Curriculum Postgraduate Programme

M. Tech. Chemical Engineering
(2022 Session onwards)

Department of Chemical Engineering

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Department Vision and Mission

Vision

The Department aspires to achieve excellence by providing best facilities in the entire spectrum of Chemical Engineering education, research and consultancy.

Mission

To become a pioneer Department of higher learning imparting state of the art education, training and research in the field of Chemical Engineering.

Programme Educational Objectives (PEOs)

PEO1: Professional competence

Imparting knowledge to postgraduate students to enable them for suitable placement in reputed industries, research and development organizations, consultancy firms, academic institutes and other organizations in the field of Chemical Engineering.

PEO 2: Professional growth

Engagement of postgraduates in life-long learning demonstrated through advanced learning and practical exposure.

PEO 3: Research, analysis, design and innovation

Inculcating research, analysis, design and innovation component.

Program Outcomes (POs)

PO1: An ability to carry out independent, collaborative and multidisciplinary research work to solve practical problems

PO2: An ability to write and present a substantial technical report/document

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

PO4: Ability to think critically and use modern tools to solve complex chemical engineering problems

PO5: Ability to work in an ethical manner for the benefit of society and encourage lifelong learning.

Structure of Curriculum for M.Tech Programme in Chemical Engineering

Duration	**Two years (4 semesters)**
Number of Courses	**12 (Theory); 4 (Practical)**
Independent Study/ Seminar	**01**
Dissertation work	**02 semesters**
Total Credits	**65**
Core Courses (Theory)	**8**
Department Electives	**4**

1st Semester

Course Code	Course	Hours/week			Credits
		L	T	P	
CH-501	Computational Techniques in Chemical Engineering	3	0	0	3
CH-503	Chemical Reactor Analysis and Design	3	0	0	3
CH-505	Process Modeling and Simulation	3	0	0	3
CH-507	Process Plant Design	3	0	0	3
CH-xxx	Elective-I	3	0	0	3
CH-xxx	Elective-II	3	0	0	3
CH-511	Computational Techniques in Chemical Engineering Lab	0	0	3	2
CH-513	Selected Experiments in Chemical Engineering	0	0	3	2
Total Credits					**22**

2nd Semester

Course Code	Course	Hours/week			Credits
		L	T	P	
CH-502	Transport Phenomena	3	0	0	3
CH-504	Advanced Separation Techniques	3	0	0	3
CH-506	Industrial Pollution Control Engineering	3	0	0	3
CH-508	Advanced Process Control	3	0	0	3
CH-xxx	Elective-III	3	0	0	3
CH-xxx	Elective-IV	3	0	0	3
CH-512	Process Modeling and Simulation Lab	0	0	3	2
CH-514	Industrial Pollution Control Lab	0	0	3	2
Total Credits					**22**

3rd Semester

Course Code	Course	Hours/week			Credits
		L	T	P	
CH-600	Dissertation (Part-I)	-	-	12	6*
CH-601	Project Seminar/Independent Study	-	-	6	3
Total Credits					**9**

4th Semester

Course Code	Course	Hours/week			Credits
		L	T	P	
CH-600	Dissertation (Part-II)	-	-	24	12*
Total Credits					**12**

Grand total credits = 65

**The credits shall be consolidated after the evaluation of Dissertation (Part-II)*

<u>List of Departmental Electives</u> (3 Credits each)

S.N.	Course Code	Course Title
1.	CH-516	Petrochemical Technology
2.	CH-517	Energy Management and Audit
3.	CH-518	Introduction to Multiphase Flow
4.	CH-519	Natural Gas Engineering
5.	CH-520	Energy Efficiencies in Thermal Utilities
6.	CH-521	Process Intensification
7.	CH-522	Advanced Heat Transfer and Fluid Dynamics
8.	CH-523	Rubber & Plastic Technology
9.	CH-524	Polymer Technology
10.	CH-525	Biomass Conversion Processes
11.	CH-526	Industrial Rheology
12.	CH-527	Membrane Separation Processes
13.	CH-528	Fertilizer Technology
14.	CH-529	Environment Impact Assessment
15.	CH-530	New and Renewable Energy Sources
16.	CH-531	Nanomaterials, Nanoscience and Nanotechnology
17.	CH-532	Leather Fashion Design Technology
18.	CH-533	Instrumental Methods of Analysis
19.	CH-534	Chemical Process Safety and Hazard Management
20.	CH-535	Petroleum Engineering and Technology
21.	CH-536	Computational Fluid dynamics
22.	CH-537	Paint Technology
23.	CH-538	Microbiology for Chemical Engineers
24.	CH-539	Photocatalysis
25.	CH-540	Cement Technology
26.	CH-541	Biorefinery and Bioproducts Engineering
27.	CH-542	Interfacial Science and Engineering
28.	CH-543	Materials for Chemical Engineers
29.	CH-544	Catalysis

Syllabi for M.Tech Chemical Engineering Programme

Course Code	Course Title	L	T	P
CH-501	**Computational Techniques in Chemical Engineering**	**3**	**0**	**0**

Pre-requisites: Knowledge of Differential Equations.

Course objectives: This course has been designed to develop the understanding the computational methods to solve the problems related to the chemical engineering applications. The students are exposed to learn the basic principles, and logical skills in solving the problems using computational methods.

Syllabus:

Linear equations. Solution of linear system by Gaussian elimination with backward substitution, The Gauss-Jordan modification (method), Iterative solution for linear systems, Iterative refinement for linear systems, Jacobi iterative method for linear systems, Gauss-Seidel iterative technique for linear systems, Convergence for the Jacobi method.

Introduction to numerical computations in chemical engineering: General introduction to the subject of numerical analysis, Representing numbers, Polynomial curve fit by least squares method and its application to chemical processes. Newton's divided difference interpolation, Forward differences with equally space base points, Bisection method for one variable, Fixed point iteration for one variable, Newton's method for one variable, Secant method for one variable, Regula Falsi for one variable. **Nonlinear equations**. Fixed point iteration for non-linear systems, Newton's method for non-linear systems, Evaluation of the Jacobian, Steepest decent techniques for non-linear systems

Higher-order ordinary differential equations. Higher order ODEs, R-K for systems of ODE's.

Statistics and data analysis.

Applications to Chemical Engineering: Applications of computational techniques to different chemical engineering problems eg. Calculation of specific volume of real gas binary mixtures, rate equations, material and energy balance, equipment design, handling of experimental data and curve fitting, bubble and dew point calculations, process control etc.

Course Outcomes:

1. The students would be well versed with the principles of computing methods with the theory involved in solving the chemical engineering problems.

2.The students would be able to independently solve the problems in the chemical engineering and would be aware about its applications.

3. Able to convert any chemical engineering problems in mathematical forms.

4. Ability to understand and solve the numerically chemical engineering problems.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	√		√	√	
2	√		√	√	
3	√		√	√	
4	√		√	√	

Recommended books:

1. S. K. Gupta," Numerical Methods for Engineers", Wiley Eastern, (1995).
2. P. Abuja, "Introduction to Numerical methods for chemical engineering", PHI learning Pvt, (2006).
3. S. C. Chapra, R.P. Canale, "Numerical Methods for Engineers", 5th Edition; McGraw Hill(2006).
4. A. Gourdin, M Boumhrat; "Applied Numerical Methods" Prentice Hall India, (2000).
5. G. M. Philips, P. J. Taylor, "Theory and Applications of Numerical Analysis",2nd Edition., Academic Press (1996).
6. Kenneth J. Beers, "Numerical Methods for Chemical Engineering",Cambridge University (2007).

Course Code	Course Title	L	T	P
CH-503	**Chemical Reactor Analysis and Design**	**3**	**0**	**0**

Pre-requisites:	Chemical Reaction Engineering I
Course Objectives:	The course aims to understand the chemical kinetics for homogeneous and heterogeneous reactions and their applications in design of batch and flow reactors. The course aims at understand the non-ideal flow, physical properties of solid catalysts, catalytic and non-catalytic heterogeneous systems.
Syllabus:	**Introduction** Kinetics of homogeneous and heterogeneous chemical and biochemical reactions, single and multiple reactions, order & molecularity, rate constant, elementary and non elementary reactions, Review of design of single and multiple reactions in batch reactor, plug flow reactor, CSTR, and semi batch reactor, packed bed reactors and fluidized bed reactors. **Non Ideal Flow** Residence time distribution of fluid in vessel, Mean residence time, Models for non ideal flow, Dispersion model, N Tanks in series model, conversion in a reactor using RTD data. **Catalysts** Theories of heterogeneous catalysis, Classification of catalysts, catalyst preparation, Promoter and inhibitors, Catalysts Deactivation/Poisoning **Non Catalytic Fluid Solid Reactions** Kinetics and Mass transfer, Selection of model, PCM and SCM models, diffusion through gas film control, diffusion through ash layer control, chemical reaction control, Reactor Design. **Heterogeneous Processes** Global rates of reaction, Types of Heterogeneous reactions, Catalysis, The nature of catalytic reactions, Mechanism of catalytic reactions. Physical Adsorption and Chemisorption, Adsorption isotherms, Rates of adsorption isotherm. **Heterogeneous Process** Effect of Intra Pellet and Mass Transfer on reaction rate, effect of heat transfer on rate of reaction. Gaseous diffusion in single cylindrical pore. Mechanism and kinetics of heterogeneous reactions. **Non isothermal reactor design** General design procedure, optimum temperature progression, adiabatic operation, non adiabatic operation, semi batch reactors. Steady state and unsteady state operations in C.S.T.R and Plug flow reactors, Reactor stability with special reference to C.S.T.R. Introduction to optimization of chemical reactors.
Course Outcomes:	1. To understand the mechanism of chemical kinetics for various types of reactions 2. To design the reactors for homogeneous and heterogeneous reactions 3. To analyze the non-ideality in the flow reactors 4. To understand physical properties and preparation of solid catalysts.

Mapping of course outcomes (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		
2	√		√	√	
3		√	√	√	√
4	√	√	√		

Recommended Books:

1. Levenspiel O., "Chemical Reaction Engineering", 3rd Edition, John Wiley & Sons, Singapore, (1999).
2. Fogler H. S., "Elements of Chemical Reaction Engineering", 3rd Edition, Prentice Hall Inc., (1999)
3. Smith J. M., "Chemical Engineering Kinetics", 3rd Edition, McGraw Hill, (1981).
4. Hill C. G., "Chemical Engineering Kinetics and Reactor Design", John Wiley, (1977).
5. Froment, G.F. and Bischoff, K. B., "Chemical Reactor Analysis and Design", 2nd Edition, John Wiley and Sons, NY, (1990).

Course Code	Course Title	L	T	P
CH-505	Process Modeling and Simulation	3	0	0

Pre-requisites:	Chemical Process Calculations, Heat Transfer, Mass Transfer, Chemical Reaction Engineering
Course Objectives:	The course aims at developing the ability of students in mathematical treatment of chemical engineering processes. The objective is to understand the basic concepts of process modeling and simulation. Starting from formulation of the model, the course presents several processes from chemical engineering, where simulation approaches and mathematical tools are discussed.
Syllabus:	**Process Model** Definition of mathematical model, Classification of models, uses of mathematical models, principles of formulation. **Process Simulation** Scope of process simulation, Formulation of a problem, steady state simulation, Simulation strategies, Process simulator, Structure of process simulator. **Phenomenological Models for Chemical Engineering Systems** Series of isothermal constant holdup CSTRs, CSTRs with variable holdups, Isothermal/non-isothermal plug flow reactors, Two heated tanks, Gas phase pressurized CSTR, Non-isothermal CSTR, Single component vaporizer, Multi-component flash drum, Batch reactor, Reactor with mass transfer, Ideal binary distillation column, Multi-component non-ideal distillation column, Batch distillation with holdup, pH systems, Lumped parameter model of gas absorber, Lumped parameter model of liquid-liquid extraction column, Model foe heat exchanger, Model for interacting & non-intracting tanks, Model for biochemical reaction. **Data Driven Model for Chemical Engineering Systems (Black Box Model)** Use of neural net statistical modeling, short review of artificial neural network, topology and threshold functions, Back propagation algorithms, Application of ANNs in Chemical Engineering, introduction to Genetic Algorithm. **Computer Simulation** Introduction, Computer programming, Newton- Raphson Method, False Position Methods, Euler Method, Runge-Kutta Method.
Course Outcomes:	1. The student would understand the basic concepts of process model formulation, analysis of variables, parameter estimation and simulation with mathematical techniques 2. The student would understand the basic laws of chemical engineering and their mathematical treatment. 3. The student would be able to develop models for chemical engineering systems. 4. The student would get familiar with common mathematical and computational tools for simulation of different chemical engineering processes

Mapping of course outcomes (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓		✓		✓
2	✓		✓		✓
3	✓			✓	
4	✓		✓	✓	✓

Recommended Books:

1. Luyben W L , "Process Modeling Simulation and Control for Chemical Engineers", international ed. McGraw Hill (1990).
2. Rose L M, " The Application of Mathematical Modeling to Process Development and Design", First Ed. Applied Science Publisher Limited., London (1974).
3. Bequette , " Process Dynamics- Modeling, Analysis and Simulation", PHI International (2003).
4. Rase H F, "Chemical Reactor Design for Process Plants, Vol II: Case Studies and Design Data", 1st Ed., John Wiley and Sons, New York (1997)
5. Denn M Morton, " Process Modeling", First Ed. Longman Publisher (1986).

Course Code	Course Title	L	T	P
CH-507	**Process Plant Design**	**3**	**0**	**0**

Pre-requisites: Engineering chemistry and physics, Heat Transfer, Mass Transfer

Course Objectives: The course aims at teaching the basic concepts in the mechanical design of process vessel or process equipment. The course will introduce the basic designing of shell-and-tube heat exchangers. The course also includes the designing principles of distillation and absorption columns. The course will be dealing with design of common process vessels such as pressure vessels, storage tanks and tall vessels.

Syllabus:

Introduction

Principles involved in the design and construction of plant, plant layout, auxiliaries, offsite facilities, optimized production schedules, break-even point, profitability.

Design of heat-exchange equipment

Classification of shell and tube heat exchanger material of construction, cleaning of heat exchangers, heat transfer fluid, agitated vessels, description of shell, tubes, bonnet and channel, pass partition plate, nozzle, baffles, tie rods, baffle spacers, flanges, gaskets and expansion joints. Process design of double pipe and shell and tube heat exchangers.

Design of mass-transfer equipment

Types of mass transfer equipments, packed and tray type towers. Tray Hydraulics: Bubble cap columns, perforated plate columns and packed towers Process design of tray and packed towers. Design of other process equipments.

Storage Tanks

Introduction to Indian standards for storage tanks and their use to design cylindrical and spherical vessels under internal pressure, fixed roof and open roof tanks

Mechanical design of tall vessels and vessel supports

Basics of vessel designing for distillation and absorption columns, types of stresses induced in tall vessels and their analysis, upwind and down-wind designing, types of supports for different vertical and horizontal process vessels, stress analysis for complete design of the vessel along with support

Course Outcomes:

1. To understand the Indian and global standards in process design
2. To be able to perform stress analysis in pressure vessels and tall vessels
3. To be able to perform the process and mechanical designing of heat-exchange equipments
4. To be able to perform the process and mechanical designing of mass transfer equipments

Mapping of course outcomes (CO) & program outcomes (PO)

Course Objectives	Program Outcomes				
	1	2	3	4	5
1			✓		✓
2	✓	✓	✓		
3	✓	✓	✓	✓	
4	✓	✓	✓	✓	

Recommended Books:

1. Bhattacharya B C, “Chemical Equipment Design”, CBS Publisher (1985).
2. Kern D Q, “Process Heat Transfer”, McGraw Hill (2001)
3. Perry’s, “Handbook of Chemical Engineering” McGraw Hill, 7th Ed (1997).
4. Ludwig E E, “Applied Process Design for Chemical and Petrochemical Plants (Vol. 1,2 and 3)”, 3rd Ed., Gulf Publishing Company, Houston (1995)
5. Ulrich, G D, “A Guide to Chemical Engineering Process Design and Economics”, John Wiley (1984).

Course Code	Course Title	L	T	P
CH-511	Computational Techniques in Chemical Engineering Lab	0	0	3

Pre-requisites: Knowledge of Differential Equations.

Course objectives: This course has been designed to develop the understanding the computational methods to solve the problems related to the chemical engineering applications. The students are exposed to learn the basic principles, and logical skills in solving the problems using computational methods.

List of Experiments :

1. To fit a best curve for the Re Vs Pr data (or Re vs f or growth of bacteria vs time data etc) using available software.
2. Estimation of specific volume of a non-ideal gas following Van der Waals equation by solving non-linear equation using trial and error Method.
3. Estimation of specific volume of a non-ideal gas following Van der Waals equation by solving non-linear equation using Newton Raphson Method.
4. Calculation of bubble point and dew point.
5. Numerical integration over batch reactor to find time using Simpson's rule/ trapezoidal rule
6. Numerical integration over plug flow reactor to find time using Simpson's rule/ trapezoidal rule
7. Calculation of adiabatic flame temperature
8. Solution of simultaneous material balance equations using Gauss Jordan elimination method
9. To study the transient behaviour of Continuous stirred tank reactor.
10. Simulation of pipe flow problem
11. Simulation of heat transfer in metal pipe/blocks for various types of boundary conditions.
12. Simulation of settling of solid particle in fluid.
13. Generation of velocity profile and shear stress profile for various fluids under laminar conditions.
14. Simulation of 2-dimensional heat transfer in metal block.
15. Simulation of drying behaviour of wet solid.

Course Outcomes:

1. The students would be well versed with the principles of computing methods with the theory involved in the solving the chemical engineering problems.
2. The students would be able to independently solve the problems in the chemical engineering and would be aware about its applications.
3. Able to convert any chemical engineering problems in mathematical forms.
4. Ability to understand and solve the numerically chemical engineering problems.

Mapping of course objectives (CO) & program outcomes (PO)					
Course Outcomes	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	√		√	√	
2	√		√	√	
3	√		√	√	
4	√		√	√	

Recommended books:

1. S.K. Gupta," Numerical Methods for Engineers", Wiley Eastern, (1995).
2. P. Ahuja, "Introduction to Numerical methods for chemical engineering", PHI learning Pvt, (2006).
3. S. C. Chapra, R.P. Canale, "Numerical Methods for Engineers", 5th Edition; McGraw Hill(2006).
    a. Gourdin, M Boumhrat; "Applied Numerical Methods" Prentice Hall India, (2000).
4. **5**.G. M. Philips, P. J. Taylor, "Theory and Applications of Numerical Analysis",2nd Edition., Academic Press (1996).
5. Kenneth J. Beers, "Numerical Methods for Chemical Engineering",Cambridge University (2007).

Course Code	Course Title	L	T	P
CH-513	Selected Experiments in Chemical Engineering	0	0	3

Pre-requisites:	Fluid mechanics, Mass transfer, heat transfer and chemical reaction engineering
Course Objectives:	The course aims at performing the experiments and getting hands-on experience on concepts such as, VLE, liquid-liquid extraction, filtration, RTD in packed bed and multiphase reactors.
List of Experiments:	1. To determine the mass transfer coefficient in a Packed Liquid -Liquid Extraction Column. 2. To generate the VLE data for a binary mixture. 3. Determination of molecular weight of the given polymer sample. 4. Determination of specific cake resistance in a constant pressure vacuum filtration. 5. Regime Transition and Pressure drop studies in a Trickle bed reactor. 6. Studies on Residence Time Distribution in a packed bed reactor. 7. Dispersion studies using RTD data in a Multiphase Reactor. 8. To determine the smoke and flash point of a given diesel sample. 9. Determination of heat transfer coefficient by dropwise and filmwise condensation. 10. Determination of overall heat transfer coefficient in an open pan evaporator 11. To Determine the Tensile strength and elongation of composite materials. 12. To determine the characteristics of carbonization process with given samples. 13. To determine the characteristics of hydrothermal liquefaction process with given samples. 14. To determine the burning properties of combustible fuels.
Course Outcomes:	**1.**To experimentally analyze the VLE and liquid-liquid extraction. **2.**To experimentally analyze the RTD in packed bed and multiphase reactors. **3.**To experimentally measure the resistance in filtration process. **4.**To experimentally analyze the overall heat transfer coefficients in heat transfer processes.

Mapping of course outcomes (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓		✓		
2	✓		✓		✓
3	✓	✓	✓	✓	
4	✓		✓		

Recommended Books:

1. Smith J. C., McCabe W. L., Harriot P. H., "Unit Operations of Chemical Engineering", McGraw Hill, (2001).
2. Richardson and Coulson "Chemical Engineering Vol II", 5th Edition, Butterworth–Heinemann, (2002).
3. Bhattacharya B. C., Narayanan C. M., "Mechanical Operation for Chemical Engineers",Khanna Publishers, (1992).
4. Frank P. Incropera, "Fundamentals of heat and mass transfer" Volume 1, John Wiley, (2007).
5. Levenspiel O., "Chemical Reaction Engineering", 3rd Edition, John Wiley & Sons, Singapore, (1999).

Course Code	Course Title	L	T	P
CH-502	**Transport Phenomena**	**3**	**0**	**0**

Pre-requisites: Fluid mechanics, heat transfer, mass transfer and engineering mathematics.

Course objectives: Transport phenomena is the subject which deals with the different transport processes such as momentum, energy and mass, ubiquitous in industry as well as in nature. Momentum, heat and mass transfer are taught together due to the underlying similarities of the mathematics tools and molecular mechanisms describing such processes. The students will be made aware of the core scientific connections and will be encouraged to solve problems based on relevant analogies.

Syllabus:

Introduction to Transport Processes

Basic Mass, Momentum and Energy transport processes; micro and macroscopic views; phenomenological laws; driving forces; transport coefficients. Definition of fluxes; conservation principles; differential elementary volumes and coordinate systems; boundary conditions; dimensionless numbers. Molecular mass transport – Fick's law of binary diffusion; binary gaseous diffusion coefficient – kinetic theory; diffusion in liquids and solids. Effective transport properties (diffusion in suspensions and through pack of spheres). Steady and transient diffusion processes– examples and application to transport problems.

Momentum Transport and Viscous Flows

Newton's law of viscosity; molecular theory of viscosity of dilute gases and liquids; Couette and falling film flow; momentum as a flux and as a force – viscous stress tensor; Shell momentum balance and laminar flows – principles; Poiseuille flow; flow in an annulus; creeping flow around a sphere. Continuity and equations of change, Navier-Stokes equations. Macroscopic balances for momentum transport Turbulent flows, Reynolds experiment, drag forces; turbulence and eddy flow.

Energy Transport – Heat, Radiation, Phase Change

Fourier's law of heat conduction; thermal conductivity - molecular and effective; heat flow in one and multi-dimensional geometries; steady state and transient analytical solutions to heat conduction; heat flow and convection; nonlinear cooling, macroscopic energy balance. Radiative energy transport– Stefan-Boltzmann law; black body exchange, principles and examples; radiation through the atmosphere and greenhouse effect. Phase change and couple heat and mass transport (falling film, evaporating water drop)

Mass Transport in Solid and in Laminar Flow: Shell mass balances: boundary conditions, diffusion through a stagnant gas film, diffusion with heterogeneous chemical reaction, diffusion with homogeneous chemical reaction, diffusion into a falling liquid film l forced – convection mass transfer, diffusion and chemical reaction inside a porous catalyst: the "effectiveness factor".Analogies between heat, mass and momentum and transfer.

Course Outcomes:

1. Understanding of transport processes.
2. Ability to do heat, mass and momentum transfer analysis.
3. Ability to analyze industrial problems along with appropriate boundary conditions.
4. Ability to develop steady and time dependent solutions along with their limitations.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√	√	√	√	
2	√	√	√	√	
3	√	√	√	√	
4	√	√	√	√	

Recommended books:

1. Bird R B, Stewart W E and Light fort R N, "Transport Phenomena", John Wiley and Sons (2002).
2. Welty J R , Wilson R E and Wicks C E , "Fundamentals of Momentum , Heat and Mass Transfer", 4th ed, John Wiley and Sons (2001).
3. John C Slattery, "Momentum, Energy and Mass transfer in continua", McGraw Hill, Co. (1972).
4. Bennet C U and Myers J E, " Momentum, Heat and Mass Transfer" Tata McGraw Hill Publishing Co. (1975)
5. Robert S Brodkey and Harry C Hersing, "Transport Phenomena a Unified approach" McGraw Hill Book Co. (1988).

Course Code	Course Title	L	T	P
CH-504	**Advanced Separation Techniques**	**3**	**0**	**0**

Pre-requisites: Basic chemistry and physics, Mechanical Operations, Mass Transfer

Course objectives: The course aims at teaching the basic concepts of advanced separation techniques in chemical engineering. The course will be dealing with common processes of mass transfer such as adsorption, crystallization, distillation, extraction, leaching etc. The course will introduce the separation process that converts the substance mixture into specific product based on their physical and chemical properties.

Syllabus:

Introduction of various separation techniques

Sedimentation, Fluidization, Centrifugal Separations, Leaching, Distillation, Multi Component Distillation, Absorption of gases, Liquid – Liquid extraction, Crystallization, Drying, Membrane separation, Adsorption and Recent advances in separation techniques.

Liquid – Liquid Extraction

Ternary phase diagrams & choice of solvent, single stage and multistage cross current, co-current and counter current extraction operation for immiscible and miscible solvents, related numerical problems, Batch and continuous contact extractors.

Leaching

Mass transfer in leaching, equipment for leaching, single stage and multistage cross current, co-current and counter current leaching operations, related numerical problems, Equipment for leaching.

Adsorption

Introduction and the nature of adsorbent, adsorption equilibria, the Langmuir isotherm, BET isotherm and Gibbs isotherm, potential theory and adsorption equipments.

Membrane Separations

Types and choice of membranes, Nature of synthetic membranes, cross flow micro filtration, Ultra filtration, Reverse osmosis, Electrodialysis, Membrane fouling, Economics of membrane operations and Ceramic membranes.

Course Outcomes:

1. To understand the fundamentals of various advanced separation techniques
2. To analyze a given industrial separation problem and apply concepts of advanced separation techniques
3. To learn estimation of separation coefficient
4. To explore the use of alternative separation techniques to the existing ones

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes:	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	✓		✓		✓
2	✓	✓	✓	✓	
3			✓		
4	✓		✓	✓	✓

Recommended Books:

1. Geankopolis C J, “Transport Processes and Separation Process Principles”, Prentice Hall of India, 4th Edition, Eastern Economy Edition (2004)
2. Treybal R E , “Mass Transfer Operations” 3rd ed. , McGraw Hill (1980)
3. McCabe W L and Smith J C “Unit Operations of Chemical Engineering”, McGraw Hill (2001).
4. Coulson J M and Richardson J F “Chemical Engineering , Vol. 2, 5”, McGraw Hill (1999)
5. Walter L, Badger & Julius T.Banchero “Introduction to Chemical Engineering”, McGraw Hill (1997).

Course Code	Course Title	L	T	P
CH-506	Industrial Pollution Control Engineering	3	0	0

Pre-requisites: None

Course Objectives

To study the sources and impacts of air, water, solid, biomedical and hazardous wastes

To study the engineering systems for the prevention, control and treatment of pollutants

Syllabus:

Air Pollution Control Engineering

Overview of Definition, Sources, Characteristics and Perspective of Air Pollutants, Effects of Air Pollution on Biodiversity, Economic Effects of Air Pollution, Air Quality and Emission Standards, Engineering Systems of Control of Air Pollution by Equipment and by Process Changes, Air Pollution from Major Industrial Operations, Case studies

Water Pollution Control Engineering

Overview of Definition, Sources, Characteristics and Perspective of Water and Wastewater Pollutants, Effects of Water Pollution on Biodiversity, Economic Effects of Water Pollution, Water Quality and Emission Standards, Physical, Chemical and Biological Parameters, Engineering Systems of Control of Water and Wastewater Pollution by Primary, Secondary and Advance Treatment, Water Pollution from Major Industrial Operations, Case studies

Solid Waste Management

Overview of Definition, Sources, Characteristics and Perspective of Solid Waste, Generation, Separation, Handling, Storage and Transportation of Solid Waste, Waste Minimization of Solid Waste, Physical, Chemical and Biological Treatment of Solid Waste, Reuse and Recycling of Solid Waste, Case studies

Biomedical and Hazardous Waste Management

Overview of Definition, Sources, Characteristics and Perspective of Biomedical and Hazardous Waste, Handling, Storage, Transportation of Biomedical and Hazardous Waste, Physical, Chemical and Biological Treatment of Biomedical and Hazardous Wastes, Case studies

Course Outcomes:

1. The students are able to understand the sources and impacts of air, water, solid, biomedical and hazardous wastes on the environment.
2. The students are able to understand various engineering systems for the prevention, control and treatment of pollutants.
3. The students are able to understand industry specific standards and treatment methodologies available for industry specific pollutants.
4. The students are able to develop the skills to solve the problems related to the design of various equipment.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes:	Program Outcomes				
	1	2	3	4	5
1	√		√		√
2	√		√		√
3	√	√	√	√	√
4	√	√	√	√	√

Recommended Books:

1. Rao M. N. and Rao H. V. N., "Air Pollution", Tata McGraw Hill Publishing Company Ltd., (2005).
2. Peavy H. S., Rowe D. R. and Tchobanoglous G., "Environmental Engineering", McGraw Hill Book Company, International Edition (1985).
3. Metcalf and Eddy, Inc., "Wastewater Engineering-Treatment and Reuse", Tata McGraw Hill Publishing Company Ltd., Fourth Edition (2004).
4. Rittmann B. E. and McCarty P. L., "Environmental Biotechnology: Principles and Application", McGraw Hill International Editions, First Edition (2001).
5. Kiely G., "Environmental Engineering", Tata McGraw Hill Publishing Company Ltd, (2007).

Course Code	Course Title	L	T	P
CH-508	**Advanced Process Control**	**3**	**0**	**0**

Pre-requisites: Advanced Mathematics, Mass and Energy Balance

Course objectives: The course aims to analyze of the dynamic behaviour of chemical process systems in terms of block diagram and the stability of the process using various techniques. The students will be able to understand the control strategies to control the chemical processes.

Syllabus: Process Dynamics of Chemical Process, Mathematical Tools for Modeling: Transforms of Simple and complex Functions

First Order Systems

Transient Response for Mercury Thermometer for various forcing Functions, Liquid Level System, Mixing Process, Linearization, Response of non-Interacting and Interacting Systems.

Higher Order Systems and Transportation Lag

Response of damped vibrator or U tube manometer to various forcing functions and their analysis, transportation lag.

Controllers and Final Control Elements

Mathematical analysis of Control Valve, Proportional, Integral & Derivative Controllers

Block diagram of a Chemical Reactor Control System

Components of a Control System: Process, Measuring Element, Controller and Final Control Element, Development of Block Diagram for chemical process.

Transient Response of Control Systems

Proportional Control for Set Point Change, Proportional Control for Load Change, Proportional Integral Control for Load Change, Proportional Integral Control for Set Point Change, Proportional Control System With Measurement Lag

Stability of the System

Concept of Stability, Stability Criteria, Routh Test for Stability. Introduction to Frequency Response: Bode Diagram for First Order, Bode Diagram for Proportional, Integral and Derivative Control, Second Order System. Control System Design by Frequency Response: Bode Stability Criteria, Gain and Phase Margin, Ziegler Nichols Controller Settings.

Control Strategies for Complex Processes

Feed Forward Control, Cascade Control, Dead Time Compensation, Controller Tuning, Control valve characteristics, Theoretical analysis of complex processes.

Course Outcomes:

1. To understand the process in terms of block diagram for controlling the chemical process systems.
2. The students will able to understand the effect of various forcing function in first and higher order system.
3. The students will able to understand the transient response of controller.
4. The students can identified the stability of control systems and be able to design the control system for complex chemical processes

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		
2	√		√		
3	√	√	√	√	
4		√	√	√	√

Recommended Books:

1. Coughanower D. R., "Process System Analysis and Control", 2nd Edition, McGraw Hill. (1991).
2. Seborg, E., Mellichamp, "Process Dynamics & Control", 2nd Edition, John Wiley, (2004).
3. Stephanopoulos, "Chemical Process Control-An Introduction To Theory & Practice",1st Edition, Prentice Hall Inc.
4. Eckman D. P., "Industrial Instrumentation", Wiley Eastern Ltd., (1975).
5. Kerk F. W., Rimboi W., Tarapore R., "Instrumentation", Wiley and Sons, (1983).

Course Code	Course Title	L	T	P
CH-512	**Process Modeling and Simulation Lab**	0	0	3

Pre-requisites: Fluid mechanics, Heat Transfer, Mass Transfer and Chemical Reaction Engineering

Course objectives: This course aims at developing amongst the students the simulation techniques for solving mathematical models of chemical engineering processes by means of computer programming. These models are reduced into set of equations solvable by numerical methods and then solved with the help of software packages.

List of Experiments:

1. Introduction to ANSYS Software.
2. Simulation studies of various unit operations using ANSYS.
3. Modeling and Simulation of Isothermal CSTR.
4. Modeling and Simulation of non-isothermal CSTR.
5. Modeling and Simulation of isothermal batch reactor.
6. Modeling and Simulation of non-isothermal batch reactor.
7. Modeling and Simulation of distillation column.
8. Modeling and Simulation of heat exchanger.
9. Modeling and Simulation of cyclone separator
10. Modeling and Simulation of CSTRs in series.
11. Simulation of pipe flow problem
12. Simulation of heat transfer in metal pipe/blocks for various types of boundary conditions.
13. Simulation of settling of solid particle in fluid.
14. Generation of velocity profile and shear stress profile for various fluids under laminar conditions.
15. Simulation of 2-dimensional heat transfer in metal block.
16. Simulation of drying behaviour of wet solid.

Course Outcomes:

1. The student is able to incorporate his entire knowledge of chemical engineering principles to an industrial or academic problem.
2. The students to show their abilities to exhibit experimental, analytical and communication skills and make a record of the findings in the form of a report or thesis.
3. The knowledge from this course can lead to design of the equipments.
4. Ability to design unit processes which can yield best results.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√	√	
2	√	√	√		
3	√	√	√	√	
4	√		√	√	

Recommended books:

1. Luyben W L , “Process Modeling Simulation and Control for Chemical Engineers”, international ed. McGraw Hill (1990).
2. Lab Manuals

Course Code	Course Title	L	T	P
CH-514	**Industrial Pollution Control lab**	0	0	3

Pre-requisites: **None**

Course objectives: To give practical knowledge for the qualitative and quantitative estimation of various parameters as per standards

List of Experiments :

1. To determine the pH of a water sample.
2. To determine the total solids (TS) of a given sample.
3. To find out total dissolved solids (TDS) of a given sample.
4. To find out total fixed solid (TFS) and total volatile solids (TVS) of the given sample.
5. To determine the acidity of the given sample.
6. To determine the alkalinity of the given sample.
7. To determine the total hardness of the given sample.
8. To find out amount of sulfates in a given sample.
9. To estimate the content of chlorides in the given water sample
10. To find the quantity of the dissolved oxygen (DO) present in the given sample.
11. To determine the biochemical oxygen demand BOD of a given wastewater sample.
12. To determine the chemical oxygen demand COD of a given wastewater sample.
13. Determination of dye concentration using UV-VIS spectrometer.
14. Determination of Cr ions concentration in the water sample using double UV-VIS spectrometer.
15. Determination of particulate matter (PM) from air sample.

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Course Outcomes:

1. The students are able to understand various standards available for estimation of pollutants
2. The students are able to determine the qualitative and quantitative estimation of various pollutants
3. The students are able to understand the principles and mechanism of various equipment
4. The students are able to write the report of the practical evaluation of the parameters

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	√		√		
2	√		√		√
3	√	√	√	√	
4	√		√		

Recommended books:

1. Peavy H. S., Rowe D. R. and Tchobanoglous G., “Environmental Engineering”, McGraw Hill Book Company, International Edition (1985).
2. Website of Central Pollution Control Board, www.cpcb.nic.in

Departmental Electives

Course Code	Course Title	L	T	P
CH-516	Petrochemical Technology	3	0	0

Pre-requisites: Basic knowledge of organic chemistry and chemical technology.

Course objectives: Petrochemical technology is the subject which deals with the manufacturing processes of various chemicals whose origin is from petroleum products. This subject also deals with the information about the technologies which are being used in the manufacturing of these various products.

Syllabus:

Petrochemicals- An Overview

Growth of global and Indian petrochemicals industries, definition of petrochemicals, history of petrochemicals industry, development of petrochemicals industry in India, economics of petrochemicals industry, sources of petrochemicals- natural gas and petroleum, classification of petrochemicals.

Chemicals from Methanol and Synthesis gas,

Oxo-products, methanol, formaldehyde, carbon-di-sulphide, Hydrogen cyanide

Ethane, Ethylene and Acetylene

Synthetic ethanol, aldehyde, acetaldehyde, acetic acid, vinyl acetate, butraldehyde and ethyl hexanol and DOP, ethylene oxide, ethylene glycol, acrylonitrile, ethanol, amines, ethyl chloride, ethylene di chloride

Chemicals from Propane and Propylene

Butadiene, butanol amines, butyl acetate, methyl-ethyl ketone

Butanes, Butane, Pentanes and Pentanes

Iso-propanol, acetone, glycerol, propylene oxide, propylene glycols, cumene,

Chemicals from Aromatics

monochloro, dichloro benzene, BHC nitro benzene, benzoic acid, nitrotoluene, pthalic anhydride, isopthalic acid, terethalic acid, dimethyl terepthalate, maelic anhydride.

Future of Petrochemicals

Integrated petro chemical complex, energy crisis in petro chemical industries, natural gas as petro chemical feed stock, import of heavy feed stocks on petro chemicals, ecology and energy crisis. Coal as an alternative to oil, energy crisis and industrial fuel, synthetic fuels, trends in petro chemical industries.

Course Outcomes:

1. Students will have knowledge of the past, present and future of petrochemical industries globally and nationally.
2. Will get a knowledge regarding the manufacturing of various petrochemicals.
3. Will have ability to understand the process technology employed in the manufacturing of various petrochemical.
4. Will provide the overview of petrochemical industry.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓		✓		✓
2	✓	✓	✓	✓	
3	✓	✓	✓	✓	
4	✓	✓	✓		✓

Recommended books:

1. Rao M. G. and Sitting M. "Dryden'd Outlines of Chemical Technology", 3rd Edition, East-West Press, (1997).
2. Rao B.K.B., "A Text on Petrochemicals", 5th Edition, New Delhi, India, Khanna Publishers, (2015).
3. Sukumar M., "Introduction to Petrochemicals", Oxford and IBH publishing Co., (1992).
4. Chauvels A. and Lefebvre G., "Petrochemical Process", Vol. 4.

Course Code	Course Title	L	T	P
CH-517	Energy Management and Audit	3	0	0

Pre-requisites: None

Course objectives: The course discusses about the energy scenario, energy conservation and its importance, energy strategy for the future, energy conservation act-2001 and its features, Kyoto protocol and global warming. The students would learn about the concepts of energy management & audit.

Syllabus:

Energy Scenario: Commercial and Non-Commercial Energy, Primary Energy Resources, Commercial Energy Production, , Energy Needs of Growing Economy, Long Term Energy Scenario, Energy Pricing, Energy Sector Reforms, Energy and Environment: Air Pollution, Climate Change, Energy Security, Energy Conservation and its Importance, Energy Strategy for the Future, Energy Conservation Act-2001 and its Features. Kyoto Protocol. Global warming.

Energy Management & Audit: Definition, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments.

Energy Action Planning: Key elements, Force field analysis, Energy policy purpose, perspective, Contents, Formulation, Ratification, Organizing - location of energy management, Top management support, Managerial function, Roles and responsibilities of energy manager, Accountability. Motivating-motivation of employees: Information system designing barriers, Strategies; Marketing and communicating-training and planning.

Financial Management: Investment-need, Appraisal and criteria, Financial analysis techniquesSimple pay back period, Return on investment, Net present value, Internal rate of return, Cash flows, Risk and sensitivity analysis; Financing options, Energy performance contracts and role of ESCOs.

Project Management: Definition and scope of project, Technical design, Financing, Contracting, Implementation and performance monitoring. Implementation plan for top management, Planning Budget, Procurement Procedures, Construction, Measurement & Verification.

Energy Monitoring and Targeting: Defining monitoring & targeting, Elements of monitoring & targeting, Data and information-analysis, Techniques -energy consumption, Production, Cumulative sum of differences (CUSUM).

Course Outcomes:

1. Students will be able to understand the current energy scenario along with energy management and strategies
2. Students will be able to take action on energy planning
3. Students will acquire the knowledge of financial management
4. Students will be able to analyze the data for energy monitoring and targeting.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√	√	√
2	√	√	√	√	√
3	√		√	√	
4	√	√	√	√	√

Recommended books:

1. Capehart, Barney L., Wayne C. Turner and William J. Kennedy, “Guide to Energy Management” , Third Edition, Fairmont Press, Atlanta, GA, 2000;
2. Albert Thumann and D. Paul Mehta “Handbook of Energy Engineering”, by. 4th ed. Lilburn, GA: Fairmont Press; 1997
3. Loftness, Robert L. “Energy Handbook.” 2d ed. New York: Van Nostrand Reinhold Co., 1984.
4. Turner W. “Energy Management Handbook”, Ed., John Wiley &. Sons, New York, 1982 5. Lapedes, DN “ Encyclopedia of Energy”, McGraw-Hill, New York, (1976)

Course Code	Course Title	L	T	P
CH-518	Introduction to Multiphase Flow	3	0	0

Pre-requisites:	Fluid Mechanics, Reaction Engineering
Course objectives:	Introduction to multiphase flow deals with different phases of fluid such as liquid-liquid, liquid-solid and liquid – gases etc. The students will be encouraged to solve problems based on relevant phases and will be made understand RTD in multiphase flow.
Syllabus:	**Flow past immersed bodies:** Drag and drag coefficients, flow through beds of solids, motion of particles through fluids, fluidization, types of fluidization and applications. **Two-phase flow**: Two–phase flow through pipes. Lockhart-Martinelli parameters and their application in analysis of two-phase flows. **Interaction of fluids:** Mixing of a single fluid; degree of segregation, early and late mixing of fluids, models for partial segregation, mixing of two miscible fluids. Gas-liquid flow phenomenon, Types of regimes formation – trickle, pulse, bubble, dispersed bubble, spray regime etc. **Types of Multiphase-Reactors**: Various types of multiphase reactors. eg. Packed bed, packed-bubble column, trickle bed reactor, three phase fluidized bed reactor, slurry bubble column, stirred tank reactor. Characteristics of above mentioned reactors such as; fluid flow phenomena and flow regimes, flow charts/ correlations, pressure drop, liquid hold up etc. Reactors involving Newtonian and non-Newtonian fluids. **RTD in Multiphase Flow systems**: Non Ideal Flow: Residence time distribution of fluid in vessel, E, F & C Curve, Mean and variance, the Dirac delta function, residence time, linear and non-linear processes, models for non ideal flow, dispersion model, N tanks in series model, model for small deviations from plug flow and long tails, conversion in a reactor using RTD data, diagnosing ills of operating multiphase reactors, models for multiphase reactors. Two parameter model; PD model; three parameter models; PE Model.
Course Outcomes:	1. Solve problems involving different phases. 2. Solve problems involving motion of particles in fluid, fluid–solid operations in packed beds and fluidized beds. 3. Select optimal sequence in multiple reactor systems 4. Solve RTD problem in multiphase flow system.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√	√	√
2	√	√		√	√
3	√			√	√
4	√			√	√

Recommended books:

1. Levenspiel O, "Chemical Reaction Engineering", 3rd Ed , John Wiley & Sons, Singapore (1999).
2. Fogler H Scott, "Elements of Chemical Reaction Engineering", 3rd ed, Prentice Hall Inc. (1999).
3. Shah Y.T., "Gas-Liquid-Solid Reactor Design", McGraw Hill Int. New York, 1979.
4. Westerterp K.R., van Swaaij W.P.M., and Beenackers A.A.C.M., "Chemical Reactor Design and Operation", John Wiley & Sons, 1993.
5. Doraiswamy L.K., and Sharma M.M., "Heterogeneous Reactions: Volume 2 Fluid-Fluid-Solid Reaction", John Wiley & Sons, 1984, Singapore

Course Code	Course Title	L	T	P
CH-519	Natural Gas Engineering	3	0	0

Pre-requisites: Fundamental knowledge of organic chemistry, thermodynamics, heat and mass transfer, fluid mechanics and petroleum crude and natural gas recovery.

Course objectives: This course deals with the principle involve in the recovery of natural gas from reservoir by the application of knowledge of various chemical engineering subjects such as thermodynamics, heat transfer, mass transfer, fluid dynamics and process control. It also deals with the processing, transmission and storage of natural gas.

Syllabus:

Gas from Condensate and Oilfields

Scope of natural gas industry, basic thermodynamic and system energy concepts in natural gas engineering, review of physical and chemical properties of natural gas and associate hydrocarbons, phase behavior studies of two phase hydrocarbon systems, equations of states, multiple flashes, water-hydrocarbon system, vapor liquid equilibrium.

Flow of Fluids

Compression calculations, heat transfer and mass transfer principles and applications in natural gas engineering, gas flow measurement, process control and instrumentation in natural gas processing plants.

Natural Gas Processing

Field separation and oil absorption process, refrigeration and low temperature processing, liquefaction process, dehydration, sweetening, and sulfur recovery from natural gas, processing for LPG, LNG, CNG system.

Transmission of Natural Gas

Specifications, utilization of natural gas, underground storage and conservation of natural gas.

Unconventional Gas

Coal bed methane, natural gas hydrate, conversion of gas to liquid, economic consideration for development of gas fields.

Course Outcomes:

1. The students will learn about the sources and recovery of natural gas.
2. Students will also attain the use of heat transfer and mass transfer principles in natural gas engineering.
3. Student also learns about natural gas processing, transmission of natural gas and unconventional gases.
4. The students will have a thorough understanding of scientific and engineering principles and their application to natural gas engineering problems.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1					
2			✔	✔	
3	✔			✔	
4	✔	✔	✔	✔	

Recommended books:

1. Kumar S, “Gas Production Engineering”, Gulf Publishing Co. (1987)
2. Beggs H D, “Gas Production Operations”, OGCI Publication (1984).
3. Ikoku C K, “Natural Gas Engineering” – John Wiley (1984).
4. Alexandre R, “Natural Gas: Production, Processing and Transport” – Hyperion Books (1995).
5. Donald L Katz, “Hand Book of Natural Gas Engineering” Mc Graw Hill

Course Code	Course Title	L	T	P
CH-520	**Energy Efficiencies in Thermal Utilities**	**3**	**0**	**0**

Pre-requisites: None

Course objectives: The course discusses about the fuels and their properties, steam and boilers,
The students will also learn about the insulations and refractories and economical measures in furnaces and boilers along with ways of recovering waste heat.

Syllabus:

Introduction: Fuels, Properties of Fuel oil, Coal and Gas, Storage, handling andpreparation of fuels, Principles of Combustion, Combustion of Oil, Coal, and Gas

Boilers: Types, Combustion in boilers, Performances evaluation, Analysis of losses, Feed water treatment, Blow down, Energy conservation opportunities.

Steam System: Properties of steam, Assessment of steam distribution losses, Steam leakages, Steam trapping, Condensate and flash steam recovery system, Identifying opportunities for energy savings.

Furnaces: Classification, General fuel economy measures in furnaces, distribution, Temperature control, Draft control, Waste heat recovery.

Insulation and Refractories: Insulation-types and application, Economic thickness of insulation, Heat savings and application criteria, Refractory-types, selection and application of refractories, Heat loss.

FBC boilers: Introduction, Mechanism of fluidised bed combustion, Advantages, Types of FBC boilers, Operational features, Retrofitting FBC system to conventional boilers, Saving potential.

Cogeneration: Definition, Need, Application, Advantages, Classification, Saving potentials

Waste Heat Recovery: Classification, Advantages and applications, Commercially viable waste heat recovery devices, Saving potential.

Course Outcomes:

1. Students will be able to understand the fuels and their combusting characteristics
2. Students will be able to learn boilers and furnaces from heat saving point of view
3. Students will acquire the knowledge of insulations and refractories as heat saving materials
4. Students will be able to learn the means of thermal energy savings and recovery

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	√				√
2	√	√	√	√	√
3	√		√	√	√
4	√		√	√	√

Recommended books:

1. A.K.Shaha, Combustion Engineering and Fuel Technology, Oxford & IBH Publishing Company.
2. James J.Jackson ,Steam Boiler Operation, Prentice-Hall Inc, New Jersey, 1980.
3. Fuel Economy in furnaces and Waste heat recovery-PCRA 13
4. D N Nandi,Handbook on Refractories , Tata McGraw-Hill Publishing Company Limited, New Delhi.
5. Douglas M.Considine Energy Technology Handbook, McGraw Hill Inc, New York, 1977.
6. George Polimeros,Energy Cogeneration handbook Criteria for Central Plant Desing Industrial Press Inc, N.Y.
7. D.A.Reay, E & F.N.Span, Heat Recovery Systems London, 1979.

Course Code	Course Title	L	T	P
CH-521	Process Intensification	3	0	0

Pre-requisites: Advanced Mathematics, transport phenomena, chemical reaction engineering, process control, process equipment design

Course objectives: The course aims to introduce concept of process integration in chemical and allied industries.

Syllabus:

Introduction

Chemical Process Design and Integration, Onion Model of Process Design, Applications of Process Intensification.

Pinch Technology

Pinch Technology Significance, Selection of Pinch Temperature Difference, Stream Splitting, Process Retrofit.

Basic Element of Pinch Design

Pinch Design Methods, Heuristic Rules, Data Extraction, Designing, Optimization, Super Targeting, Grid Diagram, Composite Curve, Problem Table Algorithm, Grand Composite Curve.

Heat Exchanger Network

Design of Different Heat Exchanger, Composite Curve, Heat Recovery, Thresholds Problem, Utility Selection, Heat Pump Integration, Energy Targeting, Area Targeting, Number of Units Targeting, Shell Targeting, and Cost Targeting.

Heat and Mass Integration

Heat Engine, Heat Pump, Distillation Column, Reactor, Evaporator, Drier, Refrigeration System.

Course Outcomes:

1. Able to understand the chemical process and process integration.
2. Ability to modify processes for minimization of heat, area, number of units and cost of chemical industries and allied industries.
3. Able to improve separations, heat transfer, mass transfer, mixing and integration of different process.
4. Ability to do pinch analysis and analyze heat exchanger network

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1			✔	✔	
2		✔	✔	✔	
3	✔		✔	✔	✔
4			✔		✔

Recommended books:

1. Kemp I. C., “Pinch Analysis and Process Integration: A User Guide on Process Integration for the Efficient Use of Energy”, 2nd Ed., Butterworth-Heinemann, (2007).
2. El-Halwagi M.M., “Process Integration”, 7th Ed., Academic Press. (2006)
3. Smith R., “Chemical Process Design and Integration”, 2nd Ed., Wiley (2005)
4. Shenoy U.V., “Heat Exchanger Network Synthesis”, Gulf Publishing (1995)
5. Linnhoff B., Townsend D. W., Boland D, Hewitt G. F., Thomas B. E. A., Guy A. R., and Marsland R. H.; "A User Guide on Process Integration for the Efficient Uses of Energy", Inst. of Chemical Engineers.

Course Code	Course Title	L	T	P
CH-522	**Advanced Heat Transfer and Fluid Dynamics**	**3**	**0**	**0**

Pre-requisites: **Fluid Mechanics, Heat Transfer**

Course objectives: The course aims in understanding the application of heat and fluid dynamic concepts in various engineering problems.

Syllabus:

Heat Transfer

Application of dimensional analysis to convection problems Heat Transfer in laminar turbulent and flow in closed conduits. Natural Convection heat transfer. Analogies between momentum heat and mass transfer. Heat transfer in packed fluidized beds.

Condensing heat transfer co-efficients. Condensation of mixed vapours in presence of non-condensible cases. Boiling liquid heat transfer.

Fluid Dynamics

Dimensional Analysis: Buckingham Pi-theorem, Rayleigh method, Geometric Kinematic and dynamic similarity, scale up numerical problems on pumps, drag force, and agitation.

Differential Equation of fluid flow: Continuity equation for one dimensional and three dimensional flow. Derivation of momentum equation (Navier-Stoke's equation) for three dimensional flow.

Laminar flow of viscous fluids: Effects of viscosity on flow, pressure gradient in steady uniform flow, Poseuille equation and friction factor, Reynolds number, velocity profiles in isothermal flow in circular tube and annuli and friction factor relations. Flow in infinite parallel plates and shear stress.

Turbulent flow of viscous fluids: Prandtl mixing length theory, Reynolds equation for in compressible turbulent flow. Reynolds stresses Statistical theory of turbulence Measurement of turbulence, hot wire anemometer and its use in turbulence parameters.

Turbulent flow in closed conditions: Logarithmic and universal velocity distribution for turbulent flow in smooth tubes. Friction factor for rough and smooth tubes.

Course Outcomes:

1. Able to understand the chemical process and process integration.
2. Ability to modify processes for minimization of heat, area, number of units and cost of chemical industries and allied industries.
3. Able to improve separations, heat transfer, mass transfer, mixing and integration of different process.
4. Ability to do pinch analysis and analyze heat exchanger network

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✔		✔		
2	✔		✔		
3	✔		✔		
4	✔		✔		

Recommended books:

1. Holman J P, "Heat Transfer", McGraw Hill Book Co. (1992).
2. Incropera F P and DeWitt D P, "Introduction to Heat Transfer," 2nd Ed John Wiley New York (1996).
3. Knudsen, &Katz "Fluid Dynamics and Heat Trasnfer" McGrawHill Book Co.(1974)
4. McCabe, Smith & Harriat, "Unit Operations of Chemical Engineering" McGraw HillBook Co. (1993)
5. Gupta,Santhosh K, "Momentum Transfer Operative" Tata McGraw Hill.

Course Code	Course Title	L	T	P
CH-523	**Rubber & Plastic Technology**	**3**	**0**	**0**

Pre-requisites: Chemical Technology

Course objectives: The course aims at understanding the basic concepts of rubber and plastic structure, properties and their processing techniques.

Syllabus:

Rubber & elastomers: natual & synthetic chlorinated, oxygenated, cycle rubber, Runa S. Buna N, Butyl rubber, neoprene, thiokols, polyisoprene rubber, polyurethane, Fillers, accelerators, activators, antioxidants & other additives, mastication & compounding, vulcanization theory & technology, Latex testing, formulation, fabrication, rubbers of commercial importance.

Introduction to Plastics: Polythene, LDPE, Poly Propylene, Copolymers of ethylene, polystyreme, acrylic plastics, Polyvinyl acetate, PVC, Polytetrafluoro ethylene (PTFE), Polymidesm, Polyesters, Polyurethanes, Polycarbonates, cellulose plastics, phenolic resins.

Plastic material processing technology: mouldings, extrusion, injection, blow & compression moulding, vaccum forming, compounding, designing with plastics, plastics of commercial importance.

Course Outcomes:

1. To develop understanding of fundamentals of rubber & elastomers and, their structure, properties and manufacturing techniques.
2. Able to know the properties of various plastic materials.
3. Understanding process technology and applications of plastics.
4. Understanding process technology and applications of rubbers.

Mapping of course outcomes (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	√		√		
2	√		√		
3	√		√		
4	√		√		

Recommended books:

1. Polymer Science & Technology of Plastics Rubber by P. Ghosh
2. Text book of polymer science by f.w.Billmeyer.
3. Polymer Science by V.R. Gowariker, N.V. Viswanathan & J. Sreedharan.
4. Introduction to Polymer chemistry by R.B. Seymour.
5. P.J. Flory, Inter Science, Principles of Polymer Chemistry, Cornell University Press 1953.
6. Text book of Polymer Science &Engg. By Anil Kumar & S. Gupta

Course Code	Course Title	L	T	P
CH-524	Polymer Technology	3	0	0

Pre-requisites: Chemical Technology

Course objectives: The course aims at understanding the basic concepts of polymer structure, properties and engineering. It also includes the manufacturing processes and process kinetics of different polymers. To familiarize with different processing techniques, common testing and evaluation methods for various polymeric materials.

Syllabus:

Introduction
Brief overview of polymer industry in India, Polymer fundamentals and classification. Physico-chemical structure of polymers. Physical properties of polymers. Functionality, Glass transition temperature, Addition, Condensation, Step- growth and Chain –growth polymerization.

Molecular weight estimation
Average molecular weight – Number and weight average, Sedimentation and viscosity average molecular weights, Molecular weight and degree of polymerization, Significance of molecular weight.

Polymerization Processes
Bulk, Solution, Emulsion and Suspension polymerization, Comparison of polymerization processes.

Polymerization Kinetics
Chemistry of step reaction polymerization, Mechanism and kinetics of poly condensation reactions and free- radical chain polymerization.

Synthetic Fibers
Types of Fibers, Spinning Techniques, Manufacturing Technology and Applications of different types of fibers: Cellulosic fibers, Polyamides, Polyesters, Acrylics, Olefins, Vinyls and Vinylidines, Fluorocarbons.

Plastics
Manufacturing Technology and applications of different types of plastics: Polyethylene, Phenolics, Polypropylene, Poly vinyl chloride and co-polymers, Polystyrene, Phenol formaldehyde, Epoxies, Urethane.

Elastomers
Structure, properties and preparation of natural rubber and synthetic rubbers. Manufacture of Styrene-Butadiene Copolymer, polymeric oils and rubbers based on Silicon. Rubber compounding and reclaiming.

Testing and Evaluation of polymers
Physical testing, Electrical Properties, Softening Temperature tests, Melt flow Index.

Course Outcomes:

1. To develop understanding of fundamentals of polymers, their structure, properties and manufacturing techniques.
2. Ability to study the polymerization processes and process kinetics.
3. Understanding process technology and applications of fibers, plastics and rubbers.
4. To familiarize with various testing and evaluation methods for polymeric materials.

Mapping of course outcomes (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓		✓		
2	✓	✓	✓	✓	
3	✓		✓		✓
4	✓	✓	✓		

Recommended Books:

1. Gowariker V. R., Viswanathan N. V., Sreedhar J., "Polymer Science", New Age International Publishers, 37, (1996).
2. Billmeyer F. W., "Text Book of Polymer Science", Wiley Tappers, (1994).
3. Ghosh P., "Polymer Science and Technology of Plastics and Rubber", Tata McGraw Hill, (2001).
4. Gupta R. K., Kumar A., "Fundamentals of Polymer Engineering", 2nd Edition, Marcel Dekkar, (2003).
5. Fried J. R. "Polymer Science and Technology", PHI Learning, (2008).

Course Code	Course Title	L	T	P
CH-525	**Biomass Conversion Processes**	**3**	**0**	**0**

Pre-requisites: None

Course objectives: Characterize different biomass feedstocks based on its constituents and properties • Understand the analytical techniques to characterize biomass• Understand and evaluate various biomass pretreatment and processing techniques in terms of their applicability for different biomass type for biomass conversion processes; combustion, pyrolysis, gasification and liquefaction for production of value added bio-products.

Syllabus:

Introduction:

Importance of Bioenergy and bio-fuels, Global and Indian scenario, Types of biomass, characterization-proximate and ultimate analysis, determination of structural components of biomass.

Pretreatment of biomass:

Pretreatment processes specific to various conversion processes for production of targeted products, Physical treatment processes, thermal, biological, chemical, physiochemical treatment processes

Conversion processes:

Biochemical conversion processes, Thermochemical conversion processes-Combustion, gasification, pyrolysis, hydrothermal liquefaction. Catalytic processes-types of catalysts, their influence on product quality. Reaction kinetics-thermogravimetric study, determination of kinetic parameters using various models. Various types of bio-fuels and bio-products-importance, characterization, properties, life cycle analysis and their environmental impacts. Integrated hybrid conversion processes. Design of a biorefinery by incorporating various unit operations, mass and energy balance, sustainability aspects using Aspen plus and other simulation packages.

Course Outcomes:

1. Understand basic concepts about biomass derived energy.
2. Understand and evaluate various biomass pretreatment and processing techniques.
3. Able to understand the various biomasses to energy conversion processes.
4. Ability to design a sustainable biorefinery for biofuels and bioenergy production by combining various processes

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes 1	2	3	4	5
1	√		√	√	√
2	√	√	√	√	√
3	√	√	√	√	√
4	√		√	√	√

Recommended books:

1. Pandey, A., Larroche, C., Ricke, S.C., Dussap, C.-G., Gnansounou, E., Biofuels: Alternative feedstocks and conversion processes, Academic Press, U.S.A., 2011.
2. Brown, R.C. (Ed.) Thermochemical processing of biomass into fuels, chemicals and power, Wiley, 2011.
3. Clark, J., Deswarte, F. (Ed.) Introduction to chemicals from biomass, John Wiley and Sons, U.K., 2008.
4. Basu, Prabir. Biomass gasification, pyrolysis and torrefaction: practical design and theory. Academic press, 2013.
5. Chen, Hongzhang, and Lan Wang. Technologies for biochemical conversion of biomass. Academic Press, 2016.

Course Code	Course Title	L	T	P
CH-526	**Industrial Rheology**	**3**	**0**	**0**

Pre-requisites: Undergraduate level courses in Fluid Mechanics, Heat Transfer , Mass Transfer and Transport phenomena.

Course objectives: Rheology is the subject which deals with the rheological properties (viscosity, shear modulus, loss modulus etc) of solids, fluids, viscoelastic fluids and solids. Most of the industrial flows are non-Newtonian in nature and are not studied enough in the undergraduate courses and with this course students will be able to understand the importance of rheology and the working principles of different kinds of rheometer. Finally, students will be able to understand and analyze the industrial flows.

Syllabus:

Introduction

Introduction to rheology, solid and fluid behaviour, time independent fluid behaviour, time dependent fluid behaviour (thixotropy and rheopexy), linear viscoelasticity, nonlinear viscoelasticity, dimensional considerations.

Rheometry for Non Newtonian Fluids

Shear flow rheometry- Capillary viscometers, rotational viscometers, normal stress measurements, Introduction and working of Capillary viscometers, rotational viscometers, stress rheometers, basics of elongational flow rheometry.

Rheology of Polymeric Liquids

Polymer chain conformation, different regimes of polymeric solutions-dilute, semi-dilute and concentrated, effect of temperature.

Flow in Pipes and in Conduits of Non-Circular Cross Section

Fluid flow in laminar flow in circular tubes, power law fluids, bingham plastic, yield pseudo plastic fluids, generalized Reynolds no for time independent fluids, laminar flow in two infinite parallel plates, laminar flow in concentric annulus.

Momentum and Heat Transfer In Boundary Layer Flows

Laminar flow in circular tubes, full developed heat transfer to power law fluids in laminar flow, laminar flow of power law liquids over a plate.

Course Outcomes:

1. Understanding the importance of rheology.
2. Introducing the theories of linear and nonlinear viscoelasticity.
3. Exposure to complex fluids and their behaviour in stress and strain controlled experiments .
4. Ability to analyze the industrial non-Newtonian flows.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1			✓		✓
2	✓		✓	✓	✓
3	✓		✓	✓	✓
4	✓		✓	✓	✓

Recommended books:

1. Christopher W. Macosko, 'RHEOLOGY principles, measurements and applications', 1st ed., Wiley-VCH, (1994).
2. Bird, Stewart W. E. and Lightfoot, "Transport Phenomena", John Wiley and Sons, (2002).
3. Chabra, Richardson, "Non Newtonian fluids in Process Industries", Butterworth, Melbourne, (1999).
4. Faith A. Morrison, "Understanding Rheology", OXFORD university press, New York (2001).
5. Welty J. R., Wilson R. E., Wicks C E, "Fundamentals of Momentum, Heat and Mass Transfer", 4th Edition, John Wiley & Sons, (2001).Tanners R. I., "Rheology: An Historical perspective", Elsevier, Amsterdam, (1998).
6. Skelland, A. H. P., "Non Newtonian Flow and Heat Transfer", Wiley, New York, (1967).

Course Code	Course Title	L	T	P
CH-527	**Membrane Separation Processes**	**3**	**0**	**0**

Pre-requisites:	Advanced Mathematics, Transport phenomena
Course objectives:	The objective of the course is to impart knowledge to the students about various membrane separation processes, and its applications. It is also covering the fundamentals as well as the recent developments of different processes as well as their industrial applications. Students are exposed to the basic principles, operating parameters, types of membrane used, flux equation, transport mechanism, and applications of membrane-based technologies.
Syllabus:	**Introduction:** Introduction to membrane and membrane process, historical developments in membranes, Commercial membrane separation processes, new membrane separation process under development. **Membrane Transport Theory:** introduction, solution diffusion model, three parameter models, pore flow membranes, concentration polarization. **Membranes and Modules:** Isotropic and Anisotropic membranes, liquid membrane, metal and ceramic membrane, hollow fibre, spiral wound, plate and frame, and tubular modules. **Reverse Osmosis:** Introduction and definition, theory and design, different membrane modules, selected applications and economics. **Ultra filtration:** Introduction and definition, theory and design, membrane module and process configuration, applications and economics. **Micro filtration:** Introduction and definition, theory of cross flow filtration, dead end micro filtration, applications and economics. **Emulsion liquid membranes:** Introduction and definition, theory and design, selected applications and economics. **Dialysis, Electodialysis, Pervaporation, Gas permeation:** Brief introduction and applications.
Course Outcomes:	1. Understand the basic principles for different membrane separation processes and its applications. 2. Student learn the basics of membrane synthesis and various membrane modules. 3. The students are capable of applying various transport models for the calculation of membrane fluxes and the other of separation properties for various membrane systems. 4. Students are able to identify established membrane separation processes and learn concepts of upcoming membrane separation processes.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	✓	✓		✓	
2	✓		✓		
3			✓	✓	✓
4			✓	✓	

Recommended books:

1. Wilson & Sirkar, Membrane Handbook, Mc Grawhill, London, (2001)..
2. Nune and Peinemann, Membrane Technology in chemical industries, Wiley, New York, (2000).
3. Cheryan Munir, Ultra filtration Handbook, Technomic, New York, (1985)
4. Noble and Stern, Membrane separation and technology, principles and applications, Elsevier, (1995).
5. Baker R W, Membrane technology and applications, Wiley, New York, (2000).

Course Code	Course Title	L	T	P
CH-528	**Fertilizer Technology**	**3**	**0**	**0**

Pre-requisites: Chemical Technology

Course objectives: The course will provide the knowledge on various types fertilizer, their methods of production, Material of construction, economics and corrosion problems of the fertilizer industry.

Syllabus:

Introduction:
Elements required for plants growth, Classification of fertilizers, Compound, Complex & bulk blended fertilizers. N-P-K values & calculations.

Nitrogenous Fertilizers: Manufacturing Processes for Ammonia, Effects of various factors on the process. Manufacture of ammonium sulphate, ammonium chloride, Ammonium phosphate, Ammonium nitrate, nitric acid, Urea etc.Economics & other strategies, Material of construction & corrosion problem.

Phosphatic fertilizers: Calculation of percentage tricalcium phosphate of lime in phosphatic rock. Manufacture of triple super phosphate & single super phosphate, Nitrophosphate, Sodium phosphate, phosphoric acid & other phosphatic fertilizers.

Potash Fertilizers: Manufacture of potash fertilizers like potassium sulphate, potassium chloride etc.

Other Fertilizers:
Mixed fertilizers and granulated mixtures; biofertilisers, nutrients, secondary nutrients and micro nutrients; fluid fertilizers, controlled release fertilizers.

Course Outcomes:
1. Ability to understand the importance of fertilizers.
2. Able to know different methods of production of various fertilizers.
3. Able to understand the various engineering problems occurring in fertilizer industries.
4. Ability to get knowledge on material of construction and corrosion problems

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓		✓		
2	✓		✓		
3	✓	✓		✓	✓
4	✓	✓		✓	✓

Recommended books:

1. Dryden C E, “Outlines of Chemical Technology”, East –West Press Pvt. Ltd., New Delhi, 2 nd Edition (1973)
2. Austin G T, “Shreve’s Chemical Process Industries”, McGraw Hill Book Company, New Delhi 5th Edition (1986)
3. Chemical Engineering Education Development Centre– “Chemical Technology I, II, III , IV , Manual of Chemical Technology, Indian Institute of Technology , Madras”.
4. Shukla S D and Pandey G N, “A text book of Chemical Technology Vol I”, Vikas Publishing House Pvt. Ltd., New Delhi
5. 5. Shukla S D and Pandey G N, “A text book of Chemical Technology Vol lI”, Vikas Publishing House Pvt. Ltd., New Delhi

Course Code	Course Title	L	T	P
CH-529	**Environmental Impact Assessment**	**3**	**0**	**0**

Pre-requisites: None

Course objectives:

The objective of the course is to introduce students to the process of Environmental Impact Assessment (EIA) and the procedures that are followed in environmental management in industry.

Students are introduced with some of the basic environmental assessment techniques

Through case studies, students will learn to present and explain the components and decision making processes involved in environmental assessment.

Students will create a visual representation of data that comprises an environmental impact statement

Syllabus:

Environment Impact Assessment (EIA)

Concept of EIA, Origin of EIA, Procedure of EIA, Evaluation Methodology for EIA, Scope Studies, Preparation and Review of Environment Impact Statement (EIS).

Life Cycle Assessment (LCA)

Introduction of LCA, Importance of LCA, Environmental Parameters in LCA, Documentation in LCA.

Waste Minimization

Introduction, Types of Waste, Benefits of Waste Minimization, Elements of Waste Minimization Programme, Integrated System for Waste Management.

Environmental Audit (EA)

Concept of EA, Necessity and Importance of EA, Audit Items, Audit Procedures.

Environmental Management System (EMS)

Introduction, Terminology and Certification, Environmental Standards, the International Standard Organization (ISO), the ISO 9000 and the ISO 14000 Family of Standards, Guides and Technical Reports, ISO 14001 Certification as a Tool for Sustainable Development

Case Studies

Discussion and analysis of various Case studies of environmental engineering projects.

Course Outcomes:

1. Ability to understand the current EIA methods and the techniques and tools used
2. Ability to understand the current assessment methods and legislation
3. Ability to understand the current environmental monitoring systems
4. Ability to apply knowledge acquired to the process of environmental impact modeling and prediction as a design tool with application to a number of case studies

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓		✓	✓	
2	✓		✓		
3		✓		✓	✓
4	✓		✓		

Recommended books:

1. Anjaneyulu Y., “Environment Impact Assessment Methodologies”, B S Publications, (2002).
2. Canter L. W., “Environment Impact Assessment”, McGraw Hill, Second Edition, (2005).
3. Garg S. K., Garg R., Garg R., “Ecological and Environmental Studies”, Khanna Publishers, First Edition, (2006).
4. Santra S. C., “Environmental Science”, New Central Book Agency (P) Ltd., Second Edition, (2006).
5. Uberoi N. K., “Environmental M

6. anagement”, Excel Books, Second Edition, (2006).

Course Code	Course Title	L	T	P
CH-530	New and Renewable Energy Sources	3	0	0

Pre-requisites: none

Course Information: The course aims at understanding the use of various alternate energy sources like solar, wind, geothermal, Bioenergy etc.

Syllabus:

Introduction: Global and Indian scenario, sources, Energy conservation, types of NCES with applications

Solar Energy: Role and development of new renewable energy sources, instruments for measuring solar radiations, solar radiation data, Flat plat and concentrating collectors, classification of concentrating collectors, advanced collectors, different methods of solar energy storage, solar ponds, solar applications: Solar heating/cooling technique, solar distillation and drying, photovoltaic energy conversion.

Geothermal Energy: Resources, types of wells, methods of harnessing the energy

Wind Energy: Sources and potentials, horizontal and vertical axis, wind mills, wind regime analysis and evaluation of wind mills.

Biomass and Biofuels: Recycling of agricultural waste, anaerobic/aerobic digestion, and types of biogas digesters, gas yield, and combustion characteristics of bio gas, design of biogas system for heating, lighting and running IC engines. Introduction to Biofuels such as biodiesel, ethanol, biobutanol etc. and their production and present status.

Ocean Energy: OTEC, settling of OTEC plants, thermodynamic cycles

Tidal Energy: Potential and conversion technique, mini hydel power plants and their economics

Course Objectives:

1. To understand the importance of alternate energy sources
2. To know the concepts and application of solar energy
3. To know the concepts and application of geothermal and wind energy
4. .To know the concepts and application of Bioenergy, ocean and tidal energy

Mapping of course objectives (CO) & program outcomes (PO)

Course Objectives	Program Outcomes				
	1	2	3	4	5
1	✓	✓		✓	✓
2	✓			✓	
3	✓			✓	
4	✓			✓	✓

Recommended Books:

1. Rai G D, “Non-conventional energy sources” khanna publishers
2. Kumar Ramesh and Narosa, “Renewable Energy Technologies”
3. Ashok V Desai, “Non-convetional energy”, Wiley Eastern
4. Sukahme, “Solar energy” Mc Graw Hill Edition
5. K. Mittal and Wheeler, “Non-conventional energy system, A H Wheeler Publishing Co Ltd

Course Code	Course Title	L	T	P
CH-531	**Nanomaterials, Nanoscience and Nanotechnology**	**3**	**0**	**0**

Pre-requisites: Engineering chemistry and physics

Course Objectives: The course aims at understanding the bottom-up (includes both chemical and physical methods) and the top-down methods (mainly physical methods) for the synthesis of nanostructured materials. The course also focuses on different type of nanostructures such as carbon nanotubes (CNT), metal and metal oxide nanoparticles, self-assembly of these nanostructures. The devices developed out of these nanostructures shall be also discussed.

Syllabus:

Introduction

Nanotechnology, history, motivation, materials, devices and systems.

Synthesis and Characterization of Nanomaterials

Top down & Bottom up Fabrication, Solution based Synthesis of Nanoparticles, Vapour Phase Synthesis & Synthesis with framework, Lithography and Chemical Patterning, Nanolithography, Dip Pen Lithography, e-beam lithography, Liftoff lithography.

Artificially Layered Materials: Semiconductor Nanomaterials, Quantum Well, Quantum wires, Quantum Dots, Super lattices & Layered Structures, Quantum Computing. Self-assemblies of nanostructures, Supramolecular & Dimension Control in Nanostructures, thermodynamics and coded self-assemblies.

Carbon-based Nanostructures and Biomaterials

Carbon molecules, clusters, carbon nanotubes and their applications DNA & Nanomaterials, Bio-nanocomposites, Biometrics, molecular motors. DNA Computing, Biophotonics.

Nanostructure-based devices

Electronic, Magnetic, Mechanical, Photonic, Fluidic and Biomedical devices.

Course Outcomes:

1. To understand the basic concepts of nanostructures and their properties.
2. To study the synthesis processes, for the manufacture of nanomaterials.
3. To understand the structure and property relationship of various nanomaterials.
4. To get familiar with the latest devices and technologies based on nanomaterials.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes:	Program Outcomes				
	1	2	3	4	5
1			✓		✓
2		✓	✓		
3	✓			✓	
4	✓			✓	✓

Recommended Books:

1. Poole, C. P., Owens, F. J., “Introduction to Nanotechnology”, Wiley, (2003).
2. Ratner, M., Ratner, D., “Nanotechnology”, Prentice Hall, (2003).
3. Wilson, M., Kannagara, K., Smith, G., Simmons, M., Raguse, B., “Nanotechnology”, CRC Press, (2002).
4. Ozin, G. A., Andre, C. A., “Nanochemistry: A Chemical approach to Nanomaterials”, Royal society of Chemists. (2005).
5. Foster, L. E., “Nanotechnology, Science Innovation & Opportunity”, Pearson Education, (2007).

Course Code	Course Title	L	T	P
CH-532	**Leather Fashion Design Technology**	**3**	**0**	**0**

Pre-requisites:	None
Course objectives:	The objective of the course is to impart knowledge to the students about leather manufacturing and its applications. It is also covering the fundamentals as well as the recent developments of different tanning processes. It will make students well informed about all aspects of leather products, raw materials, design, production, fashion, etc.
Syllabus:	**Leather Manufacture:** Introduction to the manufacture of leather from different hides and skins. Chemistry and Mechanisms of various Pre-tanning, Tanning and Post tanning and Finishing processes. **Tannages:** Principles involved in Inorganic and Organic tanning. **Leather Auxiliaries:** Introduction to the Auxiliaries used during Leather processing. **Leather Machinery:** Study of various types of Leather, Footwear, Garment and Leather Goods Machinery. **Footwear:** Anatomy of Human Foot, Foot Comfort and Foot care, Footwear Materials, Footwear Manufacture, Final Inspection and Packages. **Leather Garments and Goods:** Classification of Leather Garments and Goods, Material Selection, Designing and Styling, Pattern Production. **CAD of Leather Products:** Introduction to general CAD, Design methods using CAD for leather products. Grading of patterns for footwear and garments, International Fashion Trends, Colour Characteristics, Decorative Styling Techniques
Course Outcomes:	1. Students understand the basic principles of leather manufacturing. 2. Students learn the various tanning operation and machinery. 3. Students learn about leather auxiliaries, machinery, footwear, Garments and Goods. 4. The students are capable of applying various design methods using CAD for the development of leather products.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	✓	✓			
2		✓		✓	✓
3	✓		✓	✓	
4			✓	✓	

Recommended books:

1. Thornton J H, “Textbook of Footwear Manufacture”, Heywood, London, 1964.
2. Harvey A J, “Footwear Materials and Process Technology”, Lasra Publications, New Zealand.
3. “Fashion Drawing Method”, ESMOD, Paris, 1992.
4. Radhakrishnan P and Kothandaraman C P, “Computer Graphics and Design”.
5. “American Shoe Making”, Shoe Trades Publishing Co. , Cambridge, USA.

Course Code	Course Title	L	T	P
CH-533	**Instrumental Methods of Analysis**	**3**	**0**	**0**

Pre-requisites:

Course objectives: The objective of the course is to impart knowledge to the students about various Instrumental methods and their application in different fields of engineering and research.

Syllabus:

Spectroscopic methods: General principles, instrumental set up and analytical procedures and applications of Fourier-transform spectroscopy, Ultraviolet–visible spectroscopy, photoelectron spectroscopy, Atomic absorption spectroscopy, mass spectroscopy, Raman Spectroscopy, Nuclear Magnetic Response Spectroscopy, Flame photometry.

Thermo-Analytical methods: Theory, instrumental requirements and methodology for thermogravimetric analysis (TG), differential thermal analysis (DTA) and differential scanning calorimetry (DSC), applications.

Chromatographic Methods: Classification of chromatographic methods according to separation and development procedure, instrumentation and applications- Thin Layer Chromatography, Liquid Chromatography and Gas Chromatography

Electrochemical Techniques: Introduction, theory, principles and methodology of Coulometry, Potentionmetry and Voltammetry-Polarography.

X-Ray Methods: Fundamental Principles of X-Ray Fluorescence, Diffraction Methods

Course Outcomes:

1. The students are able to understand the concept and application of Spectroscopic methods
2. The students learn the principles and application of Thermo-Analytical methods.
3. The students can able identify the application of various chromatographic methods.
4. Students can able to learn various electrochemical and X-Ray techniques

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	✓	✓		✓	
2	✓	✓	✓	✓	
3	✓	✓	✓	✓	
4	✓			✓	✓

Recommended books:

1. Instrumental Methods of Analysis, Willard, Merritt, Dean and Settle, CBS Publisher and Distributors., 1986
2. Therma Analysis, W W Wendlandt and L W Collins, Dowden Hutechin and Ross.
3. Basic Concepts of Analytical Chemistry, S M Khopkar, Wiley Eastern.
4. Thermal methods of Analysis, Principles, Application and Problems, J Haines, Blackie Academic and Professional, 1994.
5. Chromatographic Methods, A Braithwaite and F J Smith, 5th edn. Blackie Academic and Professional, London, 1996.
6. Principles of Instrumental Analysis, Skoog, Holder, Nieman, Fifth edition, Thomson Books, 1998.

Course Code	Course Title	L	T	P
CH-534	**Chemical Process Safety and Hazard Management**	**3**	**0**	**0**

Pre-requisites:	Transport Phenomena, Mechanical Unit Operation, Process Control
Course objectives :	The objective of the course is to impart knowledge to the students about source of hazards and control techniques. This course discusses the concept of inherent safety in CPI. The course briefs the basics of fire, explosion and toxic dispersion modeling.
Syllabus:	**Introduction:** Concept of Loss prevention, types of process hazards, acceptable risks, accident and loss statistics, nature of accident process, concepts of inherent safety. **Inherent safer Designs:** Concepts of inherent safety in chemical plants, concept of dilution, substitution, moderation and Toxicology. **Brief introduction to** Dose vs response curve, toxicants entry route, threshold limit values, and regulatory bodies in safety **Fires and Explosion:** Fire triangle, definitions, flammability characteristics of liquid and vapors, LOC, models of pool fire and fire ball, confined and unconfined vapor explosions, BLEVE. **Fire prevention:** Engineering aspects of fire prevention and control, inerting procedure, static electricity, charge accumulation, static electricity control techniques, flame arrestors their design, design of sprinkler systems, flare design, fire extinguishment, Recent advances in fire prevention in control systems. **Hazard Management:** Basic components of hazard management, Risk control, Domino effect, Hazard survey, checklist, HAZOP, safety reviews, what if analysis. **Risk Assessment:** Reliability theory, event tree, fault tree, QRA, LOPA, Dow's fire and explosion index, Mond index, Dow's Chemical release model. **Security Risk Assessment:** Security vulnerability methodology, brief review of important SVA's by ACC, API and USDOJ, Introduction to Security Risk Factor Tables, Case studies.
Course Outcomes :	1. The students are able to understand the concept of loss prevention in Chemical Process Industries, and calculate the accident and loss statics for the real plant units. 2. The students learn the basics of Fire, Explosion, & toxic dispersion hazards through modeling. 3. The students learn to exhibit the skill of performing risk assessment such as conducting Dow's fire and Explosion index for the real plant units. 4. Students learn to various risk assessment techniques such as FTA, ETA and SVA methodology.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓	✓			✓
2			✓	✓	✓
3	✓	✓	✓	✓	
4	✓	✓			✓

Recommended books:

1. Crowl D A, Louvar J F, " Chemical Process Safety Fundamentals with applications", 2nd Prentice Hall, NJ (2002).
2. Coulson J M and Richardson J F , "Chemical Engineering",2nd , Vol 6, Pergamon, press (1999).
3. Dow Chemical Company, Dow's Chemical Exposure Index Guide, New York, (1993).
4. Lees F P, Loss prevention in process Industries, 2nd ed, Butterworth, London, (1996.)
5. Wells G L, Safety in process Plant Design, George godwin ltd., New York, (1980).
6. Bajpai S and Gupta J. P., Site Security for Chemical Process Industries, Journal of Loss Prevention in Process Industries, 18 (2005), 301-309.

Course Code	Course Title	L	T	P
CH-535	Petroleum Engineering and Technology	3	0	0

Pre-requisites:	Fundamental knowledge of organic chemistry, thermodynamics, heat and mass transfer, fluid mechanics and petroleum crude and various products with their characteristic properties.
Course objectives:	This course make students aware of the various refinery processes involves in petroleum refining. Information regarding raw materials and final products of petroleum refinery will also be delivered to the students.
Syllabus:	**Scope and Purpose of Refining:** Global and Indian refining scenario, Petroleum refining industry in India practice and prospects, An overview of the entire spectrum of the refinery products, refinery configuration development, Physio chemical characteristics of Petroleum and Petroleum products. **Refinery Distillation Processes:** Desalting and Stabilization of crude, Process description of typical simple distillation, Fractional distillation, crude oil distillation, vaccum distillation etc. Degree of separation (5-95 gap) and degree of difficulty of separation (Δ t 50), Packie charts, ASTM, TBP and EFV Distillation. **Fuel Refining:** Cracking, coking, reforming, alkylation, isomerisation polymerization, sweetening, visbreaking. Thermal and Catalytic solvent extraction and adsorption w.r.t refining industry. **Lube Refining**: Solvent extraction, dewaxing propane deasphalting. **Wax Refining**: Deoiling of crude wax, crystallization, catalytic, sweating microcrystalline and petroleum wax applications. **Hydro processing**: Hydro cracking, hydro treating, hydro finishing. **Refinery Feedstock**: Nature and effect of different types of refinery feedstock and their impurities on refinery configuration and operation. **Refinery Gas Processing**: Process description of typical light ends unit, acid gas removal using gas treating processes. Hydrogen Production and Hydrogen Management in refineries. **Two Phase Oil and Gas Separation equipment**: Types, their description, vessel sizing. Theory of separation and separator design. **Three Phase Oil Gas and Water Separators**: Types of separators, their description. Various control and vessel internals, theory and sizing of three phase separator. LACT units. Application of thermodynamics of Refining process.
Course Outcomes:	1. The students will learn about the sources petroleum crude. 2. Students will also get knowledge of various refinery operations involve in refineries. 3. Student also learns about the standard characteristics of the various refinery products. 4. The students will have a thorough understanding of scientific and engineering principles and their application to petroleum engineering and technology problems.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓				
2	✓	✓	✓		
3	✓	✓	✓	✓	
4	✓	✓	✓	✓	✓

Recommended books:

1. Nelson W L, “Petroleum Refinery Engineering”, Mc Graw Hill Book Co., 1985.
2. Watkins R N, “Petroleum Refinery Distillation”, Gulf Publishing Co.
3. Gary J H and Handework G E, “Petroleum Refining Technology and Economics”, Marcel Dekker, Inc., 2001.
4. Jones D S J, “Elements of Petroleum Processing”, John Willey & Sons, 1995
5. Waquier J P, “Petroleum Refining” Vol. I & II Editions, Technip, 1995.

Course Code	Course Title	L	T	P
CH-536	Computational Fluid Dynamics	3	0	0

Pre-requisites: Knowledge of Fluid Dynamics, Heat Transfer, Partial Differential Equation and Numerical Method.

Course objectives: This course aims to develop an understanding of complex energy, mass and momentum equations for fluid flow, heat transfer and mass transfer. This course make the students familiar with the numerical techniques required to solve the partial and differential equations of conservation of mass, energy, momentum and multiphase flows.

Syllabus:

Introduction to Computational Fluid Dynamics

Fundamental principles of conservation, Reynolds transport theorem, Conservation of mass, Conservation of linear momentum: Navier-Stokes equation, Conservation of Energy.

Classification of Partial Differential Equations

Mathematical classification of Partial Differential Equation, Illustrative examples of elliptic, parabolic and hyperbolic equations, Physical examples of elliptic, parabolic and hyperbolic partial differential equations.

Fundamentals of Discretization:

Discretization principles: Pre-processing, Solution, Post-processing, finite difference methods(FDM), finite element method (FEM), finite volume method(FVM), Finite well posed boundary value problem, Possible types of boundary conditions, Conservativeness, Boundedness, Transportiveness, Finite volume method (FVM).

Discretization of Convection-Diffusion Equations: A Finite Volume Approach

Finite volume discretization of convection-diffusion problem: Central difference scheme, Upwind scheme, Exponential scheme and Hybrid scheme, Power law scheme, Generalized convection-diffusion formulation, Finite volume discretization of two-dimensional convection-diffusion problem, The concept of false diffusion, QUICK scheme. Pressure velocity coupling, staggered grid, SIMPLE algorithm, PISO algorithm for steady and unsteady flows

Grid Generation

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

Multiphase flow

Introduction, computational models: Euler-Euler, Euler-Lagrange and volume-of-fluid, Stratified flows, flows in porous media, introduction to Direct Numerical Simulations.

Course Outcomes:

1.To understand mathematical characteristics of partial differential equations.

2.To understand basic properties of computational methods–accuracy, stability, consistency.

3.To learn computational solution techniques for various types of partial differential equations.

4. To learn how to computationally solve Euler and Navier-Stokes equations and apply the numerical schemes to solve complex multiphase flows.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√				
2		√			
3		√			√
4	√			√	

Recommended books:

1. H. K. Versteeg, W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The finite volume method", Longman Scientific & Technical, (1995).
2. S. V. Patankar, "Numerical Heat Transfer and Fluid Flow", McGraw-Hill, (1980).
3. T. J. Chung, "Computational Fluid Dynamics", Cambridge University Press, (2002).
4. J. Blazek, "Computational Fluid Dynamics:Principles and Applications", Elsevier, (2001).
5. John D. Anderson Jr, "Computational Fluid Dynamics", McGraw Hill Book Company, (2002).
6. 6. Bengt. Anderson, "Computational Fluid Dynamics for Engineers", Cambridge University Press, (2011).

Course Code	Course Title	L	T	P
CH-537	**Paint Technology**	3	0	0

Pre-requisites: None

Course objectives: The course focuses on paint its function, and classification. Students are exposed to the knowledge about raw materials used in paint Industry. It is also covering the fundamentals of paint manufacturing as well as their Industrial applications.

Syllabus:

Introduction: History and development of paint industry, paint its definition, function and classification.

Raw Materials: Raw material for industry, drying oils, bodied oils natural and synthetic resins, pigments and extenders.

Paint Auxiliaries: Auxiliaries like driers, plasticsers, softeners, dispersing and flatting agents varnishes and lacquers,

Manufacturing of paints: formulation and manufacturing of paints, machinery used in Paint manufactures, methods of application, applications of industrial and architectural finishes. Common defects in paint and varnishes.

Course Outcomes:

1. Students will learn the history and development of paint and surface coatings.
2. Students will understand the various nanomaterials used for paint technology.
3. Students will learn the paint auxiliaries and varnishes.
4. Students will learn formulation of various paints for different applications.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓	✓			
2	✓		✓	✓	✓
3	✓		✓	✓	
4	✓			✓	✓

Recommended books:

1. Payne H F , Organic coating technology Vol. I & II , Wiley, New York, (1954)
2. Morgans H M , Outlines of Paint technology, 3e, CBS, New Delhi, (2001)
3. Joseph Bijos , Good Painting Practices, Wiley, New York, (1967)
4. Bentley and Turner, Introduction to Paint Chemistry and principles of paint technology, fourth Edition, CRC publisher, Austria, (1997).

Course Code	Course Title	L	T	P
CH-538	**Microbiology for Chemical Engineers**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of physics and chemistry

Course objectives: The students will be made aware of fundamental and applied microbiology. They will learn the use of microbiology in the field of chemical engineering.

Syllabus:

Scope and History of Microbiology:
Scope and History of Microbiology, Classification, Characterization, Identification and Nomenclature of Microorganisms, Microscopy, Morphological, Structural and Biochemical characteristics of prokaryotes and eukaryotes (bacteria , yeast, mold, algae, protozoa, actinomycetes)

Cultivation of Microorganisms:
Microbiological media, physical conditions required for growth. Reproduction and Growth of Microorganism: Modes of cell division, growth curve of microbes, Quantitative measurement of growth.

Methods in Microbiology:
Chemical, Physical and Biological methods of selection of microorganisms, Methods of isolating pure cultures, Maintenance and preservation of pure cultures, microbial mutation.

Microbial Metabolism:
Metabolic pathways and Bioenergetics, Aerobic and Anaerobic growth, Transport of nutrients across cell membranes

Physical and Chemical Control of Microorganism:
Major groups of antimicrobial agents, Mode of action and practical applications

Energy Transduction Mechanisms in Microbial Cell:
Aerobic and anaerobic respiration, Microbial photosynthesis, Transduction, Transformation, Conjugation

Microbial Interaction:
Roles of microbes in Nitrogen, Carbon and Sulphur cycle

Application of Microorganism in various Field :
Agriculture, food, environment, medicine, public health and industry.

Course Outcomes:
1. Understanding of fundamentals of microbiology
2. Be familiar with cultivation, growth and control of microorganism
3. Be familiar with advantages and disadvantages of microorganisms
4. Understanding of application of microbiology in chemical engineering

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓	✓			
2	✓		✓	✓	✓
3	✓				✓
4	✓	✓	✓	✓	✓

Recommended books:

1. Pelczar M J, Chan E C S and Krieg N R “Microbiology, 5th Edition, ” Mc Graw Hill, New York (1995)
2. Davis B D, “Microbiology”, Harper and Row Publications, Hageston (1980)
3. Salle A J, “Fundamental Principles of Bacteriology” , 7th Edition, Tata McGraw Hill, New Delhi (1984)
4. Stanier R Y, “Text in Microbiology” McMillan Press London (1995)
5. Casida L E, “Industrial Microbiology”, New Age International Publishers, New Delhi

Course Code	Course Title	L	T	P
CH-539	Photocatalysis	3	0	0

Pre-requisites: Basic knowledge of physics, chemistry, materials and reaction engineering

Course objectives: Objective of this course is to deliver a knowledge to the students regarding photocatalysts, preparation, characterization and photocatalytic reactions.

Syllabus:

Introduction
History, photocatalysis, semiconductor materials, modifications and applications

Photocatalysts
Photocatalytic reactions, various photocatalysts, reactive oxygen species, binary semiconductors: titanium dioxide, zinc oxide; sulfides: cadmium sulfide, zinc sulfide; ternary semiconductors: strontium titanate, barium titanate, barium titanate; quaternary semiconductors: quaternary sulfides, quaternary oxides.

Metallization
Nature of metal, nature of the semiconductor, mechanism, titanium dioxide, zinc oxide.

Photocatalyst modification
Doping, effect of doping, metal doping, non-metal doping, codoping, sensitization, types of photosensitizer, composites photocatalysts.

Immobilization
Glass, inorganic-based supports, carbon-based supports, polymeric supports

Photoreactors
Fixed bed photoreactors, fluidized bed photoreactors, packed bed photoreactors, thin film reactors, annular reactors, immersion well reactor, multi-lamp reactors and slurry reactors.

Applications of photocatalysis
Hydrogen generation, water and air treatment, reduction of carbon dioxide, self-cleaning surfaces.

Course Outcomes:

1. Ability to develop an understanding of the photocatalytic processes
2. Understanding of methods of preparation and characterization of the photocatalysts
3. Ability to improve the physical and chemical properties of the photocatalysts
4. Understanding of techniques of synthesis of novel photocatalysts

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓	✓			
2	✓		✓	✓	
3	✓		✓	✓	
4	✓		✓	✓	✓

Recommended books:

1. Levenspiel O., “Chemical Reaction Engineering”, 3rd Edition, John Wiley & Sons, Singapore, (1999).
2. Fogler H. S., “Elements of Chemical Reaction Engineering”, 3rd Edition, Prentice Hall Inc., (1999).
3. Smith J. M., “Chemical Engineering Kinetics”, 3rd Edition, McGraw Hill, (1981).
4. Coulson J. M., Richardson J. F., “Chemical Engineering, Volume 3”, Pergamon Press, (1999). Sons, NY, (1990).

Course Code	Course Title	L	T	P
CH-540	**Cement Technology**	**3**	**0**	**0**

Pre-requisites: Chemistry, Physics, Mechanical operations

Course objectives: The course aims to provide knowledge to the students regarding the raw materials for the cement, manufacturing of the cement, types of the cement, testing of the cement and hydration of the cement

Syllabus:

Introduction to Cement

Cement and its importance in construction, History of cement and cement manufacturing process, material composition of cement, various unit operation of cement manufacture, the present status and future of cement industry in India.

Types of cement

Description and use of various type of Cement such as, Ordinary Portland Cement, Portland Pozzalana Cement, Portland Slag Cement, Sulphate Resistant Cement, White Portland Cement, and Low heat Cement, Masonry Cement, Oil Well Cement.

Raw material for cement

Source of Lime, Limestone, Chalk, Marl, Industrial waste, geological distribution of limestone deposits in India, Assessment of limestone deposits for Cement manufacture. Argillaceous Raw Materials: Source of Silica, Alumina, Iron Oxide, Shale and effect of coal ash and additives use as corrective materials, Fly ash , Slag, lime sludge as cement raw materials.

Manufacturing of cement

Process flow diagram, Chemical reaction during clinkerisation, Role of miner constituents in clinkerization , Thermo chemistry of clinker formation

Packing and dispatch of cement

Finish grinding of clinker with gypsum and other additives, combined grinding and separate grinding packing machines, use of grinding aids, type of packing medium, tolerances, bag and bulk supply, dispatch of cement.

Testing of Cements

Insoluble residue in cement, estimation of free lime in cement, fineness of cement, standard consistency of cement, Initial and Final setting of cement, soundness of cement, slump test of concrete, Flow table test of mortar , Heat of hydration of cement .Vee Bee consistometer test.

Hydration of cement

Hydration of clinker minerals, role of gypsum in cement hydration process, hydration of Portland cement and strength of Portland cement

Course Outcomes:

1. Ability to analyze the flow of raw material to cement formation quantitatively and qualitatively
2. Ability to apply the concepts of unit operation and unit processes that are employed in cement plants
3. Ability to identify the engineering problems associated with the manufacturing of cement
4. Ability to understand the testing and application of cement as building material

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓				
2	✓	✓			
3	✓		✓	✓	
4	✓		✓	✓	✓

Recommended books:

1. F. M. Lea, Chemistry of Cement and Concrete, Arnold, London.
2. W. H Duda, Cement Data Book, Verlag G m Bh, Berlin
3. R. H. Bouge, Chemistry of Portland Cement, Reinhold, New York.

Course Code	Course Title	L	T	P
CH-541	**Biorefinery and Bioproducts Engineering**	**3**	**0**	**0**

Pre-requisites: None

Course objectives: The course will provide the fundamental basis of bioproducts bioengineering based on the biorefinery concept, aimed to form the students on green chemical strategies for the processing of biomass and waste into valuable biomaterials, biochemicals and biofuels.

Syllabus:

Introduction:

Introduction and basic concepts: Green Chemistry, biorefineries, biofuels , Bioproducts and platform molecules **.**

Bioproducts from biomass:

Production of Biomaterials from Biomass, Chemicals from Biomass & waste, Biofuels from Biomass & Waste.

Biomass Conversion processes:

Biochemical conversion processes, Thermochemical conversion processes-Combustion, gasification, pyrolysis, hydrothermal liquefaction and Integrated hybrid conversion processes.

Biorefinery:

Design of a biorefinery by incorporating various unit operations, mass and energy balance, sustainability aspects using Aspen plus and other simulation packages. Examples of biorefinery concepts.

Course Outcomes:

1. Understanding the possibilities of biorefineries in a future scenario without fossil fuels.
2. Understanding Green Chemical approaches and alternative processes to bioproducts from biomass and waste.
3. Ability to identify key pathways for sustainable processing of feedstocks.
4. Knowing basic concepts of Biorefineries and Green Chemical methods and application to present industrial processes.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√		√		√
2	√	√	√	√	√
3	√	√	√	√	√
4	√		√	√	√

Recommended books:

1. Kamm, B., Gruber, P.R., and Kamm, M. (2006). Biorefineries – Industrial Processes and Products. WILEY-VCH.
2. Brown, R.C. (Ed.) Thermochemical processing of biomass into fuels, chemicals and power, Wiley, 2011.
3. Clark, J., Deswarte, F. (Ed.) Introduction to chemicals from biomass, John Wiley and Sons, U.K., 2008.
4. Basu, Prabir. Biomass gasification, pyrolysis and torrefaction: practical design and theory. Academic press, 2013.
5. Bergeron, C., Carrier, D.J., and Ramaswamy, S. (2012). Biorefinery Co-Products. Wiley & Sons, Ltd. ISBN: 978-0-470-97357-8.

Course Code	Course Title	L	T	P
CH-542	**Interfacial Science and Engineering**	**3**	**0**	**0**

Pre-requisites: Knowledge of chemical engineering, particularly thermodynamics, fluid mechanics, mass transfer and reaction engineering

Course objectives: This course has been designed to develop science and engineering aspects of fluid-fluid and fluid-solid interfaces. It is an interdisciplinary subject for chemical engineers, chemists and biotechnologists, this course aims to impart fundamental knowledge of the interfaces to the students and explain their applications. Based on the basic principles of thermodynamics, fluid mechanics, mass transfer and reaction engineering, this course covers some frontiers of chemical engineering.

Syllabus:

Introduction to the engineering of interfaces:
Definitions of fluid-fluid and fluid-solid interfaces; Occurrence of interfaces in science and engineering; Overview of industrial applications of various interfacial phenomena; Colloidal materials; Properties of colloidal systems; Experimental characterization of colloidal dispersions

Surface and interfacial tension:
Experimental techniques for the determination of equilibrium and dynamic tension, Shape of the surfaces: curvature and radius of curvature; Young-Laplace equation; Kelvin equation; Pendant and sessile drops; Adams-Bashforth equation; Characterization of fluid-solid interfaces; Contact angle and wetting phenomena; Young-Dupre equation; Measurement of equilibrium and dynamic contact angles; Deposition of thin films; Mechanism of film nucleation; Chemical vapor deposition, molecular beam epitaxy, sputtering and atomic layer deposition techniques; Applications of fluid-solid interfaces in crystallization, development of ceramic materials, catalysts, electronic products and nanomaterials.

Introduction to intermolecular and surface forces:
Van der Waals forces; Electrostatic double layer force; Disjoining pressure; DLVO theory; Non-DLVO forces.

Adsorption at fluid-fluid and fluid-solid interfaces
Adsorption of surfactants; Gibbs and Langmuir monolayers; Gibbs adsorption equation; Surface equation of state; Surface pressure isotherm; Langmuir-Blodgett films and their applications; Radiotracer and neutron reflection techniques for studying adsorption at fluid-fluid interfaces; Henry, Freundlich, Langmuir, Frumkin and Davies adsorption isotherms; Brunauer-Emmett-Teller theory of adsorption; Adsorption hysteresis; Characterization of adsorption at fluid-solid interfaces by vacuum and non-vacuum techniques.

Interfacial rheology and transport processes:
Surface shear viscosity; Surface dilatational viscosity; Boussinesq number; Interfacial tension gradient and Marangoni effect; Gibbs and Marangoni elasticity; Boussinesq-Scriven model; Interfacial turbulence; Motion of drops in a liquid; Thin liquid films; Disjoining pressure and body-force models; Stability of thin liquid film; Black films.

Interfacial reactions:
Reactions at fluid-solid interfaces; Langmuir-Hinshelwood model; External and internal transport processes; Interfacial polycondensation reactions; Fast and instantaneous reactions at fluid-fluid interfaces; Reactions at biointerfaces; Micellar catalysis; Phase transfer catalysis.

Biological interfaces:
Adsorption of proteins at interfaces; Biomembranes; Interfacial forces at biointerfaces; Adhesion and fusion phenomena; Biomaterials.

Course Outcomes:

1. The students would be well versed with the principles of interfacial science and engineering with the theory involved in the solving the chemical engineering problems.
2. The students would be able to independently solve the problems in the chemical engineering and would be aware about its applications.
3. Able to convert any chemical engineering problems in mathematical forms.
4. Ability to understand and solve the numerically chemical engineering problems.

Mapping of course objectives (CO) & program outcomes (PO)					
Course Outcomes	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	✓				✓
2			✓		
3	✓		✓		✓
4	✓		✓	✓	✓

Recommended books:

1. W.A Adamson and A. P. Gast, Physical Chemistry of Surfaces, John Wiley, New York, 1997.
2. P. Ghosh, Colloid and Interface Science, PHI Learning Pvt. Ltd., New Delhi, 2009.
3. P.C.Hiemenz and R. Rajagopalan, Principles of Colloid and Surface Chemistry, Marcel Dekker, New York, 1997.
4. R.J. Stokes and S. F. Evans, Fundamentals of Interfacial Engineering, Wiley-VCH, New York, 1997.
5. D. A. Edwards, D. A., H. Brenner. and D.T. Wasan, Interfacial Transport Processes and Rheology, Butterworth-Heinemann, Boston, 1990.
6. R.J. Hunter, Foundations of Colloid Science, Oxford University Press, New York, 2005
7. J. Israelachvili, Intermolecular and Surface Forces, Academic Press, London, 1992.

Course Code	Course Title	L	T	P
CH-543	**Materials for Chemical Engineers**	**3**	**0**	**0**

Pre-requisites:	Basic knowledge of material science
Course objectives:	The students will be made aware of fundamental and applied knowledge on various materials like metals, alloys, ceramics, polymers and composites and their functional and aesthetic qualities in application to the chemical process industries.
Syllabus:	**Metals and Alloys:** Engineering materials - ferrous metals - Iron and their alloys Iron and steel Iron carbon equilibrium diagram. Non-ferrous metals and alloys - Aluminium, copper, Zinc, lead, Nickel and their alloys with reference to the application in chemical industries. Properties and Corrosion of materials. **Polymers:** Overview of the design principles, characterization strategies, material properties, and applications of the various classes of polymers with reference to the application in chemical industries **Ceramics/glass:** Structure, application and processing; Clays; Refractories; Abrasives; Cement. Introduction to nano-materials and structure sensitive materials. Applications of the various ceramics with reference to the chemical industries **Composites:** Definition of composite material, Classification based on matrix and topology, Constituents of composites, Interfaces and Interphases, Distribution of constituents, Nano-composites, Performance of Composites, Fabrication Composites, Characterisation Composites, Industrial Application of Composite Materials. **Biomaterials:** Bio-implants, bimetallic alloys: Ti-based, stainless steels, Co-Cr-Mo alloys, Property requirement of biomaterials; Concept of biocompatibility, Bioinert, Bioactive and bioresorbable ceramics, biocompatible coatings on structural implant materials, Biodegradable polymers,
Course Outcomes:	1. Understanding of various properties and applications of metals and alloys 2. Able to get knowledge about polymers and ceramic materials and its application 3. Understanding the properties, structural morphology, characterization and preparation of composite materials. 4. Able get knowledge on various types of biomaterials and its applications.

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	√				
2	√		√	√	
3	√			√	√
4	√		√	√	√

Recommended books:

1. William D. Callister, “Materials Science and Engineering”,7th edn, John Wiley & Sons.
2. V. Raghavan, Materials Science and Engineering, Prentice Hal.
3. Composite materials,K.K. Chawala, 2nd ed.,(1987) Springer-Verlag, New York.
4. Biomaterials Science: An introduction to Materials in Medicine, Edited by Ratner, Hoffman, Schoet and Lemons, Second Edition: Elsevier Academic Press, 2004.
5. S. K. Hajra Choudhury, "Material Science and processes", 1st Edn. , 1977. Indian Book Distribution Co., Calcutta.

Course Code	Course Title	L	T	P
CH-544	**Catalysis**	**3**	**0**	**0**

Pre-requisites: Basic knowledge of physics, chemistry, materials and reaction engineering

Course objectives: Objective of this course is to deliver a knowledge to the students regarding catalysts, preparation, characterization and catalytic reactions.

Syllabus:

Introduction
Introduction to catalysis, adsorption in catalysis, adsorption types and kinetics

Heterogeneous catalysis
Catalyst types and preparation, precipitation and co-precipitation, solgel method, supported catalysts, drying, calcinations and formulation.

Characterization
Introduction, fundamentals of solid state chemistry, structure of solids, structure-property relationship and analysis, surface area analysis, pore analysis, XRD analysis, thermal analysis, FTIR analysis, catalyst tests

Catalytic reactions
Reaction mechanism, rate equations, kinetic analysis, internal and external transport, catalyst deactivation, assessment of catalyzed reactions, analysis of reaction data

Homogeneous catalysis
Introduction and different types of reactions, mechanism and kinetics, industrial homogeneous processes

Modern catalysts
Zeolite catalysts, nanocatalysts, photocatalysts, carbon nanotubes, non-metal and metal oxide catalysts

Course Outcomes:
1. Ability to develop an understanding of the catalytic processes
2. Understanding of methods of preparation and characterization of the catalysts
3. Ability to improve the physical and chemical properties of the catalysts
4. Understanding of techniques of synthesis of novel catalysts

Mapping of course objectives (CO) & program outcomes (PO)

Course Outcomes	Program Outcomes				
	1	2	3	4	5
1	✓	✓			
2	✓	✓			
3	✓		✓	✓	✓
4	✓		✓	✓	✓

Recommended books:

1. Levenspiel O., "Chemical Reaction Engineering", 3rd Edition, John Wiley & Sons, Singapore, (1999).
2. Fogler H. S., "Elements of Chemical Reaction Engineering", 3rd Edition, Prentice Hall Inc., (1999).
3. Smith J. M., "Chemical Engineering Kinetics", 3rd Edition, McGraw Hill, (1981).
4. Coulson J. M., Richardson J. F., "Chemical Engineering, Volume 3", Pergamon Press, (1999). Sons, NY, (1990).