THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

SEMETER-WISE COURSE SCHEME

M.Tech.

CHEMICAL ENGINEERING

2021

SCHEME OF COURSES FOR M. TECH (CHEMICAL ENGINEERING)
(w. e. f. from July, 2021)

Program Educational Objective (PEO)

1) Impart the knowledge to the students on advance topics in Chemical Engineering.
2) Create an environment conducive to working with multidisciplinary groups in academic institute, Industries and other organizations.
3) Broaden their capabilities for analytical and experimental research, analysis of data and drawing relevant conclusion for scholarly writing, presentation and knowledge creation.
4) To pursue lifelong reflective learning to fulfil their goals.

Program Outcomes:

PO1 Demonstrate knowledge of fundamentals, scientific and/or engineering principles.
PO2 Able to analyze and apply the state of art tools including software tools in addressing challenges in Chemical Processes.
PO3 Identify the constraints, assumptions and use appropriate equipment and techniques for data collection.
PO4 Analyze experimental data and interpret experimental results with respect to constraints and theory.
PO5 Ability to design process within realistic constraints to satisfy project requirement for chemical process/systems.
PO6 Able to apply scientific and/or engineering principles towards solving engineering problems
PO7 Communicate professionally to express views and to publish technical journals.

First Semester

S. No.	Course	Course Name	L	T	P	Cr
1.	PCH101	CHEMICAL ENGINEERING THERMODYNAMICS	3	1	0	3.5
2.	PCH106	REACTION ENGINEERING & REACTOR ANALYSIS	3	1	0	3.5
3.	PCH201	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING	3	0	2	4.0
4.	PCH206	TRANSPORT PHENOMENA	3	1	0	3.5
5.	PCH105	CHEMICAL ENGINEERING LAB I	0	0	2	1.0
6.	PMA102	RESEARCH METHODOLOGY	2	0	2	3.0
7.		ELECTIVE I	3	1	0	3.5
		Total	**17**	**4**	**6**	**22**

Second Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH202	PROCESS MODELING AND SIMULATION	3	0	2	4.0
2.	PCH107	SEPARATION PROCESSES	3	1	0	3.5
3.	PCH224	PROCESS DYNAMICS & CONTROL	3	1	0	3.5
4.	PCH205	CHEMICAL ENGINEERING LAB II	0	0	2	1.0
5.		ELECTIVE II	3	1	0	3.5
6.		ELECTIVE III	3	1	0	3.5
		Total	**15**	**4**	**4**	**19**

Third Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH391	SEMINAR				4.0
2.	PCH392	MINOR PROJECT				**6.0**
3.	PCH491	DISSERTATION (START)				
		Total				**10.0**

Fourth Semester

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

Total Credits: 67

Elective-I

S. No.	Course	Course Name	L	T	P	Cr
1.	PCHXXX	CHEMICAL PROCESS OPTIMIZATION	3	1	0	3.5
2.	PCHXXX	RENEWABLE ENERGY RESOURCES	3	1	0	3.5
3.	PCH216	BIOPROCESS ENGINEERING	3	1	0	3.5
4.	PCH217	ENVIRONMENTAL POLLUTION CONTROL	3	1	0	3.5
5.	PCHXXX	PETROLEUM & PETROCHEMICALS	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.	PCHXXX	POLYMER ENGINEERING	3	1	0	3.5
3.	PCH225	PROCESS EQUIPMENT DESIGN	3	1	0	3.5
4.	PCH222	ENERGY RESOURCES & MANAGEMENT	3	1	0	3.5
5.	PCHXXX	AIR POLLUTION AND ABATEMENT	3	1	0	3.5

Elective-III

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PCH231	NANOSCIENCE AND TECHNOLOGY	3	1	0	3.5
2.	PCH214	PROCESS INTEGRATION	3	1	0	3.5
3.	PCH213	PROCESS DEVELOPMENT AND SCALE-UP STUDIES	3	1	0	3.5
4.	PCHXXX	SOLID WASTE MANAGEMENT	3	1	0	3.5
5.	PCH235	MOLECULAR MODELING AND SIMULATION	3	1	0	3.5

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SYLLABUS

FOR

M. Tech.

CHEMICAL ENGINEERING

2021

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 chemical process engineering.

Review of Basic Concepts of Thermodynamics: Energy and entropy balances, Equilibrium criteria, Chemical potential, Equations of state, Theory of corresponding states, Gibbs-Duhem relation, Departure functions.

Thermodynamic Properties of Fluids: Thermodynamic properties from volumetric and thermal data, Fugacity and fugacity coefficient for real gas mixtures, Fugacity of a component in a mixture, Fugacity of liquid and solid, Ideal solutions, Raoult's law, Henry's law, excess properties, Phase equilibria from an equation of state.

Free Energy Models: Margulus, Redlich-Kister equation, Wohl's, Wilson and NRTL equations, 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.

Molecular Thermodynamics: Molecular theory of fluids, Microscopic view of internal energy, Intermolecular forces and Potential functions, Thermodynamic properties and Statistical Mechanics, Molecular basis for mixture behavior

Course learning outcomes (CLOs):
The students will be able to
1. apply fundamental concepts of thermodynamics to chemical engineering applications.
2. estimate the thermodynamic properties of fluids using the equations of state.
3. estimate the thermodynamic properties of fluids using the excess Gibbs free energy models.
4. estimate thermodynamic properties of fluids in multi-component mixtures.
5. apply the concepts of molecular thermodynamic and statistical mechanics to estimate the thermodynamic properties of fluids.

Recommended Books:

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

Evaluation Scheme:

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

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: Mole balance, Conversion, Reaction order and rate law, Kinetics of homogeneous reactions, Interpretation of reaction data. Stoichiometry of batch and flow system. Analysis of batch reactor data through differential method of analysis, Integral method of analysis and nonlinear regression.

Isothermal Reactor Design: Design equations for batch, Plug flow, Back-mix flow and Semi-batch reactors. Design of CSTRs, single CSTR, CSTRs in series, CSTRs in parallel, A second order reaction in CSTR. Pressure drop in reactors. Flow through a packed bed.

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, heterogeneous data analysis for reactor design.

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 to find reaction rate of homogeneous reaction.
2. analyze and interpret experimental data for isothermal reactors
3. solve problems involving non isothermal reactor operation and design
4. solve problems involving heterogeneous reactions and mechanisms.
5. analyze and model nonideal 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/Quizzes/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/Quizzes/Lab Evaluations)	35

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/Quizzes/Lab Evaluations)	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/Quizzes)	50
2.	Lab Evaluation (Viva-voce/record/performance)	50

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. knowledge of the various simulation approaches
4. useprocess 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/Quizzes/Lab Evaluations)	35

PCH107 SEPARATION PROCESSES

L	T	P	Cr
3	2	0	4

Course Objective:

To learn concepts and design principles of separation processes and equipment.

Introduction: Review of stage and diffusional processes, Bubble point and dew point temperature, vapor-liquid equilibrium and Binary distillation.

Multi component Distillation: Distillation of multi-component mixtures, Bubble point and dew point temperature of multi-component mixture, Fenske-Underwood-Gilliland method, Selection of two key components, Distribution of non-key components at total and actual reflux, Feed stage location, Azeotropic distillation, Extractive distillation, Reactive 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 extraction, Graphical equilibrium stage method, Determination of number of equilibrium stages, Extraction with intermediate feed and reflux, Extraction efficiency, Liquid-liquid extraction with chemical reaction, 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.

Membrane Separations: Types membrane separation processes, theory and principles of liquid and gas permeation processes, counter current and cross-current gas permeation, Dialysis, Reverse Osmosis, Ultrafiltration, Microfiltration, Pervaporation and Gas permeation chromatography.

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. Preform the multi-component distillation design calculations
2. Analyze and solve multistage liquid-liquid extraction problems
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/Quizzes/Lab Evaluations)	25

PCH224 PROCESS DYNAMICS AND CONTROL

L	T	P	Cr
3	1	0	3.5

Course Objective:
To study dynamic behavior of nonlinear, distributed and other complex systems, and design of control schemes.

Introduction: Review of dynamic behavior of linear systems and their control system design,

Linear process dynamics: Linear systems with complex dynamics, Distributed-parameter systems, Stability, and Control.

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 systems, Development of empirical models from process data, Illustrative case studies.

Design of controller using frequency response: Nyquist, Bode, and Nichols analysis, Different methods of controller tuning.

Advanced Control Strategies: Cascade control, Ratio control, Feed forward control, Override control, Dead-time compensation, Model-based control, Computed variable control, Introduction to nonlinear, adaptive, and plant wide control.

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 control schemes and their applications in various processes.
4. explain 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/Quizzes/Lab Evaluations)	25

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/Quizzes)	50
2.	Lab Evaluation (Viva-voce/Lab record/Performance)	50

PCHXXX CHEMICAL 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, Point Estimation method: Successive quadratic estimation, Solutions for one dimensional problem 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/Quizzes/Lab Evaluations)	25

PCHXXX RENEWABLE ENERGY RESOURCES

L	T	P	Cr
3	1	0	3.5

Course Objectives: To study and appreciate the various types of renewable energy resources.

Introduction: Energy, Present and future trends of energy consumption, Resources in India and worldwide, Introduction to different non-conventional energy sources, Detailed study of following resources with particular reference to India.

Solar energy: Solar radiation and its measurement, Limitation in application of solar energy, Solar collectors-types and constructional details, Solar water heating, Application of solar energy for residential and industrial heating, Drying, Space cooling, Water desalination, Photovoltaic power generation using silicon cells.

Bio-Fuels: Importance, Combustion, Pyrolysis and other thermo chemical processes for biomass utilization-performance analysis, Alcoholic fermentation, Anaerobic digestion for biogas production.

Wind Energy: Principle of energy from wind, Windmill construction, Operational details, Mechanical power production, and Electricity generation.

Tidal Energy: Introduction, Causes of tides and their energy potential, Enhancement of tides, Power generation from tides and problems, Principles of ocean thermal energy conversion (OTEC) analysis.

Geothermal Energy: Geo thermal wells and other resources dry rock and hot aquifer analysis, Harnessing geothermal energy resources.

Energy Storage and Distribution: Importance, Biochemical, Chemical, Thermal, Electrical storage, Fuel cells, distribution of energy.

Scope and Economics: Calculation of energy cost from renewable, Comparison with conventional fuel driven systems, Calculation of CO reduction, Incremental costs for renewable options.

Course Learning Outcomes (CLO):
The students will be able to:

1. calculate energy demand and availability from various resources
2. calculate the parameters associated with the use of solar energy and its harnessing
3. identify effective utilization of bio-fuels and geothermal energy resources
4. identify and analyze the ways of harnessing wind and tidal power
5. identify energy storage and distribution methods
6. analyze the economic and environmental aspects of renewable energy resources.

Recommended Books:

1. Rai, G.D., Non-Conventional Energy Sources, Khanna Publishers (2001).
2. Twiddle, J. Weir, T., Renewable Energy Resources, Cambridge University Press (1986).
3. Duffie, J. A., Beckman, W. A., Solar Engineering of Thermal Processes, John Wiley(1980).
4. Sukhatme, S. P., Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill, (2001).
5. Garg, H.P. and Prakash, J., Solar Energy: Fundamentals and Applications, Tata McGraw-Hill (2001).

Evaluation Scheme:

S. No.	Evaluation Elements	Weightage (%)
1	MST	30
2	EST	45
3	Sessional (may includes tutorials/ assignments/ quiz’s etc)	25

PCH216 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/Quizzes/Lab Evaluations)	25

PCH217 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/Quizzes/Lab Evaluations)	25

PCHXXX PETROLEUM AND PETROCHEMICALS

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

Course Objective:
To impart knowledge of petroleum refining, hydrocarbon processing, and derived petrochemicals.

Introduction: World petroleum resources, Petroleum industries in India, Chemistry and composition of crude oil, Transportation and pretreatment of crude oil, New trends in refinery.
Classification and Characterization: Classification of petroleum, Characterization of petroleum fractions.
Crude oil distillation: Impurities in crude oil, Desalting of crude oil, Atmospheric distillation and vacuum distillation units.
Conversion Processes: Thermal conversion processes, Conventional vis-breaking and soaker visbreaking process, Coking processes, Catalytic conversion processes, Fluid catalytic cracking, Catalytic reforming, Hydrocracking, Catalytic alkylation, Catalytic isomerization and catalytic polymerization.
Finishing Processes: Sulphur conversion processes, Sweetening processes, Solvent extraction process, Hydrotreating process.
Lube oil manufacturing Processes: Solvent extraction of lube oil fractions, Manufacture of petroleum wax, Hydro finishing process.
Petrochemicals: Primary petrochemicals such asethylene, propylene, butadiene, benzene, toluene, xylene and their derived polymers.

Course Learning Outcomes (CLO):

Upon completion of this course, the students will be able to:

1. select the appropriate characterization parameters.
2. specify the properties of petroleum products.
3. attain knowledge of various separation & conversion processes involved in petroleum refining.
4. attain knowledge of manufacturing of various petrochemical products.

Reference Books:

1. *Nelson, W. L. Petroleum Refinery Engineering, Tata McGraw Hill Publishing Company Limited, (1958) 4th Ed.*
2. *Garry,J.H. Petroleum Refining Technology and Economics, Marcel Dekker Inc., (2001) 4th Ed.*
3. *Wells G. M.Handbook of petrochemicals and processes, Ashgate Publishing Ltd, (1999) 2nd Ed.*
4. *Spitz P. H. Petrochemicals: The rise of an industry, John Wiley & Sons, (1999).*
5. *Sarkar, G.N. Advanced Petroleum Refining, Khanna Publishers, (2000).*

Evaluation Scheme:

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

PCHXXX POLYMER ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objective:
To understand fundamental and applied knowledge of polymers and their manufacture, processing, characterization, mathematical modeling of polymerizations, design batch and continuous reactors.

Introduction: Classification of polymers, review of types and methods of polymerization, Average molecular weight and Molecular weight distribution (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.

Polymer processing: Introduction, Rheology, Mixing and Compounding, Extrusion, Compression molding, Transfer molding, Injection molding, Blow molding, Calendaring, Coating, Casting, Thermoforming, etc.

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. Identify the synthesis technique for different polymers.
2. perform mathematical modeling of different types of polymerizations
3. determine degree of polymerization and molecular weight distribution quantitatively
4. 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/Quizzes/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 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 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. *Couper, J.R., Penney, W.R., Fair, J.R. and Walas, S.M., Chemical Process Equipment, Selection and Design, Revised Second Edition, Butterworth-Heinemann (2010).*
4. *Ludwig E.E., Applied Process Design in Chemical and Petrochemical Plants Vol I, II, III, Gulf Publishing Co. (1995).*
5. *Perry, R.H. and Green, D, Chemical Engineer's Handbook, McGraw Hill, New York. (2008).*
6. *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/Quizzes/Lab)	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/Quizzes/Lab Evaluations)	25

PCHXXX: AIR POLLUTION AND ABATEMENT

L	T	P	Cr
3	1	0	3.5

Course objectives:

To facilitate understanding of the principles underlying designing of industrial ventilation systems and mechanical devices used for particulate and gaseous emission control from various sources. To acquire basic knowledge in management strategies for the control of air pollution

Introduction: Atmospheric composition, definition, origin of air pollution, Meteorological aspects thermal phenomena of homo and heterospheres lapse rates and stability, wind roses, dynamism of atmosphere, energy balance, Plume behaviour and principles of air pollutants dispersion (with special reference to Gaussian dispersion model)

Sampling & Analysis: Stack sampling (with special emphasis on isokinetic sampling) and analysis for temperature, flow velocity, composition, CO_x, NO_x, SO_x, HC and SPM

Design of Industrial Ventilation Systems: Component of Ventilation systems, Air pollution control systems, Hood specifications and design, Duct specifications and design, Blowers, stacks.

Particulate Emission Control: Design and operation - settling chambers (Both laminar and turbulent flow), Cyclone and multiclones, Scrubbers, Bag houses and Electrostatic precipitators.

Gaseous Emissions Control: Design and operation - scrubbers for gaseous pollutant removal, Adsorption columns and condensation devices.

Control of Mobile Sources: Control of crank case emissions, Evaporative emissions control, Air fuel ratio, Automobile emission control, Catalytic convertors, Gasoline and diesel powered vehicles, Alternative fuels.

Air Pollution Mitigation Measures: Green belt design, Management strategies for air pollution abatement.

Course learning outcomes (CLOs):

The students will be able to

1. Design industrial ventilation systems
2. Design and evaluate removal efficiency of particulates of various air pollution control devices
3. Demonstrate the designing and operation of various air pollution control devices for the removal of gaseous pollutants from both stationary as well as mobile sources
4. Examine the management strategies for air pollution abatement

Recommended books:

1. *De Nevers, N., Air Pollution Control Engineering, McGraw-Hill (1995).*
2. *Flagan, R.C., and Seinfeld, J.H., Fundamentals of Air Pollution Engineering, Prentice Hall (1988).*

3. *Boubel RW, Fox DL, Turner B and Stern AC, Fundamental of Air Pollution, Academic Press, 3rd ed. (1994).*

4. *Perkins HC, Air Pollution, McGraw Hill (2004).*

Evaluation Scheme:

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

PCH231 NANOSCIENCE AND TECHNOLOGY

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, semiconductors, 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/Quizzes/Lab	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/Quizzes/Lab Evaluations)	25

PCH213 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/Quizzes/Lab	25

PCHXXX SOLID WASTE MANAGEMENT

L	T	P	Cr
3	1	0	3.5

Course Objective:

Facilitate understanding of issues and approaches associated with solid waste, hazardous waste and special category waste management. Able to access legal requirements and strategies associated with management of municipal, hazardous and special solid waste.

Introduction: Solid waste management; Nuisance potential and extent of solid waste problems; Regulatory requirements.

Characterization and Quantification: Types; composition; Methods of quantification and characterization of wastes.

Collection, Storage and Transportation of Wastes: Types of collection systems and their components; Segregation at source; solid waste transport vehicles; solid waste transit points and transport routes; storage and handling of hazardous waste.

MSW Management: Recycling; Recovery of useful components of SW and its applications; composting; bio-gasification; waste to energy production.

Hazardous waste Management: Definition; sources; classification; collection and segregation; Chemical and biological treatment of hazardous waste: Solidification and stabilization refuse derived fuel, gasification, pyrolysis, incineration, disposal, management of ETP sludge.

Sanitary landfills: Site selection and approval; design; development; operation and closer of landfills; management of leachate and landfill gases; environmental monitoring of landfill sites;

Special category wastes and their management: Construction and demolition wastes; biomedical wastes; Radioactive waste; E- waste; Plastic waste; Oil sludge and slurries.

Course Learning Outcomes (CLOs):

On the completion of course, students will be able to:

1. Understanding and appreciating the environmental pollution and nuisance potential of municipal solid waste and of special category wastes.
2. Awareness of management of MSW and hazardous waste according their characteristics (selection of management technique)
3. Acquiring the knowledge of collection and transportation and solid waste route selection and types of waste collection.
4. Regulatory requirement applicable to the handling and management of MSW and special category waste.

Recommended Books

1. *United Nations Environment Programme (UNEP) Solid Waste Management, (2005).*
2. *Pichtel, J, Waste management Practices-Municipal, hazardous and industrial, CRC Press (2005).*
3. *Vesilind P.A., Solid waste engineering, Thomson (2008).*
4. *Blude A.D and Sudaresan B.B, Solid waste management in developing Countries INSDOC (1972).*

5. *Tchobanoglous, C. Vigil, S.A. and Theisen, H., Integrated Solid waste management engineering Principles and management issues, McGraw Hill (1993).*
6. *LaGrega M., Buckingham, P., Evans, J. and ERM. Inc ., Hazardous Waste Management , McGraw Hill (2000).*

Evaluation Scheme:

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