SCHEME OF COURSES FOR M.TECH (CHEMICAL ENGINEERING)
(w. e. f. from July, 2016)

Program Educational Objective (PEO)
To produce post graduates who will be in the role of leaders in academics/research/industry

Program Objectives (POs)

- Advanced professional knowledge
- Capability to conduct systematic research
- Capability to design and develop solutions to industrial problems
- Capability to teach engineering students effectively

First Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH101	Chemical Engineering Thermodynamics	3	1	0	3.5
2.	PCH105	Chemical Engineering Lab I	0	0	3	1.5
3.	PCH106	Reaction Engineering & Reactor Analysis	3	1	0	3.5
4.	PCH107	Separation Processes	3	2	0	4.0
5.	PCH214	Process Integration	3	1	0	3.5
6.	PMA102	Research Methodology	2	0	2	3.0
		Total	**14**	**5**	**5**	**19.0**

Second Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH201	Computational Methods in Chemical Engineering	3	0	2	4.0
2.	PCH202	Process Modeling and Simulation	3	0	2	4.0
3.	PCH205	Chemical Engineering Lab II	0	0	3	1.5
4.	PCH206	Transport Phenomena	3	1	0	3.5
5.	**PCH224**	**Process Dynamics & Control**	3	1	0	3.5
6.		Elective I	3	1	0	3.5
		Total	**15**	**3**	**7**	**20.0**

Third Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.		Elective II	3	1	0	3.5
2.		Elective III	3	1	0	3.5
3.	**PCH291**	**Seminar**				4.0
4.	PCH391	Minor Project				5.0
5.	PCH491	Dissertation (start)				
		Total	**6**	**2**	**0**	**16.0**

Fourth Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH491	Dissertation				**16.0**

Total Credits: 71

List of Electives

Elective-I

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH111	Process Optimization	3	1	0	3.5
2.	PCH112	Project Engineering and Management	3	1	0	3.5
3.	PCH113	Process Development and Scale-Up Studies	3	1	0	3.5
4.	PCH114	Bioprocess Engineering	3	1	0	3.5
5.	PCH115	Environmental Pollution Control	3	1	0	3.5

Elective-II

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH221	Fluidization Engineering	3	1	0	3.5
2.	PCH222	Energy Resources & Management	3	1	0	3.5
3.	PCH223	Catalytic Reactor Engineering	3	1	0	3.5
4.	PCH225	Process Equipment Design	3	1	0	3.5
5.	PCH226	Fuel Combustion Systems	3	1	0	3.5

Elective-III

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH231	Nanochemical Engineering	3	1	0	3.5
2.	PCH333	Selected Topics in Fluid Mechanics	3	1	0	3.5
3.	PCH233	Selected Topics in Heat Transfer	3	1	0	3.5
4.	PCH234	Polymer Reaction Engineering	3	1	0	3.5
5.	PCH235	Molecular Modeling and Simulation	3	1	0	3.5
6.	PCH236	Advanced Separation Processes	3	1	0	3.5

Elective course offered by the Department to all PG students

S.No.	Course No.	Course Name	L	T	P	Cr
1.	PCH115	Environmental Pollution Control	3	1	0	3.5

PCH101 CHEMICAL ENGINEERING THERMODYNAMICS

L	T	P	Cr
3	**1**	**0**	**3.5**

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

Review of Basic Concepts of Thermodynamics: Energy and entropy balances, Equilibrium criteria, Chemical potential, Fugacity, Activity, Raoult's law, Fugacities in gas mixtures: Virial equation of state, Fugacities in liquid mixtures: Ideal solutions, excess functions, Gibbs-Duhem equation.

Thermodynamic Properties of Fluids: Thermodynamic properties from volumetric and thermal data, Equations of state, Fugacity of components in a mixture, Phase equilibria from an equation of state, Prediction of enthalpy departure and VLE characteristics from equation of state, Intermolecular forces and Potential functions: Ion-ion dipole, induction and dispersion forces, repulsion, specific chemical forces, Hydrophobic interaction and entropy effects, Theory of corresponding states.

Free Energy Models: Margulus, RK, Wohl Wilson, NRTL, UNIQUAC, UNIFAC methods.

Liquid-Liquid Equilibrium: Partial miscibility, LLE analysis, Supercritical analysis.

Multi-Component Mixtures: Fugacities in liquid mixtures, Van Laar theory, Scatchard-Hildebrand theory, Lattice model.

Non-Ideal Thermodynamics: Gas mixtures, Non-linear phase equilibrium, Molecular thermodynamics, Molecular theory of fluids.

Course learning outcomes (CLOs):

The students will be able to

1. apply fundamental concepts of thermodynamics to engineering applications.
2. estimate thermodynamic properties of substances in gas or liquid state of ideal and real mixture.
3. determine thermodynamic efficiency of various energy related processes.
4. predict intermolecular potential and excess property behavior of multi-component systems

Recommended Books:

1. *Smith, J.M., Van Ness H.C., and Abbott, M.M., Introduction to Chemical Engineering Thermodynamics, Tata McGraw-Hill (2004).*
2. *Sandler, S.I., Chemical and Biochemical Engineering Thermodynamics, John Wiley (1999).*
3. *Kyle B.G., Chemical and Process Thermodynamics, Prentice - Hall (2004).*
4. *Saad A.M., Thermodynamics: Principles and Practice, Prentice - Hall (1997).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
	MST	30
	EST	45
	Sessional (may include Assignments/Projects/Tutorials/Quizes)	25

PCH 105 CHEMICAL ENGINEERING LAB I

L	T	P	Cr
0	0	3	1.5

Course Objective:
To learn chemical engineering principles and their practical applications in the areas of mass transfer, reaction engineering and particle mechanics.

S. No.	
	Fluid and Particle Mechanics
1.	To study the power consumption in an agitated vessel for different impellers
2.	To carry out size analysis of solids sample using sieve shaker
3.	To conduct sedimentation study on particle suspension in water
4.	To study the liquid-solid fluidization phenomena
5.	To study the filtration operation and determine specific cake resistance
6.	To determine friction factor in a randomly packed bed
	Mass Transfer Operations
7.	To determine the diffusion coefficient of an organic vapor in air
8.	To determine gas film coefficient for air water system in a wetted wall column
9.	To determine mass transfer coefficient for absorption with chemical reaction in a packed bed
10.	To calculate HETP and HTU for packed distillation column operating under total reflux
11.	To study the drying characteristics of a solid under forced draft conditions
12.	To study pressure drop and tower characteristics for various flow rates in a counter current forced draft cooling tower
	Chemical Reaction Engineering
13.	To study the kinetics of a non-catalytic homogeneous reaction in a batch reactor
14.	To study the kinetics of a non-catalytic homogeneous reaction in a plug flow reactor
15.	Study of a non-catalytic homogeneous reaction in a semi-batch reactor
16.	To study residence time distribution (RTD) characteristics in a packed bed reactor
17.	To study residence time distribution (RTD) characteristics in a CSTR
18.	To study the kinetics of first order decomposition of diacetone alcohol using dilatometer

Course learning outcome (CLOs):

The students will be able to

1. plan experiments and present the experimental data meaningfully
2. apply theoretical concepts for data analysis and interpretation
3. calculate the design parameters related to fluid and particle mechanics, and mass transfer operations
4. understand the experimental procedures related to chemical reaction engineering

Recommended Books:

1. *McCabe, W.L., Smith, J.C., and Harriot, P., Unit Operations of Chemical Engineering. McGraw-Hill, (2005).*
2. *Richardson, J.F., Harker, J.H. and Backhurst, J.R., Coulson and Richardsons Chemical Engineering, Vol. 2, Butterworth-Heinemann (2007).*
3. *Treybal, R.E., Mass Transfer Operations, McGraw Hill (1980).*
4. *Fogler, H.S., Elements of Chemical Reaction Engineering, Prentice Hall of India (2003).*
5. *Levenspiel, O., Chemical Reaction Engineering, John Wiley & Sons (1998).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	Continuous evaluation (Assignments/Micro Projects/Quizes)	50
2.	Lab Evaluation (Viva-voce/record/performance)	50

PCH106 REACTION ENGINEERING & REACTOR ANALYSIS

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn about reaction kinetics for single, multiple, isothermal, non-isothermal reactions and reactor design procedures.

Chemical Kinetics: Reaction rates, Kinetics of homogeneous reactions, Interpretation of reaction data.

Isothermal Reactor Design: Design equations for batch, Plug flow, Back-mix flow and Semi-batch reactors.

Multiple Reactions: Maximizing desired product in parallel reactions and series reactions, Solutions to complex reactions.

Steady State Non-isothermal Reactor Design: Combining material and energy balances for non-isothermal CSTR and Plug flow reactors (adiabatic and with heat exchange), Adiabatic temperature and equilibrium conversion, Optimum feed temperature, Multiple steady states, Non-isothermal multiple reactions.

Solid Catalyzed Reactions: Steps in catalytic reactions: adsorption isotherms, surface reaction, desorption rate, limiting step, Diffusion and reaction in spherical catalyst pellets, Estimation of diffusion and reaction limited regimes, Mass transfer and reaction in a packed bed, Fluidized bed and multiphase reactors.

Non-ideal Reactors: Measurement of RTD, Characteristics of RTD, RTD in ideal reactors, Reactor modeling using RTD.

Course learning outcomes (CLOs):

The students will be able to

1. solve problems involving single and multiple homogeneous reactions
2. analyze and interpret experimental data for homogenous reactions
3. solve problems involving non isothermal reactor operation and design
4. solve problems involving mass transfer with reaction in solid catalyzed reaction
5. analyze and model real reactors

Recommended Books:

1. *Fogler, H.S., Elements of Chemical Reaction Engineering, Prentice-Hall India (2003).*
2. *Levenspiel, O., Chemical Reaction Engineering, John Wiley (1991).*
3. *Froment, G.F., and Bischoff, K.G., Chemical Reactor Analysis and Design, John Wiley (2001).*
4. *Smith, J.M., Chemical Engineering Kinetics, McGraw-Hill (1981).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH107 SEPARATION PROCESSES

L	T	P	Cr
3	**2**	**0**	**4**

Course Objective:
To learn conceptual design of separation processes and design of equipment involved.

Distillation: Vapor liquid equilibrium, Binary distillation, Bubble point and dew point temperature of multi-component mixture, Distillation of multi-component mixtures, Fenske-Underwood-Gilliland method, Selection of two key components, Column operating pressures, Distribution of non-key components at total and actual reflux, Feed stage location, Azeotropic distillation, Extractive distillation, Reactive distillation, Divided wall distillation.

Liquid-Liquid Extraction: Liquid-liquid equilibrium, Equilateral triangular coordinates, Choice of solvent, Stage wise contact, Multi-stage cross-current extraction, Multi-stage counter current withoutreflux, Maloney-Schubert graphical equilibrium stage method, Determination of number of equilibrium stages by graphical methods, Extraction with intermediate feed and reflux, Extraction efficiency,Liquid-liquid extraction with chemical reaction, Hunter-Nash graphical equilibrium stage method, Number of equilibrium stages, Minimum and maximum solvent to feed flow rate ratios.

Crystallization: Solid-liquid equilibrium, Nucleation, Crystal growth, Elements of precipitation, Industrial crystallizers, Crystallizer operation and design.

Adsorption: Sorbents, Sorption system, Ion exchange equilibria, Equilibria in chromatography, Kinetic and transport consideration, Mass transfer in ion exchange and Chromatography, Fixed bed adsorption, Breakthrough curve, Continuous counter current adsorption system, Chromatographic separations.

Course learning outcomes (CLOs):
The students will be able to
1. Design distillation column by shortcut methods
2. Solve multistage liquid-liquid extraction problem
3. Solve the problem related to crystallization
4. Solve the problem related to adsorption

Recommended Books:

1. *Seader, H., and Henley, J.E.,Separation Process Principles, Wiley India(2007)*
2. *Geankoplis, C., Transport Processes and Unit Operations, Prentice-Hall of India (1993).*
3. *Holland, C.D., Fundamentals of Multi-component Distillation, McGraw Hill (1981).*
4. *Sherwood, T.K., Pigford, R.L., and Wilkes, C.R., Mass Transfer, McGraw Hill (1975).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH214 PROCESS INTEGRATION

L	T	P	Cr
3	1	0	3.5

Course Objective:
To learn process integration with regard to energy efficiency, waste minimization and an efficient use of raw materials.

Introduction: Process integration, Role of thermodynamics in process design.

Network Integration: Targeting of energy, area, number of units and cost, Super targeting, Concept of pinch technology and its application, Heat exchanger networks analysis, Maximum energy recovery (MER), Networks for multiple utilities and multiple pinches.

Heat and Power Integration: Heat integration: Design columns, evaporators, dryers, and reactors, Minimization of raw water utilization and waste water generation, Flue gas emission targeting, Case studies, Concept of process integration for recycling and reuse, Mathematical approach for process integration, Case studies.

Course learning outcomes (CLOs):
The students will be able to
1. carry out pinch analysis.
2. analyze heat exchanger networks, and networks for multiple utilities
3. solve problems of heat and power integration
4. modify processes for minimization of wastewater and raw water utilization

Recommended Books:

1. *Linnhoff, D.W., User Guide on Process Integration for the Efficient Use of Energy, Institution of Chemical Engineers (1994).*
2. *Smith, R., Chemical Process Design, Mc-Graw Hill (1995).*
3. *Shenoy, V.U., Heat Exchanger Network Synthesis, Gulf Publishing (1995).*
4. *Kumar, A., Chemical Process Synthesis and Engineering Design, Tata McGraw Hill (1977).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH201 COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING

L	T	P	Cr
3	0	2	4

Course Objective:
To learn various computational techniques for analysing and solving chemical engineering problems.

Solution of Algebraic Equations: Solution of non-linear and transcendental equations in one or more than one variable, Solution of linear simultaneous equations, Solution of equations by computer programming, Excel sheet, Poly Math, and MATLAB.

Solution of Ordinary Differential Equations: Initial value problem: RK class and predictor corrector class methods, stiff ODE's and Gear's methods, Boundary value problem: Shooting methods, finite difference method, method of weighted residuals and orthogonal collocation and Galerkin technique to solve BVP in ODEs, Solution of Chemical Engineering problems (ODEs) by computer programming, excel sheet, Poly Math, and MATLAB.

Solution of Partial Differential Equations: Classification of PDEs: Parabolic, elliptical and hyperbolic equation, Review of finite difference techniques to solve partial differential equation, Application to chemical engineering systems, Concept of finite element, Similarity transformation, Method of weighted residuals, Orthogonal collocation, Least square, Finite element methods to solve PDEs with application to Chemical Engineering systems using MATLAB.

Course learning outcomes (CLOs):

The students will be able to

1. solve problems of algebraic and differential equations, simultaneous equation, partial differential equations
2. convert problem solving strategies to procedural algorithms and to write program structures
3. solve engineering problems using computational techniques
4. assess reasonableness of solutions, and select appropriate levels of solution sophistication

Recommended Books:

1. *Gerald, C.F., and Wheatley P. O., Applied Numerical Analysis, Pearson Education (2006).*
2. *Finlayson, B.A., Introduction to Chemical Engineering Computing, Wiley Interscience (2012).*
3. *Beers, K.J., Numerical Methods for Chemical Engineering, Applications in MATLAB, Cambridge University Press (2007).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	40
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	35

PCH202 PROCESS MODELING AND SIMULATION

L	T	P	Cr
3	**0**	**2**	**4**

Course Objective:
Learn to develop mathematical models of phenomena involved in various chemical engineering processes and solutions for these models.

Introduction: Process modeling and simulation, Industrial usage of process modeling and simulation, Macroscopic and microscopic mass, energy and momentum balances.

Process Models: Classification of mathematical models: Transport phenomena, population balance, Models for flash vessels, reactors, heat exchangers, distillation columns, absorption columns etc.

Process Simulation: Problem formulation, Flow sheeting problem, Specification problem, Optimization problem, Synthesis problem, Simulation approaches: Modular, equation solving, Decomposition of networks: Partitioning, tearing, signal flow graphs, System stability, Sensitivity, Determinacy.

Process Simulator(s): Commercial simulation packages (Aspen Plus/Aspen Hysys) for steady state simulation, Modeling and simulation of complex industrial systems in petroleum, petrochemicals, polymers etc.

Course learning outcomes (CLOs):
The students will be able to
1. analyze physical and chemical phenomena involved in various processes
2. develop mathematical models for chemical processes
3. use the various simulation approaches
4. use process simulators like ASPEN PLUS and ASPEN HYSYS

Recommended Books:

1. *Luyben, W.L., Process Modeling, Simulation, and Control for Chemical Engineers, McGraw-Hill (1990).*
2. *Himmelblau, D.M. and Bischoff, K.B., Process Analysis and Simulation: Deterministic Systems, John Wiley (1968).*
3. *Himmelblau, D.M and Bischoff, K.B., Process Analysis and Simulation: Stochastic Systems, John Wiley (1968).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	25
2.	EST	40
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	35

PCH205 CHEMICAL ENGINEERING LAB II

L	T	P	Cr
0	0	3	1.5

Course Objective:

To learn analytical experimental methods using sophisticated instruments and interpretation of experimental data.

S. No.	Contents
1.	To estimate concentration of a component in liquid solution by UV-VIS spectrophotometer
2.	To identify functional groups on samples by Fourier Transform Infrared Spectroscopy (FTIR)
3.	To estimate concentration of a component in liquid solution by Gas Chromatography (GC)
4.	To estimate concentration of a component in liquid solution by High Performance Liquid Chromatography (HPLC)
5.	To estimate COD in a liquid sample
6.	To estimate surface area, pore size and pore volume distribution of a porous material
7.	To estimate Total Organic Carbon (TOC) in a liquid sample by TOC analyzer
8.	Analysis of sample by Thermo Gravimetric Analysis (TGA)
9.	Strength measurement of given sample by Universal Testing Machine (UTM)
10.	To estimate BOD in a wastewater sample
11.	To calibrate Brookfield viscometer, and estimation of viscosity of a given sample
12.	To calibrate Refractometer and determination of concentration of given sample
13.	Heat transfer and pressure drop characteristics of different fluids using shell and tube heat exchanger
14.	Heat transfer and pressure drop characteristics of different fluids using plate heat exchanger
15.	Demonstration of Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), Nuclear Magnetic Resonance **(**NMR**)** Spectroscopy, CHNS analyser
16.	Determination of molecular weight and molecular weight distribution by Gel Permeation Chromatography (GPC)

Course learning outcomes (CLOs):

The students will be able to

1. select suitable instrumental techniques for analysis
2. plan experiments and operate several specific instruments
3. analyze and interpret the experimental data

Recommended Books:

1. *Willard H.H., Merritt J.L., Dean J.A., and Settle F.A., Instrumental Methods of Analysis, CBS Publisher (2009)*
2. *Skoog A.A., Holler J.F., and Crouch S.R., Principles of Instrumental Analysis, Brooks Cole, (2006).*
3. *Cleceri L.S., Greenberg A.E., and Eaton A.D., Standard Methods for the Examination of Water and Wastewater, American Public Health Association (1998).*
4. *Rouessac F., and Rouessac A., Chemical Analysis: Modern Instrumentation Methods and Techniques, Wiley(2007).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	Continuous evaluation (Assignments/Micro Projects/Quizes)	50
2.	Lab Evaluation (Viva-voce/Lab record/Performance)	50

PCH206 TRANSPORT PHENOMENA

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To be able to analyze various transport processes with understanding of solution approximation methods and their limitations.

Introduction: Basic concepts of transport phenomena, Newtonian and non-Newtonian fluids, Basic laws of momentum, energy and mass transport, Laminar and turbulent flow, Equation of continuity.

Momentum Transport: Shell momentum balance, Equations of motion, Navier's-Stokes equation, Velocity distributions with one and more than one independent variable, Time dependent flow, Velocity distributions in turbulent flow, viscous flow, Flow past immersed bodies, Boundary layer theory, Lubrication theory, Turbulent flow, Fluctuations and time smoothed equations for velocity, Time smoothed equation of change, Turbulent flow in ducts, Equation of energy, Equation of continuity, Reynolds stress, Inter-phase transport, Friction factor for flow in tube, around sphere and for packed columns, Polymeric liquids.

Energy Transport: The equation of change of non-isothermal system, Temperature distribution for more than one variable, Temperature distribution in turbulent flow, Inter-phase transport in non-isothermal system, Energy transport by radiation.

Mass Transfer: Equations of change for multi-component systems, Concentration distributions with more than one independent variable, Concentration distributions in turbulent flow, Inter-phase transport in non-isothermal mixtures.

Course learning outcomes (CLOs):

The students will be able to

1. analyze heat, mass and momentum transport in a process
2. formulate industrial problems along with appropriate boundary conditions
3. develop steady and time dependent solutions for the problem involving heat, mass and momentum transfer

Recommended Books:

1. *Bird, R.B., Stewart, W.E., and Lightfoot, E.N., Transport Phenomena, Wiley (2002).*
2. *Brodkey R.S. and Hershey H.C., Transport Phenomena: A Unified Approach, Volume 1, McGraw Hill (1988).*
3. *Brodkey R.S. and Hershey H.C., Transport Phenomena: A Unified Approach, Volume 2, McGraw Hill (2003).*
4. *Gandhi, K.S., Heat and Mass Transfer: A Transport Phenomena Approach, New age international (2011).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH224 PROCESS DYNAMICS AND CONTROL

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn about dynamic behaviour of nonlinear, distributed and other complex systems, and design their control schemes.

Introduction: Review of dynamic behaviour of linear systems and their control system design, Linear processes with complex dynamics, Distributed-parameter systems, Stability, Stability improvement.

Nonlinear process dynamics: Phase-plane analysis, Limit cycle behaviour, Saddle point behaviour, Multiplicity of steady-states, Input and Output multiplicity, Bifurcation behaviour, Dynamic Response Characteristics of More Complicated Processes, Development of empirical models from Process Data, Illustrative case studies.

Design of Controller Using Frequency Response: Nyquist, Bode and Nichols analysis, Controller gain, Different methods of controller tuning.

Advanced Control Strategies: Cascade, feed-forward and ratio control, Override control, Model based control, Digital sampling, Filtering and Control, Multi-loop and multivariable control, Real-time optimization, Model predictive control, Computed variable control, Non-linear, Multivariable control, Process monitoring, Batch process control, Introduction to plant wide control, Plant wide control system design.

Course learning outcomes (CLOs):

The students will be able to
1. model, solve and analyze the system for its behavior.
2. design controllers for simple and complex processes.
3. design of control schemes and their applications in various processes.
4. understand advanced control strategies

Recommended Books:

1. *Seborg, D.E., Edgar, T.F., and Mellichamp, D.A., Process Dynamics and Control, John Wiley (2004).*
2. *Coughanowr, D.R. and Le Blanc S.E., Process Systems Analysis and Control, McGraw Hill (2009).*
3. *Luyben, W.L., Process Modeling Simulation and Control for Chemical Engineers, McGraw Hill (1990).*
4. *Bequette, B.W., Process Control: Modeling, Design and Simulation, Prentice Hall (2003).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH111 PROCESS OPTIMIZATION

	L	T	P	Cr
	3	**1**	**0**	**3.5**

Course Objective:

To learn the modeling skills necessary to describe and formulate optimization problems arising in process systems engineering.

Introduction: Process optimization, Formulation of various process optimization problems and their classification, Basic concepts of optimization: Convex and concave functions, necessary and sufficient conditions for stationary points.

Optimization of One Dimensional Functions: Unconstrained multivariable optimization: Direct search methods, Bracketing methods: Exhaustive search method, bounding phase method, Region elimination methods: Interval halving method, Fibonacci search method, golden section search method, PointEstimation method: Successive quadratic estimation, Solutions for one dimensional problems using MATLAB.

Indirect First Order and Second Order Method: Gradient-based methods: Newton-Raphson method,bisection method, secant method, cubic search method, Root-finding using optimization techniques.

Multivariable Optimization Algorithms: Optimality criteria, Unidirectional search, Direct search methods: Evolutionary optimization method, simplex search method, Powell's conjugate direction method, Gradient based methods: Cauchy's (steepest descent) method, Newton's method.

Constrained Optimization Algorithms: Kuhn-Tucker conditions, Transformation methods, Penalty function method, Method of multipliers, Sensitivity analysis, Direct search for constraint Minimization, Variable elimination method, Complex search method, Successive linear and quadratic programming, Optimization of staged and discrete processes.

Specialized and Non-traditional Algorithms: Integer Programming: Penalty function method, Genetic Algorithms (GA), Gas for constrained optimization, Advanced GA's.

Course learning outcomes (CLOs):

The students will be able to

1. formulate the objectives functions for constrained and unconstrained optimization problems
2. use different optimization strategies
3. solve problems using non-traditional optimization techniques
4. solve optimization problems using various optimization techniques

Recommended Books:

1. *Edgar, T.F.,and Himmelblau, D.M., Optimization of Chemical Processes, McGraw-Hill (1988).*
2. *Kalyanmoy, D., Optimization for Engineering Design, Prentice Hall (1998).*
3. *Beveridge, G.S., and Schechter,R.S., Optimization: Theory and Practice, McGraw-Hill Book Co., New York (1970).*
4. *Husain, A., and Gangiah, K., OptimizationTechniques for Chemical Engineers, Macmillan Co. of India (1976).*
5. *Venkataraman, P., Applied Optimization with MATLAB programming, Wiley (2009).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH112 PROJECT ENGINEERING AND MANAGEMENT

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To understand the principles associated with effective project management and application of these principles in avoiding common difficulties associated with project management.

Introduction: Foundations of project management, Project life cost analysis, Project environment, Project selection, Project proposal, Project scope, Work breakdown Structure.

Networks: Scheduling, Critical path method, Program evaluation and review technique, Planning and scheduling of activity networks, Assumptions in PERT modeling, Time-cost trade-offs, Linear programming and network flow formulations, PERT/COST accounting, Scheduling with limited resources, Resource planning, Resource allocation, Project schedule compression, Project scheduling software, Precedence diagrams, Decision CPM, Generalized activity networks, GERT.

Projects: Estimation of project costs, Earned value analysis, Monitoring project progress, Project appraisal and selection, Recent trends in project management.

Course learning outcomes (CLOs):
The students will be able to

1. acquaint with the project management skills
2. use CPM and PERT methods in effective project management
3. carry out resource planning and project scheduling
4. perform project costing and adopt latest trends in project management

Recommended Books:

1. *Dunn, S.C., Project Engineering, Skinner (Anthony) Management Limited (1990).*
2. *Ernest, E., and Ludwig, E. E., Applied Project Engineering and Management, Gulf Pub. (1988).*
3. *Frederick, L., and Blanchard, F. L., Engineering Project Management, M. Dekker (1990).*
4. *Sinha, A.K., and Sinha, R., Project Engineering and Management, Vikas Pub. (1983).*
5. *Nigel, J., and Smith, N. J., Engineering Project Management, Wiley-Blackwell (2002).*
6. *Kenneth, K., and Humphreys, J., Cost and Optimization Engineering, McGraw-Hill (1991).*
7. *Peters, M.S., Timmerhaus, K.D., and West, R.E., Plant Design and Economics for Chemical Engineers, McGraw-Hill Education (2003).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH113 PROCESS DEVELOPMENT AND SCALE-UP STUDIES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn the basics of process development and scale-up from bench scale to the production scale.

Introduction: Description and evolution of a process system, Fundamental principles of mathematical modeling, Dimensional analysis, Homogeneous reactor scale-up.

Reactors for Fluid Phase Processes Catalyzed by Solids: Pseudo-homogeneous and heterogeneous models, Two-dimensional models, Scale up considerations.

Fluid-fluid Reactors: Scale-up considerations in packed bed absorbers and bubble columns, Applicability of models to scale-up.

Mixing Processes: Scale-up relationships, Scale-up of polymerization units, Continuous stages gas-liquid slurry processes, Liquid-liquid emulsions.

Fluidized Beds: Major scale-up issues, Prediction of performance in large equipment, Practical commercial experience, Problem areas.

Continuous Mass Transfer Operations: Fundamental considerations, Scale-up procedure for distillation, absorption, stripping and extraction units.

Solid-Liquid Separation Processes: Fundamental considerations, Small scale studies for equipment design and selection, Scale-up techniques, Uncertainties.

Course learning outcomes (CLOs):
The students will be able to
1. apply the basis of scale-up criteria
2. scale-up homogeneous and heterogeneous reactors
3. scale-up mixing and fluidization systems
4. scale-up mass transfer processes

Recommended Books:

1. *Bisio, A., and Kabel, R.L., Scale up of Chemical Processes, John Wiley (1985).*
2. *Johnstone, R. E., and Thring, M. W., Pilot Plants, Models and Scale-up Methods in Chemical Engineering, McGraw-Hill (1957).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH114 BIOPROCESS ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objective:
To introduce the engineering principles of bioprocesses including characteristics of different microbial cells, enzymes, microbial kinetics, and design considerations.

Biological Basics: Cell Structure and function, Chemicals, Cell metabolism.

Enzymes: Kinetics of enzymatic reactions and design of reactors, Immobilized enzymes and kinetics.

Microbial Growth: Kinetics of cell growth and metabolite production, Pure and mixed culture.

Mass Transfer: Transport phenomena in bioreactors, Mass transfer considerations in design and analysis of various types of bioreactors in batch, semi batch and continuous modes of operation.

Scale Up: Principles, instrumentation and control of bioprocesses.

Down-stream Processing: Separation and disintegration of cells, Extraction and concentration of metabolites.

Recombinant DNA: Recent advances in rDNA.

Course learning outcomes (CLOs):

The students will be able to

1. calculate the kinetic parameters of enzymatic reactions
2. calculate and analyze the kinetic parameters for the microbial growth
3. apply mass transfer principles in design and analysis of various types of bioreactors
4. solve problems related to extraction and concentration of metabolites

Recommended Books:

1. *Shuler, M. L., and Kargi, F., Bioprocess Engineering, Pearson Prentice Hall (2007).*
2. *Doran, P., Bioprocess Engineering Principles, Elsevier Inc. (1995).*
3. *Bailey, J. E., and Ollis, D. F., Biochemical Engineering Fundamentals McGraw Hill (1986).*
4. *Weith, W. F., Biochemical Engineering – Kinetics, Mass Transport, Reactors and Gene Expression, Wiley (1994).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH115 ENVIRONMENTAL POLLUTION CONTROL

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn about air and water pollution control techniques and solid waste management.

Introduction: Environmental pollution and socioeconomic impacts, Concept of EIA, Environmental modeling as a tool for environmental management.

Air Pollution: Air quality modeling for point, line and area sources, Dispersion modeling for short and tall stacks for short and long distances, Dense Gas Dispersion Modeling (DGADIS), Design of various pollution control equipments.

Water Pollution: Surface water quality modelling, Movement and dispersion of pollutants into aquifers, Ground water quality impacts.

Wastewater Treatment Plant design: Physical unit operations, Chemical precipitation, disinfection, adsorption, Aerobic and anaerobic biological treatment processes, Advanced wastewater treatment processes: electro-chemical treatment methods, advanced oxidation processes, membrane processes.

Industrial Noise Pollution: Properties of noise and its effects, Sources and control of industrial noise pollution.

Solid Waste: Sources and classification, Methods of solid waste disposal, Solids waste and landfill management, Natural composting, Accelerated composting of industrial sludge, Municipal solid waste management, Toxic waste management, Incineration of industrial waste.

Course learning outcomes (CLOs):

The students will be able to

1. evaluate impact of different types of waste generated
2. apply knowledge for the protection and improvement of the environment
3. model the atmospheric dispersion of air pollutants
4. monitor and design the air and water pollution control systems
5. select and implement industry specific waste treatment system

Recommended books:

1. *Sincero, P., and Sincero, G.A., Environmental Engineering: A Design Approach, Prentice Hall (1996).*
2. *Masters, G.M., Introduction to Environmental Engineering and Science, Prentice Hall (2006).*
3. *De Nevers, N., Air Pollution Control Engineering, McGraw-Hill (1995).*
4. *Flagan, R.C., and Seinfeld, J.H., Fundamentals of Air Pollution Engineering,Prentice Hall (1988).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH221 FLUIDIZATION ENGINEERING

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn the fluidization phenomena, industrial applications of fluidized beds and their operational and design aspects.

Introduction: The phenomena of fluidization, Liquid-like behaviour of fluidized beds, Comparison with other contacting methods, Fluidization quality.

Industrial Applications of Fluidized Beds: Physical operations, Synthesis reactions, Cracking of hydrocarbons, Combustion and incineration, Carbonization and gasification, Biofluidization.

Fluidization and Mapping of Regimes: Characterization of particles, Determination of effective sphericity, Fluidization without carryover of particles, Fluidization with carryover of particles, Mapping of fluidization regimes.

Dense Fluidized Beds: Distributors, Gas entry region, Gas jets, Pressure drop across distributors, Design of distributors, Bubbles in dense beds, Free-board behaviour, Estimation of TDH, entrainment and Elutriation from fluidized beds.

Bubbling Fluidized Beds: Estimation of bed properties, Heat and mass transfer, Flow models for bubbling beds, FCC and gasifier design for high and low density beds.

Course learning outcomes (CLOs):

The students will be able to

1. understand the fluidization phenomena and operational regimes
2. design various types of gas distributers for fluidized beds and determine effectiveness of gas mixing at the bottom region
3. estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for the fluidized beds
4. develop mathematical modeling for fluidized beds
5. design gas-solid fluidized bed reactors

Recommended Books:

1. *Kunni, D., and Levenspiel, O., Fluidization Engineering, Butterworth-Heinemann (1991).*
2. *Yang, W., and Amin, N.D., Fluidization Engineering: Fundamentals and Applications, American Institute of Chemical Engineers (1988).*
3. *Fan, L.S., Gas-Liquid-Solid Fluidization Engineering, Butterworths (1989).*
4. *Yang, W.C., Handbook of Fluidization and Fluid-particle Systems, CRC Press (2003).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab valuations)	25

PCH222 ENERGY RESOURCES AND MANAGEMENT

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn about energy resources, scenario, auditing and conservation in process industries.

Energy Resources: Classification of energy sources, Primary fuels and secondary fuels, Conventional and renewable energy sources.

Energy Scenario: Supply and demand, Energy intensive industries, Industrial use of energy, Importance of energy in industrial promotion and employment.

Energy Audit: Importance of energy audit and questionnaire, Instruments used in energy audit, Identification of quality and cost of various energy inputs, Evaluation of energy consumption pattern in different processes, Heat loss analysis, Electrical energy input analysis.

Energy Conservation: Analysis of scope and potential for energy conservation, Energy storage such as thermal insulation, Accumulators and storage media, Co-generation practice, Efficiency improvement in boilers and furnaces, Heat recovery techniques, Electrical energy conservation by using variable speed drives and motor controllers, LED, Analysis of pumps, Optimization of steam system.

Fuel Cells: General characteristics, types of fuel cells, Applications, Hydrogen production and storage, Safety issues and life cycle analysis of fuel cells, Economic and environmental aspects.

Course learning outcomes (CLOs):
The students will be able to
1. know the components involved in energy auditing
2. know energy conservation and waste heat recovery techniques
3. evaluate the performance of industrial boilers, furnaces
4. know the types of fuel cells, and hydrogen production/storage

Recommended Books:

1. *Charles E.B., World Energy Resources, Springer (2002).*
2. *Kenney, W.F., Energy Conservation in the Process Industries, Academic Press (1984).*
3. *Green, R., Process Energy Conservation, ChemicalEngineering Magazine, McGraw Hill (1982).*
4. *Basu, S., Fuel Cell Science and Technology, Springer (2007).*
5. *O'Hayre, R.P., Cha, S., Colella, W., and Prinz, F.B., Fuel Cell Fundamentals, Wiley (2006).*
6. *Bureau of Energy Efficiency, Government of India (www.beeindia.in)*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH223 CATALYTIC REACTOR ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objective:
To learn catalytic phenomena with extensions to reactor design and catalyst characterization.

Introduction: Current trend in applied catalysis, Evolution of important concepts and Techniques in Heterogeneous catalysis.

Adsorption: Adsorption isotherm and isobars, Kinetics of surface reactions, Rates of heterogeneous and homogeneous reactions.

Catalysis: Definition of catalyst activity, Selectivity of catalyst, Different types of catalyst and their applications, Engineering properties of catalysts, Preparation and characterization of catalysts, Method of estimating surface area, Method of estimating pore volume and diameter, Kinetics of fluid-solid, Non-catalytic and catalytic reactions and Kinetic parameters estimations.

Diffusion Effects and Deactivation of Catalysts: Effect of mass transfer on catalytic selectivity, Effect of intraparticle diffusion, Effect of interparticle transport, Bi-functional catalyst, Catalyst deactivation.

Heterogeneous Reactors: Fixed-bed reactor, Slurry reactor, Trickle bed reactor, Fluidized bed reactor and moving bed reactor.

Course learning outcomes (CLOs):
The students will be able to
1. understand and develop catalytic reaction mechanism
2. solve problems involving mass and heat transfer effects in heterogeneous catalysis
3. select catalytic materials, prepare and characterize catalysts
4. apply the concepts of heterogeneous catalytic reactions to reactor design

Recommended Books:

1. *Bowker, M., The Basis and Applications of Heterogeneous Catalysis, Oxford University Press, USA (1998).*
2. *Satterfield, C.N., Heterogeneous Catalysis in Industrial Practice, McGraw-Hill (1998).*
3. *Carberry, J.J.,Chemical and Catalytic Reaction Engineering, Dover Publications(2001).*
4. *Fogler, H.S., Elements of Chemical Reaction Engineering, Prentice-Hall (2009).*
5. *Levenspiel, O., Chemical Reaction Engineering, Wiley Eastern (2006).*
6. *Bischoff, K.B., Wilde, J.D., and Froment, G.F., Chemical Reactor Analysis and Design, Wiley (2010).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH225 PROCESS EQUIPMENT DESIGN

L	T	P	Cr
3	1	0	3.5

Course Objective:
To learn about the design procedures of process equipment used in chemical process plants.

Introduction: TEMA standards, Mass transfer equipment, Chemical reactor heating and cooling systems, General design procedures.

Heat Transfer Equipment: Shell and tube heat exchangers general design procedures, Fluid allocation, Baffles, LMTD and ε-NTU methods, Design calculations by Kerns' and Bell's methods, Condenser and re-boiler design, Plate type heat exchanger design, Fouling.

Mass Transfer Equipment: Process design calculations for binary and multi-component distillation, Fenske-Underwood-Gilliland Method, Selection of key components, Feed stage location, Types of plate contractors, Tray layout and hydraulic design, Packed towers and column internals, Types of packing, General pressure drop correlations, Column diameter and height.

Chemical Reactors: Types of heating and cooling methods, Design of helical coil system, Jacketed systems.

Software Tools: Application of software tools like ASPEN PLUS, COMSOL etc. for analysis of heat and mass transfer equipments and reactor systems.

Course learning outcomes (CLOs):

The students will be able to

1. design heat transfer equipment and mass transfer equipment
2. design cooling and heating systems of chemical reactors
3. use software tools for the analysis of process equipment

Reference Books:

1. *Ray, S., and Gavin, T., Coulson and Richardson's Chemical Engineering series Chemical Engineering Design, Volume 6 (2010).*
2. *Kern, D.Q., Process Heat Transfer, International Student Edition, McGraw Hill (2002).*
3. *Ludwig E.E., Applied Process Design in Chemical and Petrochemical Plants Vol I, II, III, Gulf Publishing Co. (1995).*
4. *Perry, R.H. and Green, D, Chemical Engineer's Handbook, McGraw Hill, NewYork. (2008).*
5. *Seader, J. D., and Henley, E. J., Separation Process Principles, Wiley (2001).*

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH226 FUEL COMBUSTION SYSTEMS

L	T	P	Cr
3	1	0	3.5

Course Objective:
To learn about types of fuels and their characteristics, and combustion systems with emphasis on engineering applications.

Introduction: Perspective of fuels and combustion technology, Types and general characteristics of fuels, Proximate and ultimate analysis of fuels, Moisture and heating value determination, Gross and net hearting values, Calorimetry, DuLong's formula, Flue gas analysis, Orsat apparatus.

Thermodynamics and Kinetics of Combustion: Properties of mixture, Combustion stoichiometry, Chemical energy, Chemical equilibrium and criteria, Properties of combustion products, First law combustion calculations, Adiabatic flame temperature (analytical and graphical methods), Simple second law analysis, Elementary reactions, Chain reactions, Pre-ignition kinetics, Global reactions, Reactions at solid surface.

Combustion of Solid Fuels: Drying, Devolatilization, Char combustion, Fixed bed combustion, Suspension burning, Fluidized bed combustion.

Combustion of Liquid and Gaseous Fuels: Spray formation and droplet behaviour, Oil fired furnace combustion, Gas turbine spray combustion, Direct and indirect injection combustion in IC engines, Energy balance and furnace efficiency, Gas burner types, Pulse combustion furnace, Premixed charge engine combustion, Detonation of gaseous mixtures.

Course learning outcomes (CLOs):
The students will be able to
1. characterize the various types of fuels
2. apply thermodynamics and kinetics of combustion
3. analyze the combustion mechanisms of various fuels

Recommended Books:

1. *Kuo, K.K., Principles of Combustion, John Wiley and Sons, Inc.(2005).*
2. *Sarkar, S., Fuels and Combustion, Orient Longman, (1990).*
3. *Sharma, S.P., and Chander, M., Fuels and Combustion, Tata Mcgraw Hill (1984).*
4. *Borman, G.L., and Ragland, K.W., Combustion Enginnering, McGraw Hill (1998).*
5. *Bhatt, B.I., and Vora, S.M., Stoichiometry, Tata Mcgraw Hill (1996).*
6. *Bureau of Energy Efficiency, Government of India (www.beeindia.in)*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH231 NANOCHEMICAL ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objective:
To learn the fundamental concepts of energy, mass and electron transport in materials confined or geometrically patterned at the nanoscale, where departures from classical laws are dominant.

Introduction: History of nano-revolution, Nano scale materials and their applications, Carbon nano tubes, Organic and inorganic nano structures, Main engineering activities of design, manufacture and testing in nanotechnology context.

Materials: An overview of the physical (mechanical, electrical) and chemical properties of different classes of solid materials such as metals, semi conductors, insulators and polymers, Focus on different nanomaterials: Carbon nanotubes, inorganic nanowires, organic molecules for electronics, biological and bio-inspired materials, metallic nanomaterials, Different shape nanomaterials, Examples of size effects of properties observed in thin films, colloids and nano-crystals.

Characterization: Photoelectron, Optical and ion spectroscopy and probe microscopy, Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM).

Applications: Examples of applications in Micro and nano-technology including, Micro fluidics, Micro Electron Mechanical Systems (MEMS) membrane technology, Drug-delivery, Catalysts and coatings.

Course learning outcomes (CLOs):

The students will be able to

1. apply basic concepts of nanotechnology and nanoscience
2. select different nano-materials and perform their characterization
3. apply the concepts of nanotechnology in chemical engineering

Recommended Books:

1. *Zikang, T. and Ping, S.,NanoScience and Technology: Novel Structures and Phenomena, Taylor and Francis (2003).*
2. *Rieth, M.,Nano-Engineering in Science and Technology: An Introduction to the World of Nano design, World Scientific (2003).*
3. *Kelsall, R., Hamley, I., and Geoghegan, M.,Nanoscale Science and Technology, Wiley (2005).*
4. *Ventra, M.D.,Evoy, S., and Heflin J.R., Jr., Introduction to Nanoscale Science and Technology, Springer (2004).*
5. *Meyyappan, M., Carbon Nanotubes, Science and application; CRCPress(2005).*
6. *Watarai, H., Teramae, N., and Sawada, T., Interfacial Nano-chemistry, Kluwer Academic/Plenum Press(2005).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH333 SELECTED TOPICS IN FLUID MECHANICS

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To learn the basics and advanced concepts of fluids and fluid flow including flow of compressible fluids, laminar and turbulent boundary layer flows and multiphase flow.

Introduction: Basic fluid flow concepts, Velocity and stress fields, Classification of fluids, Fluid kinematics, Navier-Stokes Equation, Energy equation (Bernoulli), Pipe flows, Pumps and compressors.

Flow of Compressible Fluids: Basic Equations and assumptions, Isentropic flow through nozzles, Adiabatic friction flow, Isothermal friction flow, Sonic and Sub-sonic flows

Boundary Layer: Laminar and turbulent boundary layer flows, Boundary layer parameters, Prandtl's boundary layer equations, Blasius solution, von-Karman momentum integral equation, Boundary layer separation.

Flow Pattern: Flow pattern of gas-liquid and liquid- liquid concurrent flow in horizontal and vertical tubes.

Pressure Drop and Hold-up: Holdup relations for various multiphase flow regimes, Friction factor models and Correlations of Lokhart-Martinelli and Hughmark, Evaporating and condensing one component flow, Equations of change with interphase transport.

Drops and Bubble Dynamics: Formation of drops and bubbles, Motion of single drops and bubbles, Effect of circulations and interaction for drops and bubbles.

Course learning outcomes (CLOs):
The students will be able to
1. estimate boundary layer parameters for different flows
2. apply the compressible flow equations
3. perform dynamics of pressure drop and hold-up
4. perform dynamics of drops and bubbles quantitatively

Recommended Books:

1. *McCabe, W., Smith, J., and Harriot, P., Unit Operations of Chemical Engineering, McGraw-Hill (2005).*
2. *Perry, R.H. and Green, D.W., Perry's Chemical Engineer's Handbook, McGraw-Hill (1997).*
3. *Foust, A.S., Wenzel, L.A., and Clump, C.W., Principles of Unit Operations, Wiley & Sons (1980).*
4. *Walls, G.B., One Dimensional Two-phase Flow, McGraw-Hill (1969).*
5. *Govier, G.W., and Aziz, K., Flow of Complex Mixture in Pipes, Van Norstand Reinhold Co. (1972).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH233 SELECTED TOPICS IN HEAT TRANSFER

	L	T	P	Cr
	3	**1**	**0**	**3.5**

Course Objective:

To learn the basics and advanced concepts of heat transfer and design methodologies involved in various types of heat transfer devices.

Shell-and-Tube Heat Exchangers: Classification, Design methodology, TEMA standards, Mechanical turbulators.

Plate Heat Exchangers: Introduction, Classification, Types of corrugations, Advantages over conventional heat exchangers, Design methodology.

Reactor Heating and Cooling Systems: Time required for heating and cooling of agitated batch reactors, Helical cooling coils, Jacketed vessels.

Cross Flow Compact Heat Exchangers: Classification, Types of fins, Tube-fin and plate-fin heat exchangers, Limitations, Design methodology.

Advanced Thermal Systems: Heat Pipes: Classification, Applications, Limitations, Design methodology, Micro channels**:** Applications, Advantages, Nanofluids in thermal systems.

Computational Fluid Dynamics: Applications of CFD in heat transfer systems design.

Course learning outcomes (CLOs):

The students will be able to

1. understand various types of heat transfer processes and devices
2. select and analyze the heat transfer device
3. solve the problems of heat transfer related to nano-fluids, micro-channels and heat pipes
4. use software tools for solving heat transfer problems

Recommended Books:

1. *Saunders E.A.D., Heat Exchangers: Selection, Design and Construction, Longman Scientific and Technical (1988).*
2. *Kakaç, S., and Liu, H., Heat Exchangers: Selection, Rating, and Thermal Design, CRC Press (2002).*
3. *Sinnott, R.K., Coulson, J.M., and Richardson, J.F., Chemical Engineering Design, Butterworth-Heinemann (2005).*
4. *Shah, R.K., Subbarao, E.C., andMashelkar, R.A., Heat Transfer Equipment Design, Taylor & Francis (1988).*
5. *Das, S.K., Choi, S.U., Yu, W., and Pradeep, T., Nanofluids: Science and Technology, Wiley & Sons (2007).*
6. *Anderson, D.A., Introduction to Computational Fluid Dynamics, Cambridge University Press (2005).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH234 POLYMER REACTION ENGINEERING

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:
To understand mathematical modeling of polymerizations, and design batch and continuous reactors.

Introduction: Review of types and methods of polymerization, MW and MWD in polymers, Important aspects of polymer science.

Polymerization Kinetics: Step growth and chain growth (free radical, anionic and cationic polymerization) kinetics, Modeling and Simulation, Diffusion controlled polymerization, Copolymerization.

Reactors: RTD, Macro and micro mixing in reaction vessels, Comparison of performances of batch reactors for ionic, free radical, and step growth polymerizations, their degree of polymerization and MWD.

Heterogeneous Polymerizations: Bulk, solution, suspension, and emulsion polymerization, Application of continuous emulsion polymerization, Co-ordination polymerization in fluidized bed reactor.

Reactor Design: Fundamentals of batch and continuous polymerizations reactors for tailor-making of polymers, Qualitative account of control engineering considerations.

Course learning outcomes (CLOs):

The students will be able to

1. perform mathematical modeling of different types of polymerizations
2. determine degree of polymerization and molecular weight distribution quantitatively
3. design batch and continuous reactors for the polymerization

Recommended Books:

1. *Neil A.D., Rafael G., Laurence, R.L., and Tirrel, M., Polymerization Process Modeling, VCH (1996).*
2. *Kumar, A., and Gupta, S.K., Fundamentals of Polymers, McGraw Hill (1998).*
3. *Schork, F.J, Deshpande,P.B., and Kenneth W.L., Control of Polymerization Reactors, Marcel Dekker (1993).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessionals (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH235 MOLECULAR MODELING AND SIMULATION

L	T	P	Cr
3	1	0	3.5

Course Objective:

To learn to mimic the real system and phenomena in virtual world using molecular level information and computational resources and to develop and design the novel performance chemicals and materials.

Introduction: Need of molecular modelling and simulation, Postulates of statistical mechanics, Ergodic hypothesis.

Statistical Ensembles and Partition Functions: System and particle partition function and relation to thermodynamics, Micro-canonical ensemble, Canonical ensemble, Isothermal-isobaric ensemble, Grand-canonical ensemble, Gibbs ensemble, Thermodynamic equivalence of ensembles, Ensemble average and time average equivalence.

Empirical Force Field Models: General features of molecular mechanics force fields, Bond stretching, Bond bending, Dihedrals and torsion, Non-bonded interactions, Hard and soft interactions, Electrostatic interactions, Combination/mixing rules, Standard force fields.

Simulation of Ensembles Using Monte Carlo and Molecular Dynamics Methods: Introduction to Monte-Carlo simulation, Importance sampling and the metropolis algorithm, Implementation of metropolis Monte Carlo algorithm, Simulation cell and periodic boundary conditions, Moves and acceptance criteria, Simulations in different ensembles, Multi-canonical Monte Carlo and the transition matrix, Configurational bias Monte Carlo, Calculation of thermodynamic properties, Introduction to molecular dynamics simulation, Initialization and force calculation, Algorithms to integrate the equations of motion, Thermostats and barostats, Autocorrelation functions, Free energy calculations, Molecular dynamics packages, Design and development of novel performance chemicals and materials for applications in polymers, catalysts, pharmaceuticals and solvents.

Course learning outcomes (CLOs):

The students will be able to

1. apply the principles of molecular mechanics in molecular modeling
2. apply various simulation techniques for model solutions
3. use molecular modeling software
4. design and develop novel performance chemicals and materials for applications in polymers, catalysts, pharmaceuticals

Recommended Books:

1. *McQuarrie, D.A.,Statistical Mechanics, University Science Books (2000).*
2. *Frenkel, D.,andSmit, B.,Understanding Molecular Simulation: From Algorithms to*
3. *Applications, Academic Press, (2002).*
4. *Leach, A.R., Molecular Modeling: Principles and Applications, Pearson Education Ltd. (2001).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25

PCH236 ADVANCED SEPARATION PROCESSES

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective:

To understand the governing mechanisms and driving forces of various advanced separation processes and to perform process and design calculations for advanced separation processes.

Membrane Separation Processes: Types and properties of membranes, Membrane modules, Transport mechanism in membrane process, Formation of liquid membranes, Operational aspects of liquid membrane.

Ultrafiltration: Ultrafiltration modules and applicability, Concentration polarization, Fundamentals of reverse osmosis, Osmotic pressure, Relation between chemical potential and osmotic pressure, Factors affecting the performance of reverse osmosis plant, reverse osmosis membrane module, Membrane age, Advantages, disadvantages and application of reverse osmosis process.

Pervaporation: Theory of pervaporation, Separation factor, Classical pervaporation, Factors affecting pervaporation, Air heated pervaporation, Osmotic distillation, Thermo-pervaporation, Reactive pervaporation, Advantages of pervaporation, Application of pervaporation.

Chromatographic Separations: Theory of chromatographic separation, Selectivity or separation factor, Efficiency of chromatographic system, Types of chromatography, Liquid chromatography, Liquid-solid chromatography, Advantages and disadvantages of chromatographic separations.

Gas Separation: Different techniques of gas separations and their applications.

Dialysis: Theory of dialysis, Separation factor in dialysis, Fluid film resistance in dialysis, Dialysis membrane, Applications of dialysis process.

Course learning outcomes (CLOs):

The students will be able to

1. apply modern separation techniques in various applications
2. analyze and design novel membranes for intended application
3. analyze and design pervaporation, chromatography and dialysis based separation processes

Recommended Books:

1. *Seader J.D., Ernet J. Henlay, and Keith, D., Separation Process Principles,Wiley (2010).*
2. *King, C.J., Separation Processes, Tata McGraw - Hill Publishing Co., Ltd. (1982).*
3. *Osadar, V., and Nakagawa, I.,Membrance Science and Technology, Marcel Dekkar (1992).*
4. *Schoew, H.M., New Chemical Engineering Separation Techniques,Interscience Publishers (1972).*
5. *Kestory, R.E., Synthetic Polymeric Membrances, Wiley (1987).*

Evaluation Scheme:

S.No.	Evaluation Elements	Weightage (%)
1.	MST	30
2.	EST	45
3.	Sessional (may include Assignments/Projects/Tutorials/Quizes/Lab Evaluations)	25