system, and operating parameters on mass transfer coefficient in multiphase reactors. Quantification of mass transfer coefficient. Application of correlations available to different multiphase reactors.	**(08 Hours)**
UNIT-VI	**Design Aspects of Multiphase Reactors:** Pressure drop, Fractional phase hold- up, mass and heat transfer coefficient, extent of mixing, etc.	**(08 Hours)**

Term Work:

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of multiphase reactors, keeping track of the recent technological trends and developments.

Text Books/References:

1.	L. K. Doraiswamy and M. M. Sharma, "Heterogeneous Reactions", 2nd Edition, Volume I and II.
2.	G. B. Tatterson, "Fluid Mixing and Gas Dispersion in Stirred Reactors", 10th Edition, Academic Press, London, 1994
3.	W. D. Deckwer, "Bubble Column Reactors", Cambridge University Press, New York, 2000.
4.	DiazoKunji and O. Levenspiel, "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
5.	J. F. Devidson and Harrison, " Fluidization", 10th Edition, Academic Press, London, 1994.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SEMESTER-II

K10505 MODELLING AND SIMULATION OFCHEMICAL PROCESSES		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered		
UNIT-I	**Basics of phenomenological modelling** Introduction to modeling, systematic approach to model building, fundamentals of mathematical modeling-principles of formulations, fundamental laws: continuity equations, energy equation, equation of motion, transport equations, equation of state, equilibrium, chemical kinetics, advantages and limitations of models and applications of process models of stand-alone unit operations and unit processes, classification of models-simple vs. rigorous, lumped parameter vs. distributed parameter, Steady state vs. dynamic, concept of degree of freedom for steady state and unsteady state systems.	**(08 Hours)**
UNIT-II	**Empirical modelling building and analysis** Development of steady state and dynamic lumped and distributed parameter models based on first principles, analysis of ill-conditioned systems, development of grey box models, empirical model building, statistical model calibration and validation, population balance models; Examples: simple hydraulic tank, variable hydraulic tank, mixing Vessel, mixing with reaction, steam jacked vessel	**(08 Hours)**
UNIT-III	Mathematical models of heat-transfer equipments: shell & tube heat exchangers, evaporators, partial condensers; Mathematical models of mass-transfer equipments: batch and continuous distillation columns, reactive distillation columns, packed absorption columns; Mathematical models of reactors: batch reactors, continuous-stirred tank reactors, plug-flow reactors, reactor with axial dispersion, etc.	**(08 Hours)**
UNIT-IV	**Basics of simulation** Fundamentals of simulations – Ab-initio methods, basis sets, Hartree-Fock theory, density functional theory, geometry optimization, vibrational analysis; elementary, classical statistical mechanics, elementary concepts of temperature, ensembles and fluctuations, partition function, ensemble averaging, ergodicity; molecular dynamics methodology − force field, integrating algorithms, periodic box and minimum image convention, long range forces, non bonded interactions, temperature control, pressure control, estimation of pure component properties, radial distribution function; molecular dynamics packages.	**(08 Hours)**
UNIT-V	**Parameter estimation and sensitivity analysis** Parameter estimation, parameter sensitivity analysis, statistical validity, discrimination between two models, solution strategies for lumped parameter models, stiff differential equations, solution methods for initial value and boundary value	**(08 Hours)**

	problems, solving the problems using *MATLAB or other chemical engineering software, s*olution strategies for distributed parameter models..	
UNIT-VI	**Modern approaches** Broad overview of tools, deterministic and stochastic approaches, statistical decision theory, Markov processes, queuing theory, renewal theory, reliability theory, Non-traditional techniques: Simulated annealing, ant colony method or ANN, particle swarm method, neural networks, genetic programming, genetic algorithm, fuzzy logic, Wavelet, principal component analysis, etc.	**(08 Hours)**

Term Work: Oral examination will consist of assessment of the termwork (duly certified by the teacher and HOD) and oral exam based on the term work/practical. The term work shall consist of the following:

Minimum 6 practical based on solving numerical methods mentioned in the syllabus using MATLAB/SCILAB, any language, or TK solver software, or any chemical Engineering Software.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of modeling and simulation of chemical processes, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Franks R. E. G., "Modeling and Simulation in Chemical Engineering", Wiley Interscience, NY
2.	John Ingam, Irving J. Dunn, "Chemical Engineering Dynamic Modeling with PC Simulation", VCH Publishers
3.	William L. Luyben, "Process Modeling Simulation and Control for Chemical Engineers", McGraw Hill International Edition Publishing Company
4.	Himmelblau D., K. B. Bischoff, " Process Analysis and Simulation", John Wiely & Sons
5.	Wayne Blackwell, "Chemical Process Design on a Programmable Calculator", McGraw Hill
6.	Wayne Bequette, " Process Dynamics, Modeling, Analysis and Simulation", Prentice Hall
7.	S. S. Tambe, B. D. Kulkarni, P. B. Deshpande, Elements of Artificial Neural Networks with Selected Applications in Chemical Engineering, and Chemical & Biological Sciences, 1st Ed., Louisville: Simulations & Advanced Controls Inc., KY 1996.
8	C.D.Holland, Fundamentals and Modeling of Separation Processes, Prentice-Hall Internal Publications
9	Asghar Hussain, Chemical Process Simulation, Wiley Eastern Ltd., New Delhi (1986).
10.	M.E.Davis, Modeling and Numerical Methods in Chemical Engineering, John Wiley & Sons, 1984.
11.	B.Carnahan, H.A. Luther and J.O.Wilkes, Applied Numerical Methods, McGraw-Hill, New York (1969).
12.	K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press, 2001.
13.	Singiresu S. Rao, "Applied Numerical Methods for Engineers and Scientists" Prentice Hall, Upper Saddle River, NJ, 2001
14.	W. F. Ramirez, "Computational Methods for Process Simulation", 2nd ed., Butterworths, 1997
15.	Modeling and analysis of dynamic systems, by C.M .Close, D.H. Fredrick and J. C. Newell, John Wiley & Sons, 2002
16.	Bruce A. Finlayson, Introduction to Chemical Engineering Computing, Wiley, 2010.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10506 CHEMICAL REACROR ANALYSIS AND DESIGN

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered

UNIT-I	Chemical factor affecting the choice of the reactor, Model for batch reactor optimum operation policies and control strategies, optimal batch operation time, optimal temperature policies.	**(08 Hours)**
UNIT-II	Transient and steady state analysis, Optimal design of reactors, Multiphase reactors: fluidized, trickle bed, slurry etc	**(08 Hours)**
UNIT-III	Steady state non isothermal reactor design, the energy balance, adiabatic operation, tubular rector with heat exchange, equilibrium conversion, CSTR with heat effects, multiple steady states.	**(08 Hours)**
UNIT-IV	Unsteady state non isothermal reactor design. Energy balance on batch reactor, Adiabatic operation of batch reactor, Batch reactor with interrupted isothermal operation, Semi batch reactors with a heat exchanger, Unsteady operation of CSTR, Unsteady operation of plug flow reactors	**(08 Hours)**
UNIT-V	Design of fixed bed catalytic reactors, isothermal ,adiabatic ,non isothermal	**(08 Hours)**
UNIT-VI	Non ideal flow in reactors, Estimation of dispersion/back mixing, design aspects of reactors with non ideal flow, micro and meso mixing in reactors.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of chemical reactor analysis and design, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Froment G. F. and K. B. Bischoff, " Chemical Reactor Analysis and Design", John Wiley & Sons
2.	Fogler H. S., "Elements of Chemical Reaction Engineering", Prentice - Hall, 1986
3.	Smith J. M., " Chemical Engineering Kinetics ", McGraw Hill, 1981
4.	Denbigh K. G. and J. C. Turner, " Chemical Reactor and Theory – An Introduction",3rd edition Cambridge University Press.
5.	Bruce Nauman, " Chemical Reactor Design", John Wiley & Sons.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10507 SYNTHESIS AND DESIGN OF CHEMICAL PROCESSES

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered

UNIT-I	**Introduction to SDCP** Significance of SDCP in chemical process industry, Hierarchy of chemical process design: Hierarchy, approach to process design, performance. Preliminary Process Synthesis, Synthesis of reaction: Function of process recycle, vapor cycles and purges, vapor verses liquid cycles, batch processes, process yield	**(08 Hours)**
UNIT-II	Choice of reactor: Reaction path, types of reaction systems, reactor Continuous or Batch Processing, Chemical state, Process Operations, Synthesis Steps, Synthesis Tree, Heuristics, Algorithmic Methods.	**(08 Hours)**
UNIT-III	Recycle structure, Recycle material balances, Reactor heat effects, Equilibrium limitations, Reactor design, Separation system, vapor recovery system, Liquid separation system, Distillation column sequencing, azeotropic systems, Residue Curves for Heterogeneous Systems.	**(08 Hours)**
UNIT-IV	**Heat exchanger networks** Pinch Methodology: Problem representation, temperature enthalpy diagram, simple match matrix. Heat content diagram, Temperature interval diagram. Pinch Design and Optimization: Networks for maximum energy recovery, Pinch design method, Flexibility criteria of the pinch, case studies	**(08 Hours)**
UNIT-V	**Industrial Safety and risk management** Hazards: Chemical hazards classification. site selection and plant layout. Industrial lighting and ventilation. Occupational diseases and prevention methods. Instrumentation and control for safe operation. Personal protective equipments. Management and Risk Analysis: Case studies pertaining to chemical industries. Legislations and economics: Factory Act. Environmental Act. Provisions under various acts.	**(08 Hours)**
UNIT-VI	Introduction to scale-up methods, pilot plants, models and principles of similarity. Industrial applications. Computer–Aided Design application in chemical process industries, complete plant simulation.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of synthesis and design of chemical processes, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Robin Smith, “Chemical Process Design”, McGraw Hill
2.	Hartmann K., K. Kaplick, “Analysis and Synthesis of Chemical Process System”, Elsevier, Amsterdam
3.	Jordan D.G., “Chemical Process Development – Part I”, Robert K. Krieger Publishing Company
4.	James M.Douglas, “Conceptual Design of Chemical Processes” McGraw Hill.

5.	Warren D.Seider,J.D.Seader,Daniel R. Lewin, "Process Design Principles Synthesis ,Analysis and Evaluation," John Wiley & Sons Inc.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10508 ADVANCED MASS TRANSFER

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures : 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical : 2 Hour /Week	Unit Test: 20 Marks	Practical: 01
Total : 6 Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	**Diffusion:** Steady State diffusion with heterogeneous chemical reaction, Steady state diffusion accompanied by homogeneous Chemical reaction. Unsteady state molecular diffusion in isotropic media, unsteady state diffusion for typical cases of mass transfer in infinite, semi-infinite and finite plane media and in spherical and cylindrical media.	**(08 Hours)**
UNIT-II	**Ionic Separations :** Controlling factors, applications, Theory mechanism and equipments for electrophoresis, dielectrophoresis and electro dialysis, commercial applications and design considerations.	**(08 Hours)**
UNIT-III	**Adsorption Techniques :** Mechanism, Thermal-Swing Adsorption, Pressure-Swing Adsorption, Continuous, Countercurrent Adsorption Systems, Slurry Adsorption , Fixed-Bed Adsorption (Percolation), Simulated-Moving-Bed Systems, affinity chromatography and immuno chromatography, types of equipment and commercial processes, recent advances and process economics.	**(08 Hours)**
UNIT-IV	**Multicomponent Distillation:** Tray by Tray calculation, feed plate location, operating reflux and plates, recent advances in column design and operation-Petlyuk, divided wall, kaibel, pre fractionators, post fractinator. Azeotropic distillation, Extractive distillation, Molecular distillation, Reactive distillation.	**(08 Hours)**
UNIT-V	**Membrane Separations :** Classification of membrane processes; Liquid permeation membrane processes or dialysis – Series resistance in membrane processes, Dialysis processes, Types of equipment for dialysis; Gas permeation membrane processes – Types of membranes and permeability for separation of gases, Types of equipment for gas permeation membrane processes (flat membranes, spiral-wound membranes, hollow-fibre membranes); Types of flow in gas permeation; Complete-mixing model, cross-flow model and countercurrent flow model for gas separation by membranes; Effect of processing variables on gas separation by membranes.	**(08 Hours)**
UNIT-VI	**Novel Separation Techniques :** Supercritical fluid extraction, Reactive extraction, Zone melting, separation based on thermal diffusion, separation based on surface science, adductive crystallization.	**(08 Hours)**

Term Work :

Oral examination will consist of assessment of the term work (duly certified by the teacher and HOD) and oral exam based on the term work/practical. The term work shall consist of the following.

Seminar presented and duly report prepared on any topic given from syllabus.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of advanced mass transfer, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Phillip C. Wankat , Separation Process Engineering (2nd Edition), Printice Hall,2007
2.	Marcel Mulder, Introduction to Membrane Science and Technology, Marcel Dekker, 1992.
3.	Rousseau, R. W., Handbook of Separation Process Technology, John Wiley, New York, 2009.
4.	Humphrey, J and G. Keller, Separation Process Technology, McGraw-Hill, 1997
5.	King, C. J., Separation Processes , Tata McGraw Hill Co., Ltd., 1982.
6.	T.K.Sherwood, R.L.Pigford and C.R.Wilke, Mass Transfer, McGraw-Hill, New York (1975).
7.	R.E.Treybal, Mass-Transfer Operations, McGraw-Hill, New York (1980).
8.	Anthony L Hines , Robert N Maddox , Mass Transfer Fundamentals and Applications.
9.	Sherwood, T. K., Pigford, R. L. & Wilke, C. R, Mass Transfer Mc Graw Hill, 1975
10.	Skelland, A. H. P. : Diffusional Mass Transfer, John Wiley & Sons, 1974.
11.	Crank J, The Mathematics of Diffusion, Oxford University Press London 1956

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Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SEM-III

K10601 ELECTIVE - I ADVANCED PROCESS CONTROL		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	**Response of Control Loop Components and Transfer Functions:** Open loop response, most useful forcing functions, step function, sinusoidal function and the pulse function, respective responses of the forcing functions. Response of a more complex system to forcing functions.	**(08 Hours)**
UNIT-II	**Types of Controls:** Feed forward control: Advantages and drawbacks, typical examples. Feedback control: Advantages and drawbacks, typical examples.	**(08 Hours)**
UNIT-III	**Adaptive and Inferential Control Systems:** Adaptive - Feed forward, feedback Inferential - Need for a model Examples for illustration.	**(08 Hours)**
UNIT-IV	**Response Analysis:** Stability and Testing Step response analysis Frequency response analysis Bode criterion, Nyquist Diagram, Root-Locus, Routh-Hertzwitz criterion. Pulse function Laplace transforms, transfer function of various system.	**(08 Hours)**
UNIT-V	**Dynamics of Various Systems:** Dead time, distance-velocity lag, inverse response systems, dynamic analysis, Qualitative characteristics, Distributed parameter systems.	**(08 Hours)**
UNIT-VI	**Control Strategies for various unit operations and processes:** Distillation, Drying, Absorption column, Stirred tanks. Processes: Process Design, Product quality control. Computer control: Direct Digital Control (DDC), Supervisory Digital Control, Economic justification for supervisory digital control.	**(08 Hours)**

Term Work: based on the term work/practical. The term work shall consist of the following.

- Ability of the student to explain the theory and related course material.
- The process control modules are now extensively used in industry. The student should demonstrate their working principles and the utility citing at least 4 chemical industries.
- The controllers used in chemical industry need careful monitoring.
- Students should briefly describe the type of maintenance for controllers.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of advanced process control, keeping track of the recent technological trends and developments.

Text Books/References:	
1.	George Stephanopoulos, “Chemical Process Control - An Introduction to Theory and Practice”
2.	Coulson and Richardson, “Chemical Engineering Vol 3”

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10601 ELECTIVE – I : NON CONVENTIONAL ENERGY SOURCES		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered		
UNIT-I	**Renewable Sources of Energy**: Solar energy: Thermodynamic and heat transfer aspects of solar collection; Energy storage; Solar distillation; Solar drying; Wind energy; Tidal, Wave and ocean thermal energy; Geothermal energy.	**(08 Hours)**
UNIT-II	**Fuel Cells:** Introduction, Principles; Types of fuel cells; phosphoric acid, molten salt, solid oxide and other types of fuel cells; Anodes and cathodes; Fuel cells as alternative energy source.	**(08 Hours)**
UNIT-III	**Biomass and biofuels:** Introduction, Biofuel classification; Biomass production for energy farming; Direct combustion for heat; Pyrolysis (destructive distillation); Thermochemical processes; Alcoholic fermentation; Anaerobic digestion for biogas; Vegetable oils and biodiesel; Economics of bio-mass energy systems.	**(08 Hours)**
UNIT-IV	**Hydro-power:** Introduction, Principles, Assessing the resource for small installations, An impulse turbine, Reaction turbines, Hydroelectric systems, The hydraulic ram pump, Social and environmental aspects	**(08 Hours)**
UNIT-V	**Tidal power:** Introduction, The cause of tides, Enhancement of tides, Tidal current/stream power, Tidal range power, World range power sites 447 **Ocean thermal energy conversion (OTEC):**	**(08 Hours)**

	Introduction, Principles, Heat exchangers, Pumping requirements, Practical considerations.	
UNIT-VI	**Utilization of Wastes:** Utilization of fly ash, blast furnace slag in cement and concrete, Wastes and residues	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of non conventional energy sources, keeping track of the recent technological trends and developments

Text Books/References:

1.	John Twidell & Tony Weir, Renewable Energy Resources, Second edition, Taylor & Francis, 2006
2.	Douglas C., Energy Technology Handbook, Tata McGraw Hill Publishers
3.	Rao C. S., Environmental Pollution Control Engineering, Wiley Eastern
4.	Majumdar B., A Textbook of Energy Technology, APH Publications
5.	J. T. Mcmullan, R. Morgan and R. B. Murray, Energy Resources and Supply, John Wiley & Sons, London, 1976
6.	K.C. Khandelwal, S.S.Mahdi, Biogas Technology, Tata MGH
7.	G.D. Rai, Solar Energy Utilization, Khanna Publishers, Delhi
8.	A.W. Culp, Principles of energy conservation, Tata MGH

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10601 ELECTIVE I:INDUSTRIAL WASTE WATER TREATMENT

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	Introduction, Source of Industrial waste water, Physical, Chemical & Biological characteristics Of Industrial Waste Water. Measurement of polluting strength of Ind.Waste water (physical, chemical & biological)	**(08 Hours)**
UNIT-II	Physical Unit operations: Sedimentation & Design of Settling Chambers. Filtration & Design of Filters. Coagulation, Flocculatores, Froth Flotation	**(08 Hours)**
UNIT-III	**Conventional Waste Water Treatment:** Primary Treatment (Physical).Design Principles of Grit chambers & screens. Principles of Aeration .Secondary treatments (Biological), Kinetics of Growth & Food utilization, Design Principles of A.S.P. Trickling Filters, oxidation ponds, stabilization ponds, Aerobic, anaerobic Lagoons	**(08 Hours)**
UNIT-IV	**Sludge Treatment & Disposal:** Anaerobic digestion, Aerobic Digestion, Sludge disposal, composting	**(08 Hours)**
UNIT-V	**Advanced Waste Water Treatment:-** Carbon adsorption, Ion exchange, membrane processes. Nitrogen removal, Phosphorous removal, Chemical oxidation, Recovery of materials from process effluents	**(08 Hours)**
UNIT-VI	**Solid Waste Management:** Characteristics, Solid waste collection & transport, Solid Waste Processing & recovery, Disposal of Solid waste. Hazardous waste management & Risk assessment. Types of hazardous waste, health Effects, Treatment methods & Final disposal	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of industrial waste water treatment, keeping track of the recent technological trends and developments

Text Books/References:	
1.	Metcalf & Eddy, "Waste Water Engineering" Treatment & Reuse, Tata Mc Graw-Hill. Fourth Edition 2003
2.	C.S.Rao., "Environmental Pollution Control Engineering",Wiley Eastern Ltd. New Age International, Second print 1994
3.	A. P. Sincero, G. A. Sincero, "Environmental Engg.", A design approach, Prentice Hall of India Pvt. Ltd. New Delhi 1996

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10601 ELECTIVE I: HETEROGENEOUS CATALYSIS

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	**Adsorption, Desorption:** Definition, rates of adsorption and desorption, surface areas for physical adsorption. Experimental aspects of adsorption and allied phenomena on catalyst surfaces	**(08 Hours)**
UNIT-II	**Significance of Pore Structure and Surface Area in Heterogeneous Catalysis:** Importance of pore structure and surface area, experimental methods to determine surface area, methods of ascertaining pore volume and diameter .Kelvin equation, pore size distribution by gas adsorption, pressure porosimeter, density measurement. Pore structure of adsorbents and catalysts: Hysterisis and shape of capillaries, surface area from hysteresis loops, modes for characterizing pore structures. Reaction rates in pores catalysts: Mass transfer, concentration profiles, reaction rates, pressure and temperature gradients, catalyst deactivation	**(08 Hours)**

UNIT-III	**Role of Lattice Imperfections in Heterogeneous Catalysis:** Classification of lattice imperfections, role of point dislocations and point defects, lattice imperfections and polymerization catalysts, role of geometric and electronic factors in catalytic activity.	**(08 Hours)**
UNIT-IV	**Dynamics of Selective and Poly-functional Catalysis:** Catalyst selectivity, selective formation of intermediate products, effect of pore size on electivity, mass transport of intermediate product in non-trivial poly-step reactions, selectivity of poly-functional catalysts Zeolites in catalysis: Structural aspects and synthesis of zeolites, modification of zeolites, diffusion in zeolites, applications.	**(08 Hours)**
UNIT-V	**Fischer-Tropsch synthesis: Synthesis and Decomposition of Ammonia** Catalyst cracking: catalyst composition and chemical properties, mechanism of cracking reactions. Catalysis of electrode reactions. Kinetics of catalytic reactions: Rate of chemical reaction, overall reaction rate, mass transfer through gas phase, mass transfer in pores.	**(08 Hours)**
UNIT-VI	Mass and heat transfer in solid catalyst beds. Design calculations: Isothermal conditions, adiabatic conditions, non-adiabatic conditions. Thermal selectivity of packed bed reactors. Fluidized bed reactors. Optimum design: Continuous variation of parameter along the reaction path, temperature profiles for reversible and consecutive reactions, optimum catalyst concentration in bi-functional catalyst systems	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of heterogeneous catalysis, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Thomas J. M., Thomas W. J., "Introduction to The Principles of Heterogeneous catalysis", Academic Press
2.	Srivastav R. D., "Heterogeneous catalytic Science", CRC Press
3.	Thomas S. J., Webb G., "Heterogeneous Catalysis", Oliver & Boyd Ltd.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10601 ELECTIVE I:CATALYST MATERIALS

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	**Bimetallic Catalysts:** Introduction, nature, method of preparation and characterization, catalytic properties of bimetallic systems. Supported bimetallic catalyst, chemical nature, factors affecting efficiency and uniformity of co clustering, structure, surface composition, catalytic properties.	**(08 Hours)**
UNIT-II	**Perovskite Related Oxides:** Solid state properties, Zeolite, crystal structure, non-stoichiometry, magnetic and electrical properties, ferro electric and acoustic properties,applications. Crystal chemistry and catalytic properties of oxides with scheelite structure, crystal chemistry, olefin oxidation, and mechanism. Catalytic properties of synthetic layered silicates and alumino silicate,synthetic mica-montmorillonite and nickel reducibility, layered metalsilicate catalyst.	**(08 Hours)**
UNIT-III	**Biological Catalyst:** Enzymes, incentives for using enzymes, methodology,chemical and physical properties, activity, pH-activity behavior, stability, application.	**(08 Hours)**
UNIT-IV	**Catalyst Design:** Optimization of catalyst distribution in a single pellet, the case of single and multiple reaction, isothermal and non-isothermal conditions, complex reaction system, factors affecting catalytic dispersion, optimal distribution of catalytic loading.	**(08 Hours)**
UNIT-V	**Optimization of Catalyst Distribution in a Reactor:** Single reaction and multiple reaction, isothermal and non-isothermal conditions. Catalytic deactivation, non-selective and selective poisoning..	**(08 Hours)**
UNIT-VI	**Membrane Reactor:** Membrane reactor with non-uniform catalytic distribution, optimalcatalyst distribution in pellets for an inert membrane reactor and catalyticmembrane reactor, preparation of catalytic membrane.	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in

the area of catalyst materials, keeping track of the recent technological trends and developments.	
Text Books/References:	
1.	Burton J. J. and Garton R. L., "Advanced materials in catalysis", Academic press, London, 1977.Ÿ
2.	Morbidelli M., Gavriilidis A. and Varma A., "Catalyst design: Optimal distribution of catalyst in pellets, reactorts and membrane", Cambridge university press, Cambridge,2001.
Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

ELECTIVE II: MEMBRANE SEPERATION		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered		
UNIT-I	**Introduction** Separation Processes, Introduction to membrane processes, Definition of Membrane Merits of the Processes. Classification of the membrane separation process.	**(08 Hours)**
UNIT-II	**Materials & Materials Properties** Membrane Polymers, Molecular weight, Porous & Porous membrane, Thermal, Chemical & Mechanical Properties of Inorganic membranes, Biological membranes. Retention & rejection co-efficient. Factor affecting the	**(08 Hours)**

	separation processes. Effect of polymeric structure on Tg Glass transition temperature depression.	
UNIT-III	**Preparation of Synthetic Membranes** Phase inversion membranes, Preparation by evaporation, Precipitation from the vapour phase. Precipitation by controlled evaporation, Thermal & immersion precipitation. Flat membranes, Tubular membranes, Zeolite membranes, Dense membrane. Preparation Technique for Composite Membrane, Inorganic Membranes	**(08 Hours)**
UNIT-IV	Characteristics of porous membrane, Bubble Point Method, Mercury intrusion method, Permeability Method, Ultrafiltration, Gas-adsorption desorption, Characterisation of ionic membranes, characterisation of nonporous membrane.	**(08 Hours)**
UNIT-V	Transport in membrane, Knudsen flow, Friction Model, Transport through non-porous membrane. Determination of diffusion co-efficient & solubility co-efficient. Transport in ion exchange membranes.	**(08 Hours)**
UNIT-VI	Membrane Processes, M.F, U.F, R.O, Nano filtration Dialysis, Electrodialysis, Piezodialysis, Diffusion Dialysis, Membrane reactors & membrane bioreactors, Polarization & Fouling Phenomena in Membranes, C.P in electro dialysis, Temperature Polarization, Membrane Fouling, Method to reduce Fouling.	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of membrane separation, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Osada Yoshohito, Nakagawa T., “Membrane Science and Technology”, Marcel Dekker Inc.
2.	Mulder, ”Basic Principles Membrane Technology”, Kluwer Academic Marcel of Publishers, Netherlands, 1998
3.	C.J.King, ”Separation Processes”, Tata Mc Graw-Hill

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10602 ELECTIVE II: BIOPROCESS ENGINEERING

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	Introduction, Biotechnology & Bioprocess Engineering types & structure of cells ,Growth kinetics, Growth cycle phase, effect of substrate concentration, cell concentration and death rate on growth of M.O.	**(08 Hours)**
UNIT-II	Simple Enzyme Kinetics, Michaelis-Menten Kinetics, evaluation of M.M equation parameters,line weaver, Burk plot, Eadie-Hofstee plot, factors influencing enzyme activity, immobilized enzyme technology ,immobilized kinetics	**(08 Hours)**
UNIT-III	Selection, Scale-up & Control of Bioreactors Ideal, on-ideal Bioreactors, Fed Batch reactor, sterilization reactor, Aeration & Agitation & mass transport in cellular system. Scale up difficulties, Bioreactor instrumentation & control.	**(08 Hours)**
UNIT-IV	Recovery & Purification of Product Separation of insoluble products. Cell disruption, separation of soluble products, finishing steps for purification, integration of reaction & separation	**(08 Hours)**
UNIT-V	Industrial Production of Chemicals Ethanol, Acetic acid, Citric acid, Gluconic acid. Solvents such as Glycerol, acetone, butanol. Anti-biotics such as penicilline, streptomycine, tetracycline. Production of High Fructose Corn Syrup (HFCS), production of Bakers Yeast Single Cell Protein	**(08 Hours)**
UNIT-VI	Medical & other applications of Bioprocess Engg. introduction, Tissue Engineering, Gene Therapy, Stem cell, Use of microbes in mineral beneficiation & oil recovery, Biofertilizers & Biopesticides, Biopolymer Biological treatment of Industrial Waste	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in

the area of bioprocess engineering, keeping track of the recent technological trends and developments.	
Text Books/References:	
1.	Michael L. Shuler, F. Kargi, "Bioprocess Engineering Basic Concept", Prentice Hall, India, 2nd Edition, 2002
2.	Bailey, James Ollis, Davis F,"Biochemical Engg." Mc Graw-Hill, Publications
3.	Aiba A, Humphry A. E, "Biochemical Engg
4.	Wingard L. B., "Enzyme Engg."
5.	Paulinemdoran, "Bioprocess Engg. Principles", Elsevier Publications
Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10602 ELECTIVE II:MULTICOMPONENT SEPERATION		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered		
UNIT-I	Characteristics and selection of separation process: Importance and variety of separation, economic significance, characteristics, inherent separation factor, selection, factors influencing the choice of separation process, solvent selection, selection of equipment.	**(08 Hours)**
UNIT-II	Multicomponent separation: General short-cut equation, Edmister method,distillation, absorption, extraction, alternate short-cut method, Fenske and Underwood equation.	**(08 Hours)**
UNIT-III	Multicomponent separation: Distillation, Rigorous method, Lewis-Matheson method, Thiele-Geddes method, Amundson-Pontinen method.	**(08 Hours)**
UNIT-IV	Azeotropic and extractive distillation: Activity coefficient, equilibrium relationship, binary and ternary azeotropes, selection of solvent, calculations..	**(08 Hours)**
UNIT-V	Multicomponent separation: Extraction, Rigorous method, stripping factor equation, material balance, single and cross-current multiple contact, calculations.	**(08 Hours)**
UNIT-VI	Multicomponent separation: Absorption, Rigorous method for absorption,calculations.	**(08 Hours)**

Term Work: The term work shall consist of the following.
Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the

product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of multicomponent separation, keeping track of the recent technological trends and developments

Text Books/References:

1.	Smith B. D., "Design of Equilibrium Stage Processes", McGraw Hill Book Company Ltd.
2.	King C. J., "Separation Processes", McGraw Hill Book Company Ltd.
3.	Treybal R. E., "Mass Transfer Operation", McGraw Hill
4.	Treybal R. E., "Liquid Extraction", McGraw Hill Book Company Ltd.
5.	Phillip C. Wankat, "Equilibrium Staged Separations", Prentice Hall

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10602 ELECTIVE II: FOOD PROCESS ENGINEERING

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	Introduction: Characteristics and nutritional properties of food texture, taste, flavour and aroma. Geometric, physical and functional properties of food material. Preparation for food processing, energy conservation, material and energy balance	**(08 Hours)**
UNIT-II	Processing Methods: Heating : Balancing and pasteurization, freezing, dehydration, canning, additives. Fermentation: Extrusion cooking, hydrostatic pressure cooking. Dielectric heating microwave processing and aspetic processing, infrared radiation processing, concept and equipment used	**(08 Hours)**

UNIT-III	Drying: Moisture content: Definition, method of determination, direct and indirect methods. Equilibrium moisture content: Hysterisis Effect. Psychometric of air water vapour mixture, Drying mechanism, constant rate period and falling rate period , Method and equipments used, factor affecting rate of drying	
UNIT-IV	Food conservation Operation: Sieve reduction, fibrous foods, dry foods and liquid foods. Theory and equipment, membrane	**(08 Hours)**
UNIT-V	Material handling: types of candling and conveying system food products, and their design, belt conveyors, screw conveyors, bucket elevator and pneumatic conveyor.	**(08 Hours)**
UNIT-VI	Preservation of food material: Preservation by drying, preservation by low temperature, chemical preservation .Thermal death time curve	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of food process engineering, keeping track of the recent technological trends and developments

Text Books/References:

1.	Shivshankar B., "Food Processing and Preservation", Prentice Hall of India Pvt. Ltd., New Delhi 110001, 2002
2.	Sahay and Singh, "Unit Operation in Agricultural Processing
3.	Dennis R. H., " Food Process Engineering"
4.	Rao M. A. & Rizvi S. S. H, " Engineering Properties of Food

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K10602 ELECTIVE II: FLUIDIZATION ENGINEERING

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Practical:2 Hours/Week	Unit Test: 20 Marks	TW/PR/OR: 01
Total : 6Hours/Week	Assignment: 10 Marks	Total credits: 05
	Attendance:10 Marks	
	TW :25 Marks	
	Oral:25 Marks	
	Total :150 Marks	

Topics covered

UNIT-I	Introduction and Application :Phenomenon of Fluidisation, Liquid like behavior of a fluidized bed, comparison with other methods , Advantages and Disadvantages, Types of Fluidisation. Gas behavior Of Fluidised bed :Fixed beds, minimum fuidisation velocity, Terminal velocity, and pressure drop, importance of distributor, voidage, TDH, viscosity and fluidity of fluidized beds.	**(08 Hours)**
UNIT-II	Bubbles and Emulsion phase in Dense bubbling beds: Single rising bubble, Stream of bubbles from single source, Ordinary Bubbling bed.Exprimental findings. Bubbling bed model for Emulsion phase	**(08 Hours)**
UNIT-III	Flow pattern of gas through fluidized bed: Experimental findings ,Bubbling bed model for gas interchange. Evaluation of inter change coefficient. Radial and Axial diapersion of gas. Mass and heat transfer b/w fluid and solid.	**(08 Hours)**
UNIT-IV	Conversion of gas in bubbling beds: Two region model, Model using distribution. Catalytic conversion, reaction rate, contacting efficiency, application to successive reactions, control of bubble size, baffling and scale-up.	**(08 Hours)**
UNIT-V	Entrainment and Elutriation : Entrainment at or above TDH, Entrainment below TDH. Model for entrainment from dense fluidized bed and its applications	**(08 Hours)**
UNIT-VI	Application in physical operations: Synthesis reactions, cracking and reforming of ydrocarbons, carbonization and gasification. Gas solid reactions	**(08 Hours)**

Term Work: The term work shall consist of the following.

Research survey, literature review and analysis, synthesis, design and development, experimental work, testing on the product or system, generation of new ideas and concept, modification in the existing process/system, development of computer programs, solutions, modeling and simulation related to the subject. The student is required to choose the topic in consultation with the subject teacher. The student is expected to submit a report on the work carried out throughout the semester.

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of fluidization engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Smith B. D., “Design of Equilibrium Stage Processes”, McGraw Hill Book Company Ltd.
2.	King C. J., “Separation Processes”, McGraw Hill Book Company Ltd.
3.	Treybal R. E., “Mass Transfer Operation”, McGraw Hill
4.	Treybal R. E., “Liquid Extraction”, McGraw Hill Book Company Ltd.

5.	Phillip C. Wankat, “Equilibrium Staged Separations”, Prentice Hall

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

K 10604 DISSERTATION STAGE –I		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Practical:7 Hours/Week	TW :25 Marks	TW: 21
Total : 7Hours/Week	Total :25 Marks	Total credits: 21
This stage will include comprehensive report on literature survey, design and fabrication of experimental set up and/or development of model, relevant computer programs and the plan for stage II.		

K 10603 SEMINAR		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Practical:5 Hours/Week	TW :25 Marks	TW: 5
Total : 5Hours/Week	Oral:25Marks	Total credits: 5
	Total :50 Marks	
The students will be required to select advanced research topics for the seminar and present the seminar during the semester. A detailed report should also be submitted and assessment will be based on the quality in terms of the research and development.		

SELF STUDY PAPER-I

SELF STUDY PAPER -I : OPTIMIZATION TECHNIQUES IN PROCESS DESIGN		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total: 4 Hours/Week	Internal assessment: 40 Marks	Total credits:04
	Unit Test: 20 Marks	
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered		
UNIT-I	**Introduction to optimization** Scope and Hierarchy of optimization, Essential features of optimization Problems, General Procedure for solving optimization problems, obstacles to optimization, Developing Models for optimization, Classification of Models, How to build Model, Selecting functions to fit empirical data, degree of Freedom, Formulation of objective function .	**(08 Hours)**
UNIT-II	**Classification of Optimization Techniques**, Single variable, Multivariable optimization with no constraints ,equality constraints ,inequality constraints	**(08 Hours)**
UNIT-III	**Linear Programming** Simplex method, Geometry of LPP, solution to linear simultaneous equations, Pivotal reduction of a general system of equations, sensitivity Analysis	**(08 Hours)**
UNIT-IV	**Non Linear Programming** One dimensional minimization method, unimodal function, Dichotomous search, Fibonacci Method, Golden section Method, Interpolation Method, Scanning and bracketing Method	**(08 Hours)**
UNIT-V	**Non linear Programming unconstrained optimization & constrained Optimization** Direct Search Method, Random Search method, Descent Method, Conjugate Gradient Method , Introduction to NLP constrained optimization Direct and Indirect Methods .	**(08 Hours)**
UNIT-VI	**Examples and case study for different engineering applications.**.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of optimization techniques in process design, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Edgar T F , Himmelblau D N , "Optimization of Chemical Processes", MC Graw Hill Publication .
2.	S S Rao, Optimization theory and Application, Wiley Eastern Publication

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -I: NON CONVENTIONAL ENERGY SYSTEMS		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered		
UNIT-I	**Renewable Sources Of Energy** Renewable sources of energy such as hydro, solar, wind, biomass, tidal and geothermal – their availability and limitation. Energy crisis and energy demand projection.	**(08 Hours)**
UNIT-II	**Solar Energy** Solar radiation, photovoltaic cell, pyranometer, solar thermal collectors, solar air heaters, solar constant, solar cell, applications of solar energy.	**(08 Hours)**
UNIT-III	**Wind Energy** Wind map of India, mean wind speed and wind density during different months in specific areas. Types of wind mills, their assembly and application as electric converters, pumping motors. Concept of wind farms, its applications.	**(08 Hours)**
UNIT-IV	**Bio-Mass Energy** Bio-mass as a source of energy, energy plantation, pyrolysis classification and anaerobic fermentation, types of biogas plant, their comparative status, design and application.	**(08 Hours)**
UNIT-V	**Other Alternate Sources Of Energy** Tidal power, sites for tidal power plants in India, micro-hydel power station, geothermal energy, limitations and applications of such power plants.	**(08 Hours)**
UNIT-VI	**Energy Conversation And Auditing** Conservation of energy in – domestic application and industries, use of fuel efficiently in vehicles, waste recycling fuel gas and heat recovery, energy demand management, energy accounting and auditing.	**(08 Hours)**

Text Books/References:

1.	John Twidell & Tony Weir, Renewable Energy Resources, Second edition, Taylor & Francis, 2006
2.	Douglas C., Energy Technology Handbook, Tata McGraw Hill Publishers
3.	Rao C. S., Environmental Pollution Control Engineering, Wiley Eastern

4.	Majumdar B., A Textbook of Energy Technology, APH Publications
5.	J. T. Mcmullan, R. Morgan and R. B. Murray, Energy Resources and Supply, John Wiley & Sons, London, 1976
6.	G.D. Rai, Solar Energy Utilization, Khanna Publishers, Delhi
7.	A.W. Culp, Principles of energy conservation, Tata MGH

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of non conventional energy systems, keeping track of the recent technological trends and developments.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -I: MECHANICAL ASPECTS IN CHEMICAL ENGINEERING

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test : 20 Marks	Total credits: 04
	Assignment : 10 Marks	
	Attendance :10 Marks	
	Total :100 Marks	

Topics covered

UNIT-I	Mechanical aspects of piping design and layout, Pipe and its representation, pipe fittings, methods of pipe joining, piping insulation, Piping insulation, piping symbols, design of piping systems, piping isometrics, plot plan and Pipe racks.	**(08 Hours)**
UNIT-II	Chemical equipment design - mechanical aspects, Design of Support for process vessels, basic theory for vertical vessels, design of skirt support, Bracket or lug support, leg support, ring support, horizontal support, saddle support, leg support, Ring support, engineering materials, classification and commercial applications.	**(08 Hours)**
UNIT-III	Principles of mechanical engineering in chemical engineering, Power conversion devices such as steam turbines, IC engines, different types of pumps, Air conditioning and refrigeration, ON-OFF valves, Non return and other type of valves.	**(08 Hours)**
UNIT-IV	Energy conservation and heat pumps, Energy conservation in India and World, mechanical vapor compression , heat pumps, various thermodynamic cycles, actual vapor compression heat pumps with liquid sub cooling, various types of heat pumps.	**(08 Hours)**

UNIT-V	Mechanical aspects in chemical process engineering, Alternative routes in process engineering , general approach to plant design, process research and pilot studies, process design and development , preparation of operating manual instructions, cost cutting machines, trouble shooting , green engineering and process intensification.	**(08 Hours)**
UNIT-VI	Mechanical engineering aspects in chemical engineering and technology, Study of general purpose tools and special purposes tools and machines, lathes, milling, drilling and accessories. EDM , TWEDM, hobbling, electroplating, ,ECM, arc welding, gas welding, brazing, soldering, riveting, TIC, MIG welding processes, equipment used and applications, drop forging, press forging , role forging, and industrial applications.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of mechanical aspects in chemical engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Coulson and Richardson , Chemical Engineering , Volume 2, Paragon press Oxford , New York.
2.	Treybal R.E., Mass transfer Operation Operations, third edition, Mc Hill International Publishers.
3.	Smith R, Chemical Process Design , McGraw Hill International Publishers
4.	Dodge B. F., Chemical Engineering Thermodynamics, McGraw Hill International Publishers.
5.	Thakori S B and Bhatt B I, Introduction to Process engineering and Design, Mcgraw Hill Companies
6.	Brownwell L,E, and Young E H, Process equipment design, John Willey and Sons, Inc. New York.
7.	Shingles ,J and MischkaC, Mechanical Engineering Design, McGraw Hill Edition
8.	Vijayrangan S, and Rajendran I, Materials and Mechanical Engineering Narosa Publishing Company New Delhi, Chenai, Mumbai and Kolkata
9.	Arora C P, Refrigeration and Air-conditioning, TataMcgraw Publishing Companies Ltd. New-Delhi.
10.	Agarawal B, Agarawal C, M, Basic Mechanical Engineering, Wiley India Publishers and Editions.
11.	Myer Kutz ,Mechanical Engineers Hand Book John Willey and Sons (New York)
12.	Perry R, and Green D, Perrys Chemical Engineers Hand Book Sixth Edition, International Students Edition

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -I: GREEN CHEMISTRY AND TECHNOLOGY

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test : 20 Marks	Total credits: 04
	Assignment : 10 Marks	
	Attendance :10 Marks	
	Total:100 Marks	

Topics covered

UNIT-I	Introduction: Definition, the twelve basic principles of green chemistry. Use of Renewable Feedstock, Reduction of Derivatives, Catalysis, Design for Degradation, Real-time Analysis for Pollution Prevention, Inherently Safer Chemistry for Accident Prevention.	**(08 Hours)**
UNIT-II	Green synthetic methods: Microwave synthesis, electro-organic synthesis, Design and development of environmentally friendly chemical pathways: challenges and opportunities. Materials for green chemistry and technology: Catalysis, environmental friendly catalysts, Bio-catalysis, biodegradable polymers, alternative solvents.	**(08 Hours)**
UNIT-III	Biochemical conversion: anaerobic digestion, alcohol production from biomass; Chemical conversion process: hydrolysis and hydrogenation; Biophotolysis: Hydrogen generation from algae biological pathways; Storage and transportation; Applications.	**(08 Hours)**
UNIT-IV	Green innovation & sustainability: Criteria for choosing appropriate green energy technologies, life cycle cost; the emerging trends – process/product innovation-, Eco/green technologies for addressing the problems of Water, Energy, Health, Agriculture and Biodiversity- WEHAB (eco-restoration/ phyto-remediation, ecological sanitation, renewable energy technologies.	**(08 Hours)**
UNIT-V	Global warming; greenhouse gas emissions, impacts, mitigation and adaptation; future energy Systems- clean/green energy technologies; International agreements/conventions on energy and sustainability - United Nations Framework Convention on Climate Change (UNFCC); sustainable development.	**(08 Hours)**
UNIT-VI	Environmental reporting and ISO 14001; climate change business and ISO 14064; green financing; financial initiative by United Nations Environment Programme (UNEP); green energy management; green product management , green tax incentives and rebates (to green projects and companies); green project management in action; business redesign; eco-commerce models.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of green chemistry and technology, keeping track of the recent technological trends and developments.

Text Books/References:

1. Philip G. Jessop, Chao-Jun Li ,Peter Wasserscheid , Annegret Stark, Handbook of Green Chemistry,

	3 Volume Set, Green Solvents, Viley-VCH.
2.	Paul T. Anastas, Istvan T. Horvath, Green Chemistry for a Sustainable Future.
3.	V. K. Ahluwalia, M. Kidwai**,** New Trends in Green Chemistry, Kulwer Academic Publisher.
4.	Paul T, John C., Green Chemistry: Theory and Practice, Oxford University Press, USA.
5.	Baird, C. and Cann, M., Environmental Chemistry, 4th Edition, W.H. Freeman and Company, New York, 2008.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER I- CAVITATION TECHNIQUES

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4 Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered

UNIT-I	**Introduction** The physical phenomenon , Definition, Vapor pressure, The main forms of vapor cavities, Cavitation regimes, Typical situations favorable to cavitation , The main effects of cavitation in hydraulics , Specific features of cavitating flow, Pressure and pressure gradient, Liquid-vapor interfaces, Thermal effects, some typical orders of magnitude, Non-dimensional parameters: Cavitation number, Cavitation number at inception, Relative under pressure of a cavity.	**(08 Hours)**
UNIT-II	**Acoustic Cavitation** Cavitation Bubble Temperature, Classification of Acoustic Cavitation, Sonoluminescence, Sonochemistry, Experimental Factors that Control Sonochemistry, Sites where Sonochemical Reactions Occur, The Classification of Sonochemical Reactions.	**(08 Hours)**
UNIT-III	**Synthesis of Inorganic Materials** Ultrafine powders and nanostructured materials, metal oxides, metal powders, supported nano powders etc.	**(08 Hours)**

UNIT-IV	**Synthesis of organic Materials** Homogeneous reactions, heterogeneous sono chemistry, Synthesis using alkylation reactions, addition reactions, reduction and oxidation reactions etc.	**(08 Hours)**
UNIT-V	**Environmental protection and remediation** Degradation of organic pollutants, Water purification, application of cavitation alone, combined application of cavitation and ozone, combined application of cavitation and ultraviolet light, combined application of cavitation and advanced oxidation processes(AOPs)	**(08 Hours)**
UNIT-VI	**Other applications of cavitation** Polymers: Degradation of polymers, factors affecting polymer degradation, polymer synthesis, ultrasonic processing of polymers. Sonoelectrochemistry: Electroplating in presence of ultrasound, zinc, iron, copper , nickel etc. Sonoelectro - organic synthesis.	**(08 Hours)**
Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of Cavitation techniques, keeping track of the recent technological trends and developments.		

Text Books/References:

1.	Jean-Pierre Franc, Jean-Marie Michel, "Fundamentals of Cavitation", Kluwer Academic Publishers, Dordrecht.
2.	"Sonochemistry- Kirk-Othmer Encyclopedia of Chemical Technology", John Wiley & Sons, Inc.
3.	T. J. Mason and J. P. Lorimer, "Applied sonochemistry: Uses of power ultrasound in chemistry and processing", Wiley-VCH publishers.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER-I: SAFETY ENGINEERING IN INDUSTRIES

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total: 100 Marks	

Topics covered

UNIT-I	Types of chemical Process Industries, various hazards in industries, handling of Hazardous chemicals, case study (one or two), chemical composition of hazards, case Study (one or two), first aid measures, fire fighting measures, accidental release Measures, personal protection and storage.	**(08 Hours)**
UNIT-II	Process Selection, plant operation, plant selection, construction, process system Engineering.	**(08 Hours)**
UNIT-III	Industrial pollution, pollution control aspects, pollution control acts, various Toxic materials, handling of toxic materials, and industrial gases.	**(08 Hours)**
UNIT-IV	Safety program, engineering ethics, accident and loss statistics, acceptable Risk, nature of accidental process, one or two case studies	**(08 Hours)**
UNIT-V	Government regulations, identification, MSD sheets, evaluation and control.	**(08 Hours)**
UNIT-VI	Relief concept, definitions, location of relief, relief types, relief scenario, Data for sizing relief, relief systems, design considerations and recommendations	**(08 Hours)**

Text Books/References:

1.	Environmental Engineering,Howard S Peavy, Donald R Rowe and George Tchobanogloglons, Mc Graw Hill Book company.
2.	Shreve s Chemical Process IndustriesG,eorge T Austin, Mc Graw Hill International Edition
3.	Pollution Control in Chemical Process Industries, Mahajan S B, Tata Mc Graw Hill edition (P) Ltd.
4.	Introduction to process Engineering and Design ,Thakore S.B and Bhatt B. I. Mc Graw Hill Publishing Company Ltd. New Delhi

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of safety engineering in industries, keeping track of the recent technological trends and developments.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -I: PETROLEUM ENGINEERING

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total: 100 Marks	

Topics covered

UNIT-I	Distribution of Reserves Worldwide distribution of oil and gas reserves, Subsurface data sampling and data interpretation, Measurement scaling	**(08 Hours)**
UNIT-II	Origin of Hydrocarbons , accumulation and migration of hydrocarbons, Reservoir traps.	**(08 Hours)**
UNIT-III	Properties of reservoir rocks and fluids, Rock – fluid interface, Reservoir description by direct and indirect methods, Oil and Gas in place. Chemical, physical and thermodynamic properties of petroleum and reservoir fluids	**(08 Hours)**
UNIT-IV	Drilling of oil and gas wells, Classification of wells, Drilling operating systems, Drilling fluids.New trends in drilling engineering.	**(08 Hours)**
UNIT-V	Hazard and safety measures in handling of natural gas, transportation and storage of oil and gas ,Storage of oil and gas , Types of storage tanks, underground storage of natural gas Catalytic cracking, Catalytic reforming, Hydrodesulfurization, Hydrocraking	**(08 Hours)**
UNIT-VI	Recent developments in Hydrocarbon production techniques, Hydrocarbon recovery mechanisms, Non-conventional hydrocarbon energy sources, International trading in oil and gas.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of petroleum engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Bradley, “Petroleum Engineering Handbook”, SPE
2.	Mian, M. A., “Petroleum Engineering Handbook for Practicing Engineer”, Vol. I and II, Pennwell Publication.
3.	Deshpande, B.G., “World of Petroleum”, Wiley.
4.	John, F., Cook, M., and Graham, M., “Hydrocarbon Exploration and Production”, Elsevier.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER- I: FLUID PARTICLE TECHNOLOGY

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total: 100 Marks	

Topics covered

UNIT-I	**Applications of fluidized beds** Introduction. Industrial application of fluidized beds. Physical operations and reactions.	**(08 Hours)**
UNIT-II	**Fluidization and analysis of phases** Fluidization and analysis of phases for gas-solid, liquid-solid, and gas-liquid-solid fluidized beds. Hydrodynamic characteristics: pressure drop, velocity mapping, and fractional hold- up.	**(08 Hours)**
UNIT-III	**Mixing studies in fluidized beds** Effect of geometrical, system, and operating parameters on phase mixing in fluidized beds. Quantification of phase mixing. Development of a mathematical model.	**(08 Hours)**
UNIT-IV	**Heat and mass transfer in fluidized beds** Mass and heat transfer between fluid and particles. Effect of geometrical, system, and operating parameters on heat and mass transfer coefficients. Application of correlations available for estimating heat and mass transfer coefficients	**(08 Hours)**
UNIT-V	**Circulating Fluidized Beds** Fluid and particle distribution in a fluidized bed. Introduction to circulating fluidized bed and its application. Hydrodynamic aspects of circulating fluidized beds. Standardization of circulating fluidized beds.	**(08 Hours)**
UNIT-VI	Design of fluidization system for physical operations, catalytic and non-catalytic reactions, three phase fluidization and its standardization with regards to pressure drop, fractional phase hold- up, mass and heat transfer coefficient, extent of mixing, etc.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of fluid particle technology, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Diazo Kunji and O. Levenspiel, "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
2.	J. F. Devidson and Harrison, " Fluidization", 10th Edition, Academic Press, London, 1994.

3.	Jackson, R., "The Dynamics of Fluidized Particles", Cambridge University Press, New York, 2000.
4.	Fan, L. S. And C. Zhu, "Principles of Gas- Solid Flows", Cambridge University Press, New York, 1998.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SEM –IV

K 10605 DISSERTATION STAGE –II		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Practical:10 Hours/Week	TW :150 Marks	TW & Oral:30
	Oral:75 Marks	
Total : 10Hours/Week	Total :225 Marks	Total credits: 30

This is the final stage in the dissertation work. This stage will include comprehensive report on the work carried out at this stage and relevant portions from stage I, including experimental studies, analysis and/or verification of theoretical model, conclusions. The student is required to publish at least one national/international paper based on the dissertation work. The publication/ accepted paper for publication shall be included in the report

SELF STUDY PAPER-II

SELF STUDY PAPER-II-TECHNOLOGY TRANSFER PRACTICES –BRIDGE TO INDUSTRY		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total:100 Marks	

Topics covered		
UNIT-I	Innovation and the dynamics of technological change. The interactive and non-linear nature of Innovation, Defining the Innovation Need**,** Dynamics of Technological Change and Systems of Innovation	**(08 Hours)**
UNIT-II	Theory and practice of processes of technology transfer and diffusion: Commercialization of technology; intellectual property rights. Product innovation: impact of product innovation, Product Innovation within OEM (case studies)	**(08 Hours)**
UNIT-III	success factors for product innovation; developing a product innovation strategy: Interactive learning and networks of innovation: technology Platforms; firms taxonomy	**(08 Hours)**
UNIT-IV	Systems of Innovation and the corporate value chain: fostering clustering effects. Regional innovation strategies	**(08 Hours)**
UNIT-V	SWOT Analyses of company and product, Product Portfolio Analyses: Product Life Cycle (PLC) Product Innovation and Design consultancies (case studies), New Product-Service-System development	**(08 Hours)**
UNIT-VI	External trends (PESTED) and company core competences, Strategic Gap, Selection of ideas, Market implementation	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of technology transfer practices-bridge to industry, keeping track of the recent technological trends and developments.

Text Books/References:

1.	Mytelk, L. K. a nd Smith, K. (2003), “Interactions Between Policy Learning and Innovation Theory”, in “Innovation, Competence Building,And Social Cohesion In Europe: Towards a Learning Society”, Editors: Pedro Conceição,Manuel V. Heitor and Bengt-Åke Lundvall, Edward Elgar
2.	Lundval, B.-A., and Christensen, J.L. (2003), “Broadening the Analysis of Innovation Systems – Competition, Organisational Change and Employment Dynamics in the Danish System”, in “Innovation, Competence Building, and Social Cohesion In Europe: Towards a Learning Society”, Editors: Pedro Conceição, Manuel V. Heitor and Bengt-Åke Lundvall, Edward Elgar
3.	Edquist, C. (1997). “Systems of innovation a introduction” (Chapter 1), in: “Systems of Innovation”, ed. C. Edquist, pp. 1-35

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER-II: -POLYMER ENGINEERING		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hrs/week	End Semester Examination: 60 Marks	Theory : 04
Total: 4 Hrs/week	Internal assessment: 40 Marks	Total Credits:04
	Total :100 Marks	

Topics covered		
UNIT-I	**Introduction to polymer technology** Types of polymerization, effect of temperature and pressure on polymerization, degree of polymerization, molecular weight determination.	**(08 Hours)**
UNIT-II	**Polymerization process** Manufacturing process of pthalic anhydride, propylene, acrylonitrile, adipic acid, tetrapthalic acid, LDPE, HDPE, PVC, PP, PC, polystyrene, polyurethanes, PTFE, polyester via terepthalic acid, nylon-6.	**(08 Hours)**
UNIT-III	**Polymerization reactors** Batch, continuous, plugflow, CSTR, Design consideration of batch reactor, design consideration in high pressure LDPE reactorsLLDPE & HDPE Fluid bed reactor. Types of agitators for polymerization reactors, polymer drying.	**(08 Hours)**
UNIT-IV	Polymer characterization & rehalogy. Mechanical properties of polymer, crystallinity, glass transition temperature (Tg), heat distribution temperature, mathematical models of viscoelastic behaviour of plastic, viscocity determination of polymer.	**(08 Hours)**
UNIT-V	Plastic processing – injection moulding , compression moulding , rotational moulding , transfer moulding , coating polymer blends , & composites – polymer alloys , reinforced plastics.	**(08 Hours)**
UNIT-VI	Polymer adhesives technology - Different types of adhesive , polyvinyl alcohol , rubber cement , polymer applications , identification and waste management.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of polymer engineering, keeping track of the recent technological trends and developments.

Text Books/References:

1.	"Introduction to polymer science & technology" by Dr S.D Dawande , Denett & co 1st edition 2006.
2.	Gawarikar V.R , Vishvanathan N.V , Sridhar j, polymer science , new age international p ltd,

	dariyaganj , New delhi.
3.	Bhatnagar M.S Text book of polymer vol I , II ,III. S.chand & co.ltd New delhi – 55.
4.	Rao natti S , Design formula for plastic engineering Hanser publication, Munich Viemna, New York (1991).
5.	Pattan Wj, plastic technology , theory , design , and manufacture, Ruston publishing Co Mumbai – 01.
6.	Athalye A.s plastic material handbook Vol 1 & 2 Multitech publishing Co. Ghatkopar Mumbai – 77.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -II: FOOD TECHNOLOGY		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test : 20 Marks	Total credits: 04
	Assignment : 10 Marks	
	Attendance :10 Marks	

Topics covered		
UNIT-I	Principle of food processing: Rheology of solid, semi-solid and liquid foods. Heat transfer and thermal death times, Schmidt plot procedure.	**(08 Hours)**
UNIT-II	Canning of food: Thermal processing, determining time of heat sterilization process. Conductive and convective foods.	**(08 Hours)**
UNIT-III	Balancing and freezing of foods: Balancing processes, freezing, Ultra-high temperature thermal processing, food sterilization, probability of non-sterile unit, Convective drying of food, rate of drying, time of drying.	**(08 Hours)**
UNIT-IV	Membrane processing of liquid foods: Principles, membrane configuration, types, evaporation concentration of liquid food, evaporator load calculation.	**(08 Hours)**
UNIT-V	Osmotic dehydration of food: Mechanism of osmotic dehydration, kinetics. Microwave heating of food, Frying of food, heat and mass transfer in frying.	**(08 Hours)**
UNIT-VI	Extrusion cooking of foods: extrusion process, role of moisture content. Packaging of foods, packaging materials, shelf life, water transmission rate, prediction of packaging	**(08 Hours)**

	time. Process control in food manufacturing.	

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of food technology, keeping track of the recent technological trends and developments

Text Books/References:

1.	Frazier, W.C., and Westhoff, D.C., (1995). Food Microbiology. 4th ed. New Delhi: Tata McGraw-Hill publishing Company Limited.
2.	Basic Food Microbiology; Bannett, Chapman and Hall
3.	Potter, Norman N., Hotchkiss**,** Joseph H., Food Science, fifth edition.
4	Frazier, Food Microbiology, Tata McGraw Hill, (2007).
5.	Norman W. Desrosier, James N. Desrosier, The technology of food preservation, 4th ed. Westport, Conn. : AVI Pub. Co., c1977.
6.	Fennema Karrel, Principles of Food Science, Vol-I, Marcel Dekker publisher.
7.	Food Science by Mudambi Robinson RK; 1996; Modern Dairy Technology, Vol 1 & 2; Elsevier Applied Science Pub.
8.	Charm SE, The Fundamentals of Food Engineering; 1963, AVI Pub.
9.	Sharan K., Mulvaney S. J., Rizvi S. H., Food process engineering, Wiley Interscience Publication

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER-II- MODELING AND SIMULATION OF PROCESSES

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4 Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total :100 Marks	

Topics covered

UNIT-I	**Introduction:** Models, Open loop systems, Feedback controls, cascade controls, System analysis from models, The control engineers role.	**(08 Hours)**
UNIT-II	**Modeling of dynamic systems:**	**(08 Hours)**

	Modeling principles, Modeling physical components, Obtaining a transfer function for Analysis or Simulation with SIMULINK. Modeling of various systems.	
UNIT-III	**Frequency response analysis:** Mathematical basis, Application of frequency response diagram, using MATLAB to obtain gain margin (GM) and phase margin (PM).using MATLAB to produce a Nichols Chart, comparison of various methods.	**(08 Hours)**
UNIT-IV	**Process identification:** Purpose, Direct methods, time domain fitting of step test data, direct sine wave testing, digital evaluation of Fourier transformation, auto tuning, approximate transfer functions.	**(08 Hours)**
UNIT-V	**Building blocks of feed forward neural network:** Building blocks of ANN, processing elements, connections, weights, activation and transfer functions, learning rules	**(08 Hours)**
UNIT-VI	Computer Simulation for various industrial applications.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of modeling and simulation of processes, keeping track of the recent technological trends and developments

Text Books/References:

1.	Franks R. E. G., "Modeling and Simulation in Chemical Engineering", Wiley Interscience, NY
2.	John Ingam, Irving J. Dunn, "Chemical Engineering Dynamic Modeling with PC Simulation", VCH Publishers
3.	William L. Luyben, "Process Modeling Simulation and Control for Chemical Engineers", McGraw Hill International Edition Publishing Company
4.	Himmelblau D., K. B. Bischoff, " Process Analysis and Simulation", John Wiely & Sons
5.	Wayne Bequette, " Process Dynamics, Modeling, Analysis and Simulation", Prentice Hall
6.	K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press, 2001.
7.	Singiresu S. Rao, "Applied Numerical Methods for Engineers and Scientists" Prentice Hall, Upper Saddle River, NJ, 2001
8.	W. F. Ramirez, "Computational Methods for Process Simulation", 2nd ed., Butterworths, 1997
9.	Modeling and analysis of dynamic systems, by C.M .Close, D.H. Fredrick and J. C. Newell, John Wiley & Sons, 2002

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -II: NANOSCIENCE

TEACHING SCHEME:	EXAMINATION SCHEME:	CREDITS ALLOTTED:
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total: 100 Marks	

Topics covered

UNIT-I	Introduction, Scientific Revolutions – Types of nanomachines and nanotechnology-periodic table-Atomic structure molecules and phase Energy - Molecular and Atomic size -surfaces and dimensional space -Top down and bottom up.	**(08 Hours)**
UNIT-II	Nano material synthesis methods, Introduction to Nano scale materials - Synthesis and processing, method of nano structured materials preparation – mechanical grinding, wet chemical synthesis – sol-gel processing, gas phase synthesis, gas condensation processing, chemical vapor condensation – nano composite synthesis – processing.	**(08 Hours)**
UNIT-III	Nanomaterials properties Opportunity at the nano scale - Length and time scale in structures -energy landscapes-Inter dynamic aspects of inter molecular forces	**(08 Hours)**
UNIT-IV	Quantum dots - Nano wires-Nano tubes; 2D and 3D films; Nano and mesopores, micelles, nano machines-biological membranes.	**(08 Hours)**
UNIT-V	Physical properties of nanostructured materials, Influence of Nano structuring on Mechanical - Optical, electronic, magnetic and chemical properties – gramsize effects on strength of metals optical properties of quantum dots and quantum wires carbon nano tubes -magnetic behavior	**(08 Hours)**
UNIT-VI	Nanostructures-surface chemistry of tailored monolayer -self assembling; Characterization Techniques: X-ray Diffraction, Scanning Electron Microscopy (SEM), Transmission Electron microscopy (TEM), Optical spectroscopy, Atomic Force Micrograph (AFM), Partical Size Analyzer.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of Nanoscience, keeping track of the recent technological trends and developments

Text Books/References:

1.	Charles P. Poole, Frank J. Owens, "Introduction to Nanotechnology", Wiley Interscience
2.	B S Murty, P Shankar, Baldev Raj, B B Rath, James Murday, "Textbook of Nanoscience and Nanotechnology" Universities Press (India) Private Limited
3.	Mark A. Ratner, Daniel Ratner, "Nanotechnology: A gentle introduction to the next Big Idea", Prentice Hall, 1st Edition
4.	Yury Gogotsi, "Nanomaterials Handbook", CRC Press, Taylor & Francis Group
5.	Gu¨nter Schmid, "Nanoparticles From Theory to Application", Wiley-VCH Verlag GmbH & Co
6.	C. Br´echignac P. Houdy M. Lahmani, "Nanomaterials and Nanochemistry", Springer Berlin Heidelberg

	New York
7.	Kenneth J. Klabunde, "Nanoscale Materials in Chemistry", John Wiley & Sons, Inc
8.	Alain Nouailhat, "An Introduction to Nanoscience and Nanotechnology", Wiley-ISTE; 1st Edition

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -II: PETROCHEMICAL ENGINEERING

TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total:100 Marks	

Topics covered

UNIT-I	Existing Feedstock Scenario Fossil fuel feedstock, Coal, Natural Gas and Petroleum, Reserves, Present and Future ,Production Trends, Statics for India and World, Distribution and utilization pattern of existing fossil reserves, Demand supply scenario, Cycle of oil prices, Need for alternative feedstocks	**(08 Hours)**
UNIT-II	Non conventional Fossil Fuels ,Coal Bed Methane, Coal Gasification, Shale Oil, Hydrates, Reserves, Potential, and Technologies for exploitation of these resources, Cost factor	**(08 Hours)**
UNIT-III	Coal Gasification Chemistry and Technology for coal gasification and Syngas production, Fischer TropschSynthesis, Chemistry, Catalyst and Process Technology, Other outlets for Syngas	**(08 Hours)**
UNIT-IV	Alco Chemicals -Pathways and technologies for chemicals from ethanol, isopropyl alcohol, n-butanol,isobutanol, Lube oil additives, Octane boosters	**(08 Hours)**
UNIT-V	Fundamentals of natural gas engineering, chemical composition of natural gas, Processing of Petroleum and Hydrocarbons.	**(08 Hours)**
UNIT-VI	Industrial Applications in Petrochemical Industry	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of Petrochemical Engineering, keeping track of the recent technological trends and developments

Text Books/References:

1.	Satterfield C. N., "Heterogeneous Catalysis in Industrial Practice", Second Edition, McGraw Hill, 1993

2.	Smith J. M., "Chemical Engineering Kinetics", Third Edition, McGraw Hill.
3.	Froment G. F. and Bischoff, K. B. "Chemical Reactor Analysis and Design", John Wiley & Sons.
4.	John, F., Cook, M., and Graham, M., "Hydrocarbon Exploration and Production", Elsevier.

Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER -II: PHYSICAL CONCEPTS OF UNIT OPERATIONS		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total: 100 Marks	

Topics covered		
UNIT-I	Vapor-Liquid Equilibrium, relative volatility, boiling point diagram,Raolts law, Mc Cabe-Thiele method, Lewis-Sorel method, reflux ratio, partial condenser, H-X diagram,Azeotropes, steam distillation, different types of columns and analysis.	**(08 Hours)**
UNIT-II	Applications of liquid-liquid extraction, difference between distillation and extraction,Distribution coefficient,ternary systems, selection of solvent, different stages of operation,Various types of extraction equipments.	**(08 Hours)**
UNIT-III	Equilibrium data, solubility curves, crystallization theory, classification of crystallizationEquipments, types of crystallizers, mechanism of crystallsation.	**(08 Hours)**
UNIT-IV	Application of adsorption, nature of adsorption, types of adsorption, adsorption Isotherms, different stages of adsorption, breakthrough curves.	**(08 Hours)**
UNIT-V	Introduction to leaching operation, equilibrium diagram, various stages of operation, Countercurrent leaching operation, leaching of fine solids, dorr agitator.	**(08 Hours)**
UNIT-VI	General definitions of drying, equilibrium in drying, rate of drying curve, General classification and types of dryers.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of physical concepts of unit operations, keeping track of the recent technological trends and

developments	
Text Books/References:	
1.	Coulson J,M. and Richardson Chemical Engineering Volume 2
2.	Pergaon Press, Oxford, New York (USA) King C, J.Separation ProcessesMc Graw – Hill Publications
Syllabus for Unit Test:	
Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI

SELF STUDY PAPER- II: MULTIPHASE REACTOR ENGINEERING		
TEACHING SCHEME:	**EXAMINATION SCHEME:**	**CREDITS ALLOTTED:**
Lectures: 4 Hours/Week	End Semester Examination: 60 Marks	Theory : 04
Total : 4Hours/Week	Unit Test: 20 Marks	Total credits: 04
	Assignment: 10 Marks	
	Attendance:10 Marks	
	Total: 100 Marks	

Topics covered		
UNIT-I	**Introduction to Multiphase Reactor Engineering** Types, Classification, Application of Industrial Importance	**(08 Hours)**
UNIT-II	**Thermodynamics and kinetics** Notable industrial heterogeneous systems and thermodynamic role. Application of equilibrium criteria to chemical reactions. The Gibbs energy change and equilibrium constant. Estimation of equilibrium constant for heterogeneous system by defining standard state of the phases involved. Determination of rate controlling step: intrinsic kinetics for heterogeneous systems.	**(08 Hours)**
UNIT-III	**Hydrodynamic Characteristics** Hydrodynamic characteristics of different multiphase reactors: Mechanically Agitated Contactors (MAC), Bubble Columns, Slurry Reactors, Fluidized Beds, Loop Reactors and Modified Versions	**(08 Hours)**
UNIT-IV	**Mixing Studies** Effect of geometrical, system, and operating parameters on phase mixing in multiphase reactors. Quantification of phase mixing. Development of a mathematical model.	**(08 Hours)**
UNIT-V	**Heat Transfer and Mass Transfer Studies** Effect of geometrical, system, and operating parameters on heat ransfer coefficient in multiphase reactors. Quantification of heat transfer coefficient. Application of	**(08 Hours)**

	correlations available to different multiphase reactors. Experimental techniques used for estimation of mass transfer coefficient and selection of suitable technique for a multiphase reactor. Effect of geometrical, system, and operating parameters on mass transfer coefficient in multiphase reactors. Quantification of mass transfer coefficient. Application of correlations available to different multiphase reactors.	
UNIT-VI	**Design Aspects of Multiphase Reactors** Pressure drop, Fractional phase hold- up, mass and heat transfer coefficient, extent of mixing, etc.	**(08 Hours)**

Assignment: Each student will submit assignments based on different topics in consultation with faculty, in the area of multiphase rector engineering, keeping track of the recent technological trends and developments

Text Books/References:

1.	L. K. Doraiswamy and M. M. Sharma, "Heterogeneous Reactions", 2nd Edition, Volume I and II.
2.	G. B. Tatterson, " Fluid Mixing and Gas Dispersion in Stirred Reactors", 10th Edition, Academic Press, London, 1994
3	W. D. Deckwer, "Bubble Column Reactors", Cambridge University Press, New York, 2000.
4	Diazo Kunji and O. Levenspiel, "Fluidization Engineering", 2nd Edition, Butterworth Heinemann, 1991.
5	J. F. Devidson and Harrison, " Fluidization", 10th Edition, Academic Press, London, 1994.

Syllabus for Unit Test:

Unit Test -I	UNIT – I ,II,III
Unit Test -II	UNIT – IV,V,VI