NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF CHEMICAL ENGINEERING

Revised Curriculum and Syllabi

Program Name

Master of Technology in Chemical Engineering

Effective from the Academic Year: 2021-2022

Recommended by DPAC	: 04.08.2021
Recommended in PGAC	: 16.08.2021
Approved by the Senate	: 22.08.2021

CURRICULUM

Sl. No.	Subject Code	Name of the Subject	L	T	S	C	H
Semester I							
1.	CH 1001	Fundamentals of Chemical Engineering	3	0	0	3	3
2.	CH 1002	Chemical Reactor Analysis and Design	3	1	0	4	4
3.	CH 1003	Advanced Mathematical Methods in Chemical Engineering	3	1	0	4	4
4.	CH 903*	Elective-I	3	0	0	3	3
5.	CH 903*	Elective-II	3	0	0	3	3
6.	CH 1051	Advanced Chemical Engineering Laboratory-1	0	0	4	2	4
7.	CH 1052	Process Modelling and Simulation Laboratory	0	0	4	2	4
					Total Credit	**21**	**25**
Semester II							
1.	CH 2001	Advanced Chemical Engineering Thermodynamics	3	1	0	4	4
2.	CH 2002	Advanced Transport Phenomena	3	1	0	4	4
3.	CH 903*	Elective-III	3	0	0	3	3
4.	CH 903*	Elective-IV	3	0	0	3	3
5.	CH 903*	Elective-V	3	0	0	3	3
6.	CH 2051	Advanced Chemical Engineering Laboratory-2	0	0	4	2	4
7.	CH 2052	Mini Project with Seminar	0	0	6	3	6
					Total Credit	**22**	**27**
Semester III							
1.	CH 9071	Audit Lectures / Workshops	0	0	0	0	2
2.	CH 3051	Dissertation - I	0	0	24	12	24
3.	CH 3052	Seminar – Non Project / Evaluation of Summer Training	0	0	4	2	4
					Total Credit	**14**	**30**
Semester IV							
1.	CH 4051	Dissertation - II	0	0	24	12	24
2.	CH 4052	Project Seminar	0	0	4	2	4
					Total Credit	**14**	**28**

Total Programme Credit Point: 71

List of Elective Subjects		
Sl. No.	**Subject Code**	**Name of the Subject**
1.	CH9031	Biochemical and Bio Engineering
2.	CH9032	Advanced Process Dynamics and Control
3.	CH9033	Environmental Engineering
4.	CH9034	Non-conventional Energy Engineering
5.	CH9035	Chemical Process Optimization
6.	CH9036	Multiphase Flow
7.	CH9037	Process Intensification and Green Technology
8.	CH9038	Petroleum Refining and Petrochemical Engineering
9.	CH9039	Bioprocess and bioreactor Engineering
10.	CH9040	Mathematical Heat Transfer and Fluid Flow
11.	CH9041	Ethics in Engineering Profession
12.	CH9042	Combustion Engineering
13.	CH9043	CFD Applications in Chemical Engineering
14.	CH9044	Project Engineering and Management
15.	CH9045	Hazard Analysis and Risk Management in Chemical Industry
16.	CH9046	Nanotechnology
17.	CH9047	Computer Aided Process Engineering
18.	CH9048	Advanced Water and Wastewater Technology
19.	CH9049	Biofuel Technology
20.	CH9050	Colloids and Interface Engineering
21.	CH9051	Pinch Technology in Process Industry
22.	CH9052	Catalysis in Chemical Industry
23.	CH9053	Membrane Technology for Environment Protection

Detail Syllabus of Compulsory Courses

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH 1001	**Fundamentals of Chemical Engineering**	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	• CO1: Create a fundamental understanding of fluid statics, kinematics and kinetics • CO2: Apply mass, momentum and energy balance to hydrostatic and fluid flow problems • CO3: Analyze flow of Newtonian and non-Newtonian fluids through closed pipelines and piping network • CO4: Illustrate principles of heat transfer of different heat exchanging phenomena. • CO5: Apply laws of heat transfer for energy balance ofchemical processes. • CO6: Illustrate principles of mass transfer of chemical processes. • CO7: Apply laws of mass transfer for mass balance of chemical processes.						
Topics Covered	**Module 1** **Fluid Mechanics** Fluid flow phenomena and basic equations of fluid flow. Fluid properties, Newtonian and non-Newtonian fluids, transport properties, shell-balances including differential form of Bernoulli equation and energy balance, equation of continuity, equation of motion, equation of mechanical energy, Macroscopic friction factors, dimensional analysis and similitude, Incompressible flow through pipeline and Channels systems, velocity profiles, flow meters, pumps and compressors, elementary boundary layer theory, Flow of compressible fluids. Flow past immersed bodies including packed and fluidized beds, Turbulent flow: fluctuating velocity, universal velocity profile and pressure drop. **(13 hours)** **Module 2** **Heat Transfer** Equation of energy, steady and unsteady heat conduction in different geometrical shape like cylinder, rectangular, spherical and multilayer systems. Concept of insulators a critical insulation layer thickness. Convection: Natural and forced. Radiation. Principle of heat flow in fluids, thermal boundary layer and heat transfer coefficients, LMTD and its correction factor, Overall heat transfer coefficient. Heat transfer of fluids without phase change, Regimes of heat transfer. Laminar flow heat transfer in tubes, importance of Graetz and Peclet numbers. The Reynolds analogy and Colburn analogy. Heat transfer in Transition region between laminar and turbulent flow. Boiling, condensation						

	and evaporation; types of heat exchangers and evaporators and their process calculations; design of double pipe, shell and tube heat exchangers, and single and multi **(14 hours)** **Module 3** **Mass Transfer** Fundamentals of Mass Transfer Operations, Major industrial practices of mass transfer operations in separation and purification. Principles of operation and design methods of mass transfer systems: involving humification, dehumidification, drying and cooling. Principles of operation and design methods of mass transfer systems involving: Extraction. Absorption, Adsorption, crystallization Principles of operation and design methods of mass transfer systems involving: Distillation, advanced and special distillation processes representing high process intensification and energy-saving purification Mass Transfer without phase change involving membrane applications. **(15 hours)**
Text Books, and/or reference material	**Text books:** 1. Mass Transfer Operations: R.E. Treybal 2. Unit Operations – McCabe W L and Smith J L (McGraw Hill). 3. Transport Processes and Unit Operations – Geankoplis J G, Allen A H, Lepek D H (Prentice Hall). 4. Process Heat Transfer: D. Q. Kern, MGH 5. Heat Transfer Principles and Application, B. K. Dutta, PHI. **Reference book:** 1. Coulson and Richardson’s Chemical Engineering Volume VI (Mass & Heat Transfer); 2. Membrane-based Technologies for Environmental Pollution Control, Parimal Pal, Elsevier, Science, 2020. 3. Principle of Unit Operations – Foust A S, Wenzel L A, Curtis W, Maus L, Anderson L B (Wiley)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH 1002	**Chemical Reactor Analysis and Design**	PCR	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Reaction Engineering	CT+EA

Course Outcomes	• CO1: To design & analyse ideal and non-ideal homogeneous reactors. • CO2: To design & analyse fluid-solid catalytic, non-catalytic and multiphase reactors. • CO3: To analyse thermal instability of reactors.

	• CO4: To design and analyse bioreactors.
Topics Covered	**Module 1** Ideal Reactors: Design and analysis of isothermal and nonisothermal batch, plug flow and backmix reactors. **(8 hours)** **Module 2** Non-catalytic Fluid-solid Reactors: Shrinking core model. Design and analysis of non-catalytic fluid-solid reactors. **(4 hours)** **Module 3** Fluid-solid Catalyzed Reactors: Catalysis, interaction of physical and chemical rate processes in a porous catalyst particle, effectiveness factor, selectivity. Design and analysis of Packed-bed, Moving-bed and Fluidized-bed reactors. **(9 hours)** **Module 4** Multiphase Reactors: Design and analysis of slurry and trickle bed reactors. **(7 hours)** **Module 5** Multiple Steady States and Thermal Instability of Reactors; Dynamic analysis of CSTR; Sustained oscillation and limit cycle. **(4 hours)** **Module 6** Non-ideal Reactors: Residence time distribution of fluid in vessels, RTD in ideal and non-ideal reactors, Modelling of non-ideal reactors – Segregation model, Tanks-in-series model and Dispersion model. **(5 hours)** **Module 7** Biochemical Reactors: Enzyme-catalyzed and biomass growth reaction kinetics. Design of bioreactors. **(5 hours)** Tutorial on above topics, remedial classes and class tests. **(14 hours)**
Text Books, and/or reference material	**Text books:** 1. H. S. Fogler, Elements of Chemical Reaction Engineering, Prentice Hall. 2. O. Levenspiel, Chemical Reaction Engineering, John Wiley. **Reference book:** 1. Chemical Reactor Analysis and Design - G F Froment & K B Bischoff, John (Wiley).

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH1002	**Advanced Mathematical Methods in Chemical Engineering**	PEL	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
--	CT+EA

Course Outcomes	• Conceptualization of a chemical process and its calculation needs • Understanding the various equations for Estimation of Physical Properties and thermodynamic parameters • Understanding the mathematical equations and their solution procedure related to fluid dynamics and Chemical reaction engineering • Calculations and their solution methodology related to mass transfer
Topics Covered	**Module 1** **Solutions of Algebraic Equations** Truncation error, round-off, Chopping-off error, loss of significance and propagation of error. Jacobi and Gauss-Seidel iterations, Eigen value problem, Gauss elimination, Tri-Diagonal matrix, algorithm (TDMA), Applications-heat transfer, chemical reactions, fitting straight line and polynomial etc. Newton-Rapson method, Newton's method, application in thermodynamic property calculation, bubble point calculations equations, stability analysis of a non-isothermal CSTR. **(7 hours)** **Module 2** **Solutions of Differential Equations** ODEs-Euler's Method, Runge-Kutta Method, predictor-corrector method, Crank-Nicholson method Applications in chemical reaction Engineering and heat transfer **(6 hours)** **Module 3** **Solutions of Partial Differential Equations (PDE)** Finite volume technique for PDE. Steady state convection diffusion equation, unsteady Steady state convection diffusion equation. PDE with linear and non-linear source terms **(8 hours)** **Module 4** **Numerical methods with Matlab and Excel**

	Introduction to MATLAB, Numerical Methods with MATLAB, Linear Systems, Nonlinear Equations, Regression Analysis, Interpolation., Optimization, Differentiation and Integration, Ordinary Differential Equations, Partial Differential Equations **(5 hours)** **Module 5** **Fluid Mechanics** Friction Factor, Flow of Fluids in Pipes, Friction Loss, Overall Pressure Drop, Flow through Tank, Compressible Fluid Flow in Pipes, Two-Phase Flow in Pipes, **(5 hours)** **Module 6** **Chemical Reaction Engineering** Calculations and estimations of different parameters related to the following: Reaction Rates, Continuous-Stirred Tank Reactor (CSTR), Batch Reactor, Catalytic Reactors **(5 hours)** **Module 7** **Mass Transfer** Multiple-Effect Evaporators, Shortcut Calculation Method for Multicomponent Distillation, Rigorous Steady-State Distillation Calculations **(6 hours)** Tutorial on above topics, remedial classes and class tests. **(14 hours)**
Text Books, and/or reference material	**Text Books:** 1. Chemical Engineering Computation with MATLAB., Yeong Koo Yeo, CRC Press 2. T.F. Edgar and D.M. Himmelblau," Optimization Techniques for Chemical Engineers", McGraw-Hill, New York, 1985. 3. S. S. Rao, "Engineering Optimization Theory and Practice", Third edition, New Age International Publishers, India. 4. S. K. Gupta, "Numerical Techniques for Engineers", New Age International Publishers, 3rd edition, 2015 5. Mathematical Methods in Chemical & Environmental Engineering: Ajay K. Ray, Thomson Learning, 2000. **Reference Books:** 1. K. Deo, "Optimization Techniques", Wiley Eastern, 1995. 2. R. Panneerselvam, "Operation Research", 2nd Ed., PHI Learning private Ltd, New Delhi, India. 3. Prem Kumar Gupta and D.S.Hira "Problems in Operations Research (Principles and Solutions)", S. Chand and company Ltd. New Delhi, India.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH1051	**Advanced Chemical Engineering Laboratory-1**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic knowledge of Chemical Engineering		CT+EA					
Course Outcomes	• To make the students enabled to handle different research equipment/instrument. • To make the student enabled to know exactly his/her own area of interest to carry out research project in that area in future. • To make the students enabled to analyse the experimental results with justification.						
Topics Covered	1. Adsorptive Removal of micro pollutant from aqueous solution 2. Phyco-remediation of pollutant using algae 3. Hydrodynamics study of inverse fluidization 4. Experimental investigation of CO_2 absorption in aqueous amine 5. Synthesis of graphene oxide and reduced graphene oxide 6. Determination of performance index (PFI) of Nanofiltration Membrane/ultrafiltration membrane 7. Experimental Study of Bubble Dynamics in Pool Boiling Heat Transfer 8. Advance Oxidation of Coke-Oven wastewater						
Text Books, and/or reference material	**Text Books:** 1. Coulson and Richardson, *Chemical Engineering*, Butterworth-Heinemann, 1999 2. D. Kunii and O. Levenspiel, *Fluidization Engineering*, Butterworth-Heinemann, 1991.						

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH1052	**Process Modelling and Simulation Laboratory**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
--		CT+EA					

Course Outcomes

- Conceptualization of a chemical process and its simulation needs
- Understanding the various thermodynamic property packages for Estimation of Physical Properties and thermodynamic parameters
- Understanding the simulation modules and their solution procedure related to process equipment like heat exchanger, reactor, distillation columns
- Calculations and their solution methodology related to various simulation methods in commercial simulators

Topics Covered

Module 1

Introduction to process simulation

Use of simulation, what is Flow sheet simulation? Advantage of simulation, Understanding the simulation problem, Approaches to flowsheet simulation, Sequential modular and equation oriented, Structure of a process simulator, Flow sheet tropology level, Unit operation models and physical property models, Steps in Aspen simulation. Run the first Aspen Simulation., Physical property environment, Use of method assistant to know the physical property method, Workshop on property analysis in Aspen.

a) Case study: 1. Estimating pure component property as a function of temperature and pressure of any compound in Aspen simulation

b) Case study: 2 Estimating XY, TXY, PXY, Gibbs energy of mixing curve of a binary system.

c) Case study: 3 Estimating ternary maps showing phase envelop, tie lines and azeotrope of ternary system.

(7 hours)

Module 2

Mixer, Splitter, Flash simulation in Aspen

Overview of library modules of mixer, splitter and flash separation, Workshop on Flash unit, Workshop on three phase flash unit operation block, Pump, Compressor, Turbine, Control valve, Pipe line simulation in Aspen, Overview of pump and turbine simulation, Case study of pump simulation, Models of compressor and multistage compressor. Valve model, Pipe model, Pipeline model, Case study of pipe line, pump and valve simulation.

(7 hours)

Module 3

Heat exchanger simulation

- Overview of Heat exchanger modules available in Aspen.
- Heater model.
- Workshop on heater model.

- HeatX model
- Workshop on HeatX model
- HeatX vs. Heater model
- Rigorous heat exchanger design by EDR module
- Workshop on EDR module

(7 hours)

Module 4
Reactor simulation

- Overview of reactor modules available in Aspen.
- Yield Reactor
- Stoichiometric Reactor.
- Equilibrium Reactor
- Gibbs Reactor
- Workshop on Gibbs Reactor
- CSTR
- Workshop on CSTR in series
- Plug flow Reactor
- Workshop on Plug flow reactor
- Batch Reactor
- Workshop on Batch Reactor
- Workshop on industrial Ethyl Acetate Reactor.
- Workshop on industrial Ethylene Glycol Reactor

(7 hours)

Module 5
Distillation Column simulation

- Overview of different distillation column modules available in Aspen library.
- DSTWU (Short cut Distillation design)
- DISTL (Short cut Distillation rating)
- RadFRac (Rigorous Distillation design and rating)
- Workshop on DSTWU
- Reflux ratio and number of trays.
- DISTL
- Industrial Benzes Toluene distillation
- Design spec.
- Optimum feed tray location.
- Detail design methodology for distillation use in RadFrac.
- RadFrac setup configuration sheet.
- Design spec and vary.
- RadFrac convergence problem.

(7 hours)

Module 6
Design Specification

- Understanding the design specification with a real-life case study
- Steps for using design specification
- Design specification example
- Convergence problem in Design specification.

	• Case study of design spec. **(7 hours)** **Module 7** **Sensitivity Analysis** • Understanding the Sensitivity analysis with a real-life case study • Steps for using Sensitivity analysis • Sensitivity analysis example • Plotting the sensitivity analysis results. • Case study of sensitivity analysis **(7 hours)**
Text Books, and/or reference material	**Text Books:** 1. Aspen Plus: Chemical Engineering Applications, Kamal Al-Malah, Wiley 2. Chemical Engineering Computation with MATLAB. ,Yeong Koo Yeo, CRC Press 3. S. S. Rao, "Engineering Optimization Theory and Practice", Third edition, New Age International Publishers, India. 4. S. K. Gupta, "Numerical Techniques for Engineers", New Age International Publishers, 3rd edition, 2015 5. Mathematical Methods in Chemical & Environmental Engineering: Ajay K.Ray, Thomson Learning, 2000.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH 2001	**Advanced Chemical Engineering Thermodynamics**	PCR	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basic and Undergraduate level Engineering Thermodynamics course	CT+EA

Course Outcomes	CO1: To learn the application of equation of state for ideal and non-ideal gases, and exergy analysis of chemical processes CO2: To learn various fundamental property relations and their application to estimate thermodynamic parameters CO3: To learn the thermodynamics of fluid phase equilibria CO4: To learn the statistical interpretation of distribution function for measurement of interactions and surface forces.
Topics Covered	**Module 1** Review of laws of thermodynamics, Equations of state for ideal and non-ideal gases, Kammerlingh-Onnes equation, Van der Waals equation, Redlich-Kwong equation, Peng-Robinson equation, Bennedict-Webb-Rubin equation, Law of corresponding states, Acentric factor, Virial and cubic equation of state for binary mixtures, Exergy of heat, Exergy analysis of Chemical Engg Processes. Entropy and estimation of entropy changes. **(7 hours)** **Module 2** Maxwell's relations, Clausius Clapeyron equation, Gibbs-Helmhotz equation, TDS equations, Heat capacity relations, Isothermal compressibility, Volume expansivity, Joule-Thomson coefficient. Residual properties: Estimation of residual parameters from virial and cubic equation of state, Fugacity and fugacity coefficient: Fugacity coefficient from compressibility factor, cubic and virial equation of state, Effect of temperature and pressure on fugacity. **(6 hours)** **Module 3** Thermodynamics of fluid phase equilibrium: Partial molar properties, Chemical potential, Activity and activity coefficients, their evaluation, Gibbs–Duhem equation, Fugacity in mixture, Excess functions, Ideal solution, Lewis-Randall rule, Phase equilibrium for Multi-component system, Vapour-liquid equilibrium, Excess Gibb's free energy model: Wilson equation, NRTL equation, UNIFAC (Universal Functional Activity Coefficient) method, van Laar theory, Scatchard-Hildebrand theory, Flory-Huggins theory, Liquid-Liquid equilibrium, Solid-Liquid

	equilibrium. **(10 hours)** **Module 4** Multi-reaction stoichiometry, Equilibrium criterion of Chemical Reaction, Equilibrium constant, Van't Hoff's equation, Homogeneous gas-phase and liquid-phase reaction, Heterogeneous reaction equilibria, Fuel cell. **(7 hours)** **Module 5** Statistical Thermodynamics: Thermodynamic ensemble; Most probable thermodynamic distribution function; Canonical, grand canonical and micro-canonical ensemble partition functions; Derivation of thermodynamic variables from partition functions; Statistical explanation of second and third laws of thermodynamics; Quantum statistics; Maxwell Boltzmann statistics, Fermi-Dirac statistics, and Bose-Einstein Statistics; their distributions; **(12 hours)** Tutorial on above topics, remedial classes and class tests. **(14 hours)**
Text Books, and/or reference material	**Text Books:** 1. Smith, J.M., Van Ness, H.C., and Abbott, M.M. "Introduction to Chemical Engineering Thermodynamics", 7th Edition., McGraw-Hill 2. Halder, G., Introduction to Chemical Engineering Thermodynamics, 2nd edition, 2013, PHI Learning Pvt. Ltd, New Delhi **Reference Books:** 1. Thipse, S.S. "Advanced Thermodynamics", Narosa Publishing House, New Delhi. 2. Thermodynamics and Introduction to Statistical Mechanics, B. Lindner, Wiley Interscience, 2004

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Background Core (BC) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH 2002</td><td>Advanced Transport Phenomena</td><td>BC</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Basics of Fluid Mechanics, Heat Transfer and Mass Transfer</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To create an understanding on universal approach of transport phenomena and fundamental transport processes like mass, momentum andenergy.
• CO2: To give an understanding on shell balance technique, setting of boundary conditions etc. for different geometry of a system.
• CO3: To apply NSE, equation of continuity, equation of energy etc. to different types of geometrical systems.
• CO4: To solve problems on mass, momentum and energy transport using transport phenomena approach.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1
Transport Phenomena-an universal approach, Reynold transport theorem, Fundamental transport Processes and their relation.
(3 hours)
Module 2
Momentum transport phenomena: Idea about Shell balance technique and its application in rectangular, cylindrical and spherical coordinate systems.
Navier stokes equation (NSE), Euler equation, application of NSE in rectangular, cylindrical and spherical coordinate systems. Flow through parallel plates, flow over flat plates, Steady and unsteady systems, turbulent flow
(12 hours)
Module 3
Energy transport: Basic energy transport equations, application of equation of energy for analyzing different heat conduction, convection and reactor systems, steady state and unsteady state systems, simultaneous energy and mass transport systems
(12 hours)
Module 4
Mass transport: Types of fluxes and their relation, continuity equation for a binary mixture, application of equation of continuity for different coordinate systems, steady and unsteady state systems, diffusion in porous catalyst</td></tr>
</table>

	with and without chemical reaction, diffusion in falling liquid film, turbulent mass flux, interphase mass transport. **(12 hours)** **Module 5** Transport phenomena in small- and large-scale systems and their application. **(3 hours)** Tutorial on above topics, remedial classes and class tests. **(14 hours)**
Text Books, and/or reference material	**Text Books:** 1. Analysis of Transport Phenomena by William M. Deen, Oxford Univ Pr; 2nd Edition, 2011. 2. Transport Phenomena by Bird, Stewart & Lightfoot, Wiley, 2nd Edition, 2010. **Reference Books:** 1.Transport Phenomena: A Unified Approach by Brodkey& Hershey, McGraw-Hill Chemical Engineering Series, Brodkey Publishing, 2003 2. Transport Phenomena: An Introduction to Advanced Topics, Larry A. Glasgow, Wiley, July 2010.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH2051	**Advanced Chemical Engineering Laboratory-2**	PCR	0	0	4	4	2

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
None	CT+EA

Course Outcomes	• CO1: Understanding the working mechanism of different instruments. • CO2: Acquiring knowledge on data analysis of different instruments.
Topics Covered	1. Determination of total organic and inorganic carbon using TOC analyser 2. Determination of heavy metal from wastewater using Atomic absorption Spectrometer 3. Estimation of anion from wastewater using ion chromatography 4. Detection/prediction of presence of functional group/s in a sample by UV spectroscopy 5. Detection/prediction of presence of functional group/s in a sample by fluorescence spectroscopy 6. Detection of components with quantification by HPLC 7. Detection of components with quantification by GC-MS 8. Prediction of presence of functional groups in a sample by FTIR 9. Thermal stability analysis of solid sample using TGA 10. Rheological study of fluids using viscometer 11. Surface area analysis using BET apparatus 12. Detection of pore size distribution, adoption, desorption and surface area calculation using porosimeter.
Text Books, and/or reference material	• Lab Manual • Study materials will provided by instructor.

Detail Syllabus of Elective Courses

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit (C)
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH 9031	**Biochemical and Bio-Engineering**	PEL	3	0	0	3	3

Pre-requisites:	Course Assessment methods (Continuous (CT) and end assessment (EA))
--	CT+EA
Course Outcomes	
Topics Covered	Basics of Microbiology, Molecular Biology, Biophysics, Genetic Engineering, Microbial and enzymatic kinetics, Applied Tissue Engineering: Clinical and industrial perspective, Design of minimally invasive surgical tools, Principles of Biocompatibility, Biomedical Engg. Biomolecular material science, Herbal products, Targeted Drug delivery and control drug release/kinetics, Monoclonal antibody production through Hybridoma technology, Bio-Microfludics and Bionano Technology, Biopolymer materials, Bioseparation and Bioprocess Engg. Vaccine and bio-similars manufacturing process, Bio-Transport and bio-reaction process, Bio-hydromettalurgy, Bioenergy, Value added product recovery from waste using Bio-tools. etc. Introduction to Pharmaceutical industry, Bulk drug manufacturing.
Text Books, and /or reference material	**Text Books:** 1. Microbiology by Michael Pelczar, McGraw-Hill Education, 1998. 2. Bioprocess Biotechnology Fundamental by S N Mukhopadhyaya, Piva Books Pvt. Ltd. 3. Bioreactor system design by Mercuk, Dekker Publication 4. Industrial biotechnology by K Watson, CBS Publishers and Distributor **Reference Books:** 1. Bailey, J. E., and D. F. Ollis. Biochemical Engineering Fundamentals. 2nd ed. New York, NY: McGraw-Hill, 1986.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9032	**Advanced Process Dynamics and Control**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
	CT+EA

Course Outcomes	• Determining the control structures in chemical processes • Understanding multiple MIMO systems and their dynamical interactions • Understanding the working of Model Predictive Control (MPC) • Awareness of different implementations steps of MPC in industry • Determining the controller settings for MIMO systems.
Topics Covered	**Module 1** **SISO control system** Purpose of Process Control in Chemical Process Industries (CPI), Basic Feedback control loop, Control hardware; Process dynamics, Regulatory PID Control Layer, Advance Regulatory Control (ARC) Layer, Basis of cascade control, Ratio control, Feedforward control, split range control, Shortcomings of Simple Regulatory PID Control **(10 hours)** **Module 2** **Model Predictive Control (MPC) and MIMO control system** MIMO control systems, Basic concept of Multivariable Model Predictive Control, Function of Multivariable Model Predictive Optimizing Controller, Relevance of Multivariable Predictive Control (MPC) in Chemical Process Industry in Today's Business Environment, Position of MPC in Control Hierarchy, Advantage of Implementing MPC, How Does MPC Extract Benefit? Application of MPC in Oil Refinery, Petrochemical, Fertilizer, and Chemical Plants, and Related Benefits **(10 hours)** **Module 3** **Theoretical base of Model Predictive Control (MPC)** Concept of Controlled variables, manipulated variables and Disturbance variable, Features of MPC, Brief Introduction to Model Predictive Control Techniques, Simplified Dynamic Control Strategy of MPC, Historical Development of Different MPC Technology **(10 hours)** **Module 4** **MPC Implementation Steps** Preliminary Cost–Benefit Analysis, Assessment of Base Control Loops, Functional Design of Controller, Conduct the Preliminary Plant Test

	(Pre-Stepping), Conduct the Plant Step Test, identify a Process Model, Perform Offline Controller Simulation/Tuning, Commission the Online Controller, Online MPC Controller Tuning, Hold Formal Operator Training, Performance Monitoring of MPC Controller, Maintain the MPC Controller, Summary of Steps Involved in MPC Projects with Vendor **(10 hours)**
Text Books, and/or reference material	**Text Books:** 1. SK Lahiri, Multivariable predictive Control-Applications in industry, Wiley. 2. P. K. Sarkar, Advanced Process Dynamics and Control, Prentice-Hall of India Pvt. Ltd. 3. D.E. Seborg, T.F. Edgar, E.A. Mellichamp, F. J. Doyle, Process Dynamics and Control, 3rd edition, John Wiley & Sons, NY. 4. B.A. Ogunnaike and W.H. Ray, 1994, Process Dynamics, Modeling, and Control, Oxford University Press.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9033	**Environmental Engineering**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basic subjects of Chemical Engineering and Mathematics	CT+EA

Course Outcomes	• CO1: To illustrate the fundamental concepts in environmental engineering dealing with water, air, and land pollution • CO2: To illustrate different techniques as used for treatment of wastewater with special emphasis on design, operational features, etc • CO3: To design and analyse the equipment as used for removal of particulate and gaseous pollutant from waste gas • CO4: To analyse the techniques used for treatment of industrial wastes and case studies
Topics Covered	**Module 1: Introduction and Physico-chemical Treatment** Introduction to environment, Constituents of environment, Sources of water and its uses: domestic and industrial. Domains of environmental degradation and its root causes, Characteristics of drinking and wastewaters, WHO standards, Physical, chemical and biological treatment techniques, Treatment options and selection of appropriate treatment scheme. Physico-chemical treatment units, Screening, Grit Chamber, Mixing, Principles of settling, Coagulation, Flocculation, Design and operation of settling tanks, Chemical treatments, Advanced oxidation, WET oxidation, Catalytic degradation, Membrane based separation, Ion exchange and disinfection of water, Adsorption, etc. **(10 hours)** **Module 2: Biological Treatment** Process design and operation of attached growth, suspended growth, hybrid/integrated process, Design and operation of biological treatment units like ACS, Biofilter, Trickling Filter, RDC, Design and operations of lagoons, and troubleshooting of ACS units, Phycoremediation; Toxicity analysis of untreated and treated wastewater for its further use. **(10 hours)** **Module 3: Air Pollution** Air pollution- sources, classification, health hazards, Dispersion of air pollutants, plume behaviour, Stack design, abatement techniques of air pollutants, Design and operation of control devices, Design and operational problems of gravity separators, cyclone separators, ESP, Filtration, Bag Filter – Operation and Principle, Water scrubbing, venture scrubber Abatement of gaseous pollutants like SO_x, NO_x, CO_2 etc., Powers and functions of state and central PCBs, GHG emission, global warming, climate change. **(10 hours)**

	Module 4: Industrial wastes and Case Studies Industrial wastes and their sources: Various industrial processes, Sources and types of solid, liquid, gaseous wastes, Solid waste management, Noise & radiation emissions. Processes responsible for deterioration of environment, Various waste water streams, Control and removal of specific pollutants in industrial wastewaters, e.g., oil and grease, bio-degradable organics, chemicals such as cyanide, fluoride, toxic organics, heavy metals, radioactivity etc. Wastewater reuse & recycling, Modern trend in load reduction. Effluent treatment plant design, Concept of zero discharge effluent. Recent trends in industrial waste management, Cradle to grave concept, Life cycle analysis, Clean technologies, Case studies of various industries, e.g., dairy, fertilizer, distillery, sugar, pulp and paper, iron and steel, metal plating, thermal power plants, etc. Concept of waste utilization and value added product recovery and its impact in society. **(12 hours)**
Text Books, and/or reference material	**Text Books:** 1. Wastewater Engineering-Treatment and Reuse. Metcalf & Eddy, 4th Edition, McGraw-Hill, 2003; Publisher: McGraw-Hill Science/Engineering/MathISBN-13: 978-0070418783, ISBN-10: 0070418780. 2. Environmental Engineering, M. L. Davis and D. A. Cornwell; 3rd Edition (January 1, 1998), Publisher: WCB/McGraw-Hill; ISBN 10: 0070159114ISBN 13: 9780070159112. **Reference Books:** 1. Fundamentals of Water Treatment Unit Processes: Physical, Chemical, and Biological. David Hendricks. Publisher: CRC Press/ IWA Publishing, 2011; ISBN-10: 1420061917, ISBN-13: 978-1420061918. 2. Environmental Engineering. Howard Peavy, Donald Rowe, George Tchobanoglous Publisher: McGraw Hill Education (India) Private Limited; First edition (1 August 2013); ISBN-10: 9351340260, ISBN-13: 978-9351340263. 3. Environmental Pollution Control Engineering. C.S. Rao; 2nd Edition, Publisher: New Age International, 2006; ISBN-13:9788122418354, ISBN-10:812241835X. 4. Air Pollution Control Equipment. H. Brauer and Y. B. G. Verma; Latest Edition; Publisher: Springer, 1981; ISBN-13:9783540104636, ISBN-10:3540104631. 5. Environmental Engineering. Arcadio P. Sincero and Gregoria A. Sincero; 1st Edition (August 18, 1995), Publisher: Prentice Hall; ISBN-13: 978-0024105646, ISBN 10: 0024105643. 6. Edmund, B. Besselieve P.E. “The Treatment of Industrial Wastes”, Mc-Graw Hill. 7. Nancy, J.S. “Industrial Pollution Control: Issues and Techniques”, Van Nostrand Reinhold. 8. Shen, T.T. “Industrial Pollution Prevention Handbook”, Springer-Verlag. Environment (protection) Act - 1986, Ministry of Environment and Forest, Government of India.

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH9034</td><td>Non-conventional Energy Engineering</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Fundamental of fuels, Mathematics</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Learn about energy technology of different conventional and nonconventional energy resource and Recent worldwide energy market scenario.
• CO2: Design & analyze of different renewable energy collectors and renewable energy thermal power plants.
• CO3: Learn industrial and domestic applications of different renewable energy sources.
• CO4: Solve energy technology problems of different difficulty levels through tutorials</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1
Energy Scenario: Classification of Energy Sources, Energy resources (Conventional and nonconventional), Energy needs of India, and energy consumption patterns. Worldwide Potentials of these sources. Energy efficiency and energy security. Energy and its environmental impacts, Distributed generation.
(4 hours)
Module 2
Solar Energy: Solar radiation and its measurement, limitations in the applications of Solar Energy, Solar collectors – types, and constructional details. Solar water heating, applications of Solar Energy for heating, drying, space cooling, water desalination, solar concentrators, photovoltaic power generation using silicon cells. solar water heating, solar cooling, solar distillation, solar refrigeration, solar dryers, solar pond, solar thermal power generation, solar energy application in India, energy plantations, Photo voltaic (PV) technology: Present status, solar cells, cell technologies, characteristics of PV systems, equivalent circuit, array design , building integrated PV system, its components, sizing and economics. Peak power operation. Standalone and grid interactive systems.
(10 hours)
Module 3
Wind Energy: Wind speed and power relation, power extracted from wind, wind distribution and wind speed predictions. Wind power systems: system</td></tr>
</table>

components, Types of Turbine, Turbine rating. Choice of generators, turbine rating, electrical load matching, Variable speed operation, maximum power operation, control systems, system design features, stand alone and grid connected operation. Small Hydro Systems.

(10 hours)

Module 4

Nuclear Energy: Nuclear fission principles, types of nuclear reactors (BWR, PWR, PHWR, LMCR, GCR, FFR). Nuclear reactor analysis: four factor formula, resonance absorption, reactor buckling, multiplication factor, thermal utilisation coefficient, reflector saving, fast fission factor, optimum moderator to fuel ratio. Radioactive waste disposal.

(6 hours)

Module 5

Geothermal Energy: Geo technical wells and other resources dry rock and hot aquifer analysis, harnessing geothermal energy resources. Ocean wave energy conversion, ocean thermal energy conversion, tidal energy conversion.

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. Biofuels such as biodiesel, ethanol, biobutanol etc. and their production and present status.

(8 hours)

Module 6

Energy Storage and Distribution: Importance, biochemical, chemical, thermal, electric storage. Fuel cells, distribution of energy. Energy Storage -Sensible, latent heat and thermo-chemical storage-pebble bed etc. materials for phase change-Glauber's salt-organic compounds.

(4 hours)

Text Books, and/or reference material

Text Books:

1. Goldmberg J., Johansson, Reddy A.K.N. & Williams R.H., Energy for a Sustainable,World, John Wiley.
2. Bansal N.K., Kleeman M. & Meliss M., Renewable Energy Sources & Conversion Tech., Tata McGraw Hill.
3. Sukhatme S.P., Solar Energy, Tata McGraw Hill
4. Mittal K.M., Non-Conventional Energy Systems, Wheeler Pub.
5. Pandey G.N., A Text Book on Energy System and Engineering, Vikas Pub.
6. Rai G.D., Non-Conventional Energy Sources, Khanna Pub.

Reference Books:

1. Venkataswarlu D., Chemical Technology, I, S. Chand
2. Rao S. & Parulekar B.B., Energy Technology, Khanna Pub.

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<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH9035</td><td>Chemical Process Optimization</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Mathematics, Chemical Engineering Computing Laboratory</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1. Able to apply the knowledge of optimization and optimum design and an overview of optimization methods.
• CO2. Ability to solve various multivariable optimization problems and solve chemical process optimization issues using MATLAB.
• CO3. Develop skills to implement the theory and applications of optimization techniques in a comprehensive manner for solving linear and non-linear, geometric, dynamic, integer and stochastic programming techniques.
• CO4. Identify, formulate and solve a practical engineering problem of their interest by applying or modifying an optimization technique.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1
The nature and organization of optimization problems, scope and hierarchy of optimization, examples of applications of optimization in chemical industry, essential features of optimization, general procedures for solving optimization problems, basic concepts of optimization, continuity of functions, unimodal vs multimodal functions, convex and concave functions, convex region, necessary and sufficient conditions for an extremum of an unconstrained function, interpretation of the objective function in terms of its quadratic approximation.
(5 hours)
Module 2
Optimization of unconstrained function, one dimensional search, numerical methods for optimizing a function of one variable, scanning and bracketing procedures, Newton, Quasi, Newton and Secant methods of uni, dimensional search, region elimination methods, polynomial approximation methods, one dimensional search applied in a multidimensional problem, evaluation of uni-dimensional search methods, unconstrained multivariable optimization , direct methods, indirect methods–1 st order, 2 nd order; secant methods.
(10 hours)
Module 3
Linear programming and applications, basic concepts in linear programming, degenerate LPs–graphical solution, natural occurrence of linear constraints, simplex method of solving linear programming problems, standard LP form,</td></tr>
</table>

	obtaining a first feasible solution, revised simplex method, LP applications in chemical industry. **(7 hours)** **Module 4** Linear Regression, Multiple, polynomial and general least square regression, Nonlinear regression; Regression: MATLAB implementation. **(5 hours)** **Module 5** Teaching-Learning based optimization(TLBO), Implementation of TLBO in MATLAB, Particle Swam Optimization (PSO), Implementation of PSO in MATLAB, Differential Evolution(DE), Implementation of DE in MATLAB, Genetic Algorithm(GA), Implementation of GA in MATLAB, Other MATLAB optimization tools and in-built functions. **(15 hours)**
Text Books, and/or reference material	**Text Books:** 1. Edgar, T.F. and Himmelblau, D.M., Optimization of Chemical Processes, McGraw Hill, 1989. 2. Deb K., Optimization for engineering design, Algorithms and examples, Prentice Hall of India, New Delhi, 2005. 3. Urbanier, K. and McDermott, C., Optimal Design of Process Equipment John Wiley, 1986. **Reference Books:** 4. Reklaitis, G.V., Ravindran, A., Ragsdell, K.M., Engineering Optimization, John Wiley, New York, 1980. 5. Biles, W.E. and Swain, J.J., Optimization and Industrial Experimentation, Inter Science, New York, 1980. 6. Seinfield, J.H., Lapidus, L., Process Modelling, Estimation and Identification, Prentice Hall, Englewood Cliffs, new Jersey, 1974.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9036	**Multiphase Flow**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Fluid mechanics, heat transfer, transport phenomena, mathematical methods	CT+EA

Course Outcomes	• CO1: To learn the fundamental concepts and applications of multiphase flow • CO2: To learn the numerical models and methods for transport mechanisms and design strategy for multiphase flow • CO3: To learn the dynamics of bubble, drop and solid particle • CO4: To learn the measurement methods for multiphase flow
Topics Covered	**Module 1** Fundamental concepts and applications of multiphase flow Two-phase flow; three-phase flow; components; fields; space and time-averaging; volume/void fraction; flow quality; superficial velocities; phase velocities; volumetric flux; velocity ratio; slip; volume and mass-centered velocity; homogeneous flow; drift flux; separated flow; Martinelli parameters; two-phase multiplier and correlations; two-phase pressure drop; isothermal and non-isothermal flows; applications of nuclear, thermal, petroleum, chemical industries and in nature. **(5 hours)** **Module 2** Flow patterns and transitions Flow patterns; identification and classification; flow pattern maps and transition in gas-liquid, solid-gas, solid-liquid, gas-solid-liquid flows; boiling channel; bubble column, fluid bed; trickle beds; prediction of holdup and pressure drop in different flow regimes. **(5 hours)** **Module 3** Numerical models and methods Conservation equations for mass, momentum and energy for heat transfer and flow field in multiphase flow; homogeneous and separated flow model; drift flux model; two-fluid models; Eulerian and Lagrangian methods; numerical methods for solutions; closure equations for fluid-wall and interfacial transports of heat and momentum; drift flux and slip correlations for bubbly, slug, annular and stratified flows. **(12 hours)**

	Module 4 Dynamics of bubble, drop and solid particle Growth of bubble and drop; terminal velocity of bubble, drop and particle; pinch-off; contact line and triple contact lines; coalescence; breakup and collapse; deformation of bubbles and particles; flow around a spherical particle; flow through porous medium. **(7 hours)** **Module 5** Measurement methods in multiphase flow: Two-phase pressure drop, void fraction, phase indication; phase distributions; phase velocities; anemometry; velocimetry; densitometry; optical methods; electrical methods. **(10 hours)**
Text Books, and/or reference material	**Text Books:** 1. Yadigraoglu, G., Hewitt, G. F., Introduction to Multiphase flow – Basic Concepts, Applications and Modeling. Springer, 2018. 2. Wallis, G. B., "One Dimensional Two Phase Flow", McGraw Hill Book Co., New York, 1969. 3. Collier, J. G. and Thome, J. R., Convective Boiling and Condensation, 3rd ed., Oxford University Press 4. Ghiaasiaan, S. M., Two-Phase flow, Boiling, and Condensation, Cambridge University Press, 2007. 5. Crowe, C. T., Sommerfeld, M. and Tsuji, Y., Multiphase Flows with Droplets and Particles, CRC Press, 1998. 6. Govier, G. W. and Aziz. K., "The Flow of Complex Mixture in Pipes", Van Nostrand Reinhold, New York, 1972. 7. Prosperetti, A., Tryggvason, G., Computational Methods for Multiphase Flow, Cambridge University Press, 2007 **Reference Books:** 1. G. Hetsroni, Handbook of Multiphase Systems, Mcgraw-Hill Book Company, New York, 1982.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9037	**Process Intensification and Green Technology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
--		CT+EA					

Course Outcomes	• CO1: Understanding the concept, need and benefits of process intensification amidst stringent environmental regulations, concerns for energy security and sustainable development • CO2: Learn different approaches of achieving process intensification • CO3: Learning the principles of green chemistry and green processing • CO4: Learning design, operation, analysis and application of selected process intensification technologies
Topics Covered	**Module 1** Basics of Process Intensification, definitions, routes, benefits, need for process intensification, sustainable development issues 4 Hrs Module 2: Twelve principles of green chemistry. Matrices for chemistry: Effective mass yield, carbon efficiency, atom economy, reaction mass efficiency, Environmental factor (E). **(4 hours)** **Module 2** Process Intensification by Multifunctional equipment, Principles, design, operation and case studies. **(4 hours)** **Module 3** Process Intensification by reactive distillation: Principles, design, control, feasibility, technical evaluation, case studies. **(4 hours)** **Module 4** Process Intensification by catalytic distillation: Principles, design, operation, application, economics. **(4 hours)** **Module 5** Process Intensification by Membrane application: principles, modular design issues, energy saving prospects, space-saving prospects, green processing prospects, case studies. **(4 hours)** **Module 6** Case studies of process intensification in lactic acid manufacture, glutamic acid manufacture, industrial wastewater treatment and reuse, recovery of

	valuables. **(6 hours)** **Module 7** Process Intensification through cavitation reactors, oscillatory baffled reactors, sono-chemical, hydrodynamic cavitation reactors, case studies. **(4 hours)** **Module 8** Process Intensification through monolith reactors: Hydrodynamics, design, advantages, applications. **(4 hours)**
Text Books, and/or reference material	**Text Books:** 1. Intensification of bio-based processes, A. Gorak, Andrzej Stankiewicz edited. RSC publication 2. A. Stankiewicz, J.A. Moulijin, Re-engineering the Chemical Processing Plant, Process intensification, Marcel Dekker, New York (2004) 3. Membrane based technologies for environmental pollution control, P.Pal, Elsevier Sci.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9038	**Petroleum Refining and Petrochemical Engineering**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Fuel and combustion	CT+EA

Course Outcomes	• CO1: Understanding the role of petroleum as energy source amidst world energy scenario • CO2: Learning design and operation of petro refineries and petrochemical complexes • CO3: Learning safe practices in operations of refineries and petrochemical complexes • CO4: Identifying challenges, energy security issues and environmental issues
Topics Covered	**Module 1** Petroleum - Origin and Occurrence, Exploration, Estimation and recovery, Evaluation of crude, Properties, testing and specifications of petroleum products, Problems & Prospectus of petroleum refining in India. **(10 hours)** **Module 2** Processing of Crude Petroleum - Atmospheric and Vacuum distillation, column control schemes, Conventional thermal cracking – vis-breaking and design variables of vis-breaking – coking: Fluid coking, flexi coking, delayed coking and hardware considerations – catalytic conversion processes -fluid catalytic cracking with special reference to catalyst and reactor design configurations – hydro-treating, hydrodesulphurization and hydro-cracking – Reforming: process, catalyst, reactor design configuration – alkylation – isomerization – lube oil manufacturing process, solvent – de-asphalting, solvent de-waxing. **(12 hours)** **Module 3** Production of finished petroleum goods like, LPG, Kerosene, Petrol, Diesel, Lubricating Oil, Bitumen, environmental norms of products. **(4 hours)** **Module 4** Petrochemical technology: Petrochemical industry overview, primary raw materials for petrochemicals, first generation petrochemicals – hydrocarbon intermediates and their production, non-hydrocarbon intermediates, olefin production, processing of olefins from steam cracking and fluid cracking. **(6 hours)**

	Module 5 Aromatics production– benzene, toluene and xylene derivatives – Properties, applications and production technologies, third generation petrochemicals – polymers, elastomers, polyurethanes and synthetic fiber. **(10 hours)**
Text Books, and/or reference material	**Text Books:** 1. Ram Prasad, “Petroleum Refining Technology”, Khanna Publishers, Delhi, 2000 2. J. H. Gary, G. H. Handwerk and M. J. Kaiser, “Petroleum Refining Technology and Economics”, 5th Edition, CRC Press, New York, 2007 3. G. D. Hobson and W. Pohl, “Modern Petroleum Technology”, 6th Edition, Wiley, New York, 2000. 4. Nelson, W.L “Petroleum Refinery Engineering” McGraw Hill Publishing Company Limited, 1985. 5. B. K. Bhaskara Rao, “A Text on Petrochemicals”, Khanna Publishers, New Delhi, 2008. **Reference Books:** 1. R. A. Meyers, “Handbook of Petroleum Refining Processes”, 2nd Edition, McGraw Hill, New York, 1996 2. J. A. Moulijin, M. Makkee and A. Van Diepen, “Chemical Process Technology”, Wiley, New York, 2001. 3. I. D. Mall, “Petrochemical Process Technology”, Macmillan India Ltd, New Delhi, 2007. 4. Sami Matar and Lewis F Hatch, “Chemistry of Petrochemical Processes”, Gulf Publishing Company, Houston, Texas, 2000.

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH 9039	**Bioprocess and Bioreactor Engineering**	PEL	3	0	0	3	3
Pre-requisites:			Course Assessment methods (Continuous (CT) and end assessment (EA))				
Chemical Reaction Engineering			CT+EA				
Course Outcomes	• CO1: To identify the difference in reaction engineering behaviour between enzyme catalysed reaction and life cell catalysed reaction • CO2: To illustrate the mechanism of enzyme catalysed reaction in both free and immobilized form and to recognize different factors affecting the rates. • CO3: To analyse biochemical rate laws in global perspectives. • CO4: To analyse parametric sensitivity, instability etc. • CO5: To design industrial bioreactor and develop scale-up and control strategies.						

Topics Covered	**Module 1:** Introduction to the kinetics of Bioprocess; Enzyme kinetics; Cell growth kinetics; Kinetics of metabolic product synthesis by cells; Introduction of segregated and non-segregated models; Kinetics of immobilized enzymes and cells. **(12 hours)** **Module 2:** Background of bioreactors, Type of bioreactors – Airlift bioreactors, Airlift pressure cycle bioreactors, Loop bioreactor, Stirred tank bioreactors, Fluidized bed bioreactors, Trickle bed bioreactor, Bubble column fermenter, Design equations for CSTR fermenter, Two stage reactors, Reactors with non-ideal mixing, Parametric sensitivity, Multiplicity in Biosystems, Global and local stability analyses of Bioreactors **(10 hours)** **Module 3:** Bioreactor controlling probes, Characteristics of bioreactor sensors, Temperature measurement and control, DO measurement and control, pH/redox measurement and control, Detection and prevention of the foam, Biosensors. **(10 hours)** **Module 4:** Downstream processing in bioprocesses; Industrial application of bioprocesses. **(10 hours)**
Text Books, and /or reference material	**Text Books:** 1. J. E. Bailey, D. F. Ollis, Biochemical Engineering Fundamentals, Second Edition, Mc. Graw Hill Inc., Singapore, 1986. 2. H. W. Blanch, D. S. Clark, Biochemical Engineering, Special Indian Edition, Marcel Dekker Inc. New York, 2007. 3. M. L. Shuler, F. Kargi, Bioprocess Engineering - Basic Concepts, Second Edition, Prentice Hall of India Private Ltd., New Delhi, 2002. **Reference Books:** 1. P. M. Doran, Bioprocess Engineering Principles, Academic Press, California, 2009. 2. J. Nielsen, J. Villadsen, G. Liden, Bioreaction Engineering, Second Edition, Springer, 2007. 3. D. G. Rao, Introduction to Biochemical Engineering, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2008.

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH 9040	**Mathematical Heat Transfer and Fluid Flow**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Heat transfer, fluid mechanics, transport phenomena, mathematical methods	CT+EA

Course Outcomes	• CO1: To learn the mathematical models and methods for the design strategy for heat transfer equipment applications of nuclear, aerospace, thermal, metal, petroleum, chemical industries. • CO2: To learn how to derive analytically the variation of local Nusselt number, temperature and velocity fields to validate the numerical solutions.
Topics Covered	**Module 1** **Introduction to mathematical methods** Method of separation variables; method of combination variables; solutions of ODEs and PDEs (1-D and 2-D) using gamma functions, beta functions, error functions, Bessel's functions, green functions, power series, Fourier series, Fourier-Legendre series, integral transform, Fourier transform, Laplace transform Finite difference method, adaptive finite difference method; volume of fluid; finite element method **(10 hours)** **Module 2** **Heat transfer in laminar flow** Equations of energy, motion and continuity; differential and integral equation of momentum and thermal boundary layers; boundary layer approximation, initial and boundary conditions; exact solution of boundary layer equations; Steady-state laminar flow over a semi-infinite flat plate – analytical solution of Navier- Stokes equation and Blasius equation, Laminar boundary heat transfer from a semi-infinite plate at a constant temperature; Heat transfer in high velocity thermal boundary layer Heat transfer in laminar flow through pipe; constant heat flux and constant wall temperature; fully developed flow and entrance length; Exact solution of Sturm-Liouville systems, computation of Eigen functions and Eigen values; Bessel's functions and zeros; orthogonal Eigen functions. Natural convection on a vertical flat plate **(10 hours)**

	Module 3 **Heat transfer in spherical geometry** Stokes flow past sphere; potential flow; stream functions; steam lines; velocity vector fields; dynamics of vortex motion Heat transfer to heat transfer from a solid sphere in stagnant liquid; steady-state Solution of heat transfer to a moving sphere a constant diameter in stagnant liquid; Similarity solutions for a transient heat conduction problem; similarity solutions of the boundary layer equations for natural convection over spherical surface. Exact solution of heat transfer and flow field during the growth and departure of a vapor-bubble; evaporation from drops **(8 hours)** **Module 4** **Heat transfer in turbulent flow** Reynolds averaged Navier-Stokes equation (RANS); Prandtl's mixing-length hypothesis; universal velocity profile; Reynolds averaged form of energy equation; turbulent heat transfer in pipe; k-ε model of turbulence; conjugate heat transfer problems. **(6 hours)** **Module 5** **Numerical solutions** Navier-Stokes equation; Blasius equation; Sturm-Liouville systems; heat transfer and flow field in single-phase and two-phase flow with phase change. **(8 hours)**
Text Books, and/or reference material	**Text Books:** 1. W.M. Kays, Convective heat and mass transfer, First, McGraw Hill Book Company, New York, 1966. 2. W. J. Minkowycz, E. M. Sparrow, G. E. Schneider, R. H. Pletcher, Handbook of Numerical Heat Transfer, Wiley Interscience, New York, 1988 3. H. Schlichting, Boundary layer theory,; McGraw Hill Education; 7th edition, New York, 2014 4. G. Biswas, A. Dalal, V. K. Dhir, Fundamentals of Convective Heat Transfer, CRC Press-Taylor and Francis, India, 2019. 5. B. Weigand, Analytical Methods for Heat Transfer and Fluid Flow Problems, Springer, 2015. 6. L. Prandtl, O.G. Tietjens, L. Rosenhea (Translator) Fundamentals of Hydro- and Aeromechanics, Dover Publications Inc,New York, 1934. 7. R. B. Bird, W. E. Stewart, E. N. Lightfoot, Transport phenomena, 1st ed., John Wiley & Sons, New York, 1960.

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<tr><td>CH9041</td><td>Ethics in Engineering Profession</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">--</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• To help the students appreciate the essential complementarily between 'VALUES' and 'SKILLS' to ensure sustained happiness and prosperity, which are the core aspirations of all human beings
• To facilitate the development of a Holistic perspective among students towards life and profession as well as towards happiness and prosperity based on a correct understanding of the Human reality and the rest of Existence. Such a holistic perspective forms the basis of Universal Human Values and movement towards value-based living in a natural way.
• To highlight plausible implications of such a Holistic understanding in terms of ethical human conduct, trustful and mutually fulfilling human behavior and mutually enriching interaction with Nature</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1
Course Introduction - Need, Basic Guidelines, Content and Process for Value Education
Understanding the need, basic guidelines, content and process for Value Education.
Self-Exploration–what is it? - its content and process; ‘Natural Acceptance’ and Experiential Validation- as the mechanism for self-exploration
Continuous Happiness and Prosperity- A look at basic Human Aspirations
Right understanding, Relationship and Physical Facilities- the basic requirements for fulfilment of aspirations of every human being with their correct priority
Understanding Happiness and Prosperity correctly- A critical appraisal of the current scenario
Method to fulfil the above human aspirations: understanding and living in harmony at various levels.
(10 hours)
Module 2
Understanding Harmony in the Human Being - Harmony in Myself!
Understanding human being as a co-existence of the sentient ‘I’ and the material ‘Body’
Understanding the needs of Self (‘I’) and ‘Body’ - Sukh and Suvidha
Understanding the Body as an instrument of ‘I’ (I being the doer, seer and enjoyer)
Understanding the characteristics and activities of ‘I’ and harmony in ‘I’</td></tr>
</table>

	Understanding the harmony of I with the Body: *Sanyam* and *Swasthya*; correct appraisal of Physical needs, meaning of Prosperity in detail Programs to ensure *Sanyam* and *Swasthya* - Practice Exercises and Case Studies will be taken up in Practice Sessions. **(10 hours)** **Module 3** **Understanding Harmony in the Family and Society- Harmony in Human-Human Relationship** *Understanding Harmony in the family – the basic unit of human interaction* Understanding values in human-human relationship; meaning of *Nyaya* and program for its fulfillment to ensure *Ubhay-tripti*; Trust (*Vishwas)* and Respect (*Samman)* as the foundational values of relationship Understanding the competence meaning of *Vishwas*; Difference between intention and competence Understanding the meaning of *Samman*, Difference between respect and differentiation; the other salient values in relationship Understanding the harmony in the society (society being an extension of family): *Samadhan, Samridhi, Abhay, Sah-astitva* as comprehensive Human Goals Visualizing a universal harmonious order in society- Undivided Society (*Akhand Samaj),* Universal Order (*Sarvabhaum Vyawastha)*- from family to world family! - Practice Exercises and Case Studies will be taken up in Practice Sessions. **(11 hours)** **Module 4** **Implications of the above Holistic Understanding of Harmony on Professional Ethics** Natural acceptance of human values, Definitiveness of Ethical Human Conduct, Basis for Humanistic Education, Humanistic Constitution and Humanistic Universal Order Competence in professional ethics: a) Ability to utilize the professional competence for augmenting universal human order b) Ability to identify the scope and characteristics of people-friendly and ecofriendly production systems, c) Ability to identify and develop appropriate technologies and management patterns for above production systems. Case studies of typical holistic technologies, management models and production systems Strategy for transition from the present state to Universal Human Order: a) At the level of individual: as socially and ecologically responsible engineers, technologists and managers b) b) At the level of society: as mutually enriching institutions and organizations **(11 hours)**
Text Books, and/or reference	**Text Books:** **1.** R.R Gaur, R Sangal, G P Bagaria, A foundation course in Human Values and professional Ethics, Excel books, New Delhi, 2010, ISBN 978-8-174-46781-2.

material	**Reference Books:** 1. B L Bajpai, 2004, *Indian Ethos and Modern Management*, New Royal Book Co., Lucknow. Reprinted 2008. 2. PL Dhar, RR Gaur, 1990, *Science and Humanism*, Commonwealth Purblishers. 3. Sussan George, 1976, *How the Other Half Dies,* Penguin Press. Reprinted 1986, 1991 4. Ivan Illich, 1974, *Energy & Equity,* The Trinity Press, Worcester, and HarperCollins, USA 5. A.N. Tripathy, 2003, *Human Values*, New Age International Publishers. 6. Primary resource material will be provided by the course instructor

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9042	**Combustion Engineering**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
--		CT+EA					

Course Outcomes	• CO1: Mass and energy balance during combustion of solid, liquid and gaseous fuel. • CO2: Reaction kinetics and mechanism of Pyrolysis, Combustion and gasification. • CO3: Burner design for different industrial application. • CO4: Clean coal technologies, coal bed methane blending of biomass with coal.
Topics Covered	**Module 1** Properties of solid liquid and gaseous fuels, Classification, Composition, Lower and higher heating values. And its estimation technique, Various stages of combustion. Definition and demarcation of pyrolysis, combustion and gasification. Coal gasification technologies, chemical reactions, process conditions, design of gasification equipment. Underground coal gasification technology, process route. Clean coal Technologies: What is clean coal technology? Principle and objectives. Oxy fuel combustion, Bio char, Carbon capture and storage, Carbon sequestration, Kyoto Protocol, Mitigation of global warming, Refined coal, Coal bed methane deposits, CBM recovery through micro porous network, Primary method Dewatering process, Secondary method (Carbon dioxide injection technique). **(10 hours)** **Module 2** Stoichiometry of combustion - Chemical equations, Mass and energy balance of solid liquid and gaseous fuel combustion, concept of mixture fraction and equivalence ratio, problems on Fuel Efficiency, excess air ratio and use of gas analysers. Combustion of liquid and gaseous fuels: Theory of diffusion flame, development differential equation of diffusion flame and its solution **(10 hours)** **Module 3** Combustion of solid fuels Stages of combustion- drying, devolatilization, volatile combustion, combustion of residual char. Pulverized coal combustion, Combustion in fluidized bed system, burning rate in fluidized bed, factors affecting combustion efficiency. Combustion in bubbling fluidized bed boilers Combustion mechanism dense phase and lean phase concept and mass and energy balance, Recirculation of fly ash, effect of design parameters on combustion efficiency.

	Single particle combustion modelling- Single particle combustion modelling using volume reaction model, reaction mechanism and role of pore surface area. Heat and species transport equation in porous medium. Excremental technique in TG/DTA and drop tube furnace. **(12 hours)** **Module 4** Data analysis of thermo gravimetric and isothermal mass loss apparatus. Model based and model free kinetic analysis. Estimation of kinetic parameters. Concept of Thiele modulus and its derivation and integration of it in mm sized particle combustion and gasification. Case study for solid waste biomass and extraction of solid liquid and gaseous fuels. Reaction conditions and its effect of relative proportions of yield. **(10 hours)**
Text Books, and/or reference material	**Text Books:** 1. Combustion and Fuel Technology, A.K. Shaha 2. Combustion and gasification in Fluidized bed, Prabir Basu, Taylor & Francis

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH9043</td><td>CFD Applications in Chemical Engineering</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Basics of Fluid Mechanics, Transport Phenomena, Numerical Methods</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To learn basics of continuum based modelling and simulations; its area of applications and limitations.
• CO2: To learn different discretization methods of continuum based governing equations.
• CO3: To learn different steps of CFD simulations.
• CO4: To learn the use of CFD techniques in realistic problems.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1
Introduction: Illustration of the CFD approach, CFD as an engineering analysis tool, Review of governing equations, Modelling in engineering, Partial differential equations- Parabolic, Hyperbolic and Elliptic equation, CFD application in Chemical Engineering, CFD software packages and tools.
(5 hours)
Module 2
Principles of Solution of the Governing Equations: Finite difference, Finite volume and Finite element Methods, Convergence, Consistency, Error and Stability, Accuracy, Boundary conditions, CFD model formulation.
(8 hours)
Module 3
Mesh generation: Overview of mesh generation, Structured and Unstructured mesh, Guideline on mesh quality and design, Mesh refinement and adaptation.
(4 hours)
Module 4
Solution Algorithms: Discretization schemes for pressure, momentum and energy equations - Explicit and implicit Schemes, First order upwind scheme, second order upwind scheme, QUICK scheme, SIMPLE, SIMPLER and MAC algorithm, pressure-velocity coupling algorithms, velocity-stream function approach, solution of Navier-Stokes equations.
(15 hours)
Module 5
CFD Solution Procedure: Problem setup – creation of geometry, mesh</td></tr>
</table>

	generation, selection of physics and fluid properties, initialization, solution control and convergence monitoring, results reports and visualization. **(5 hours)** **Module 6** Case Studies: Benchmarking, validation, Simulation of CFD problems by use of general CFD software, Simulation of coupled heat, mass and momentum transfer problem. **(5 hours)**
Text Books, and/or reference material	**Text Books:** 1. Numerical heat transfer and fluid flow by S.V. Patankar, Hemisphere Publishing Corporation, 1980. 2.Introduction to Computational Fluid Dynamics by Anil W. Date, Cambridge University Press, 1st Edition, 2005. 3. P.S. Ghosdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw-Hill (1998). **Reference Books:** **1.** Muralidhar, K.,and Sundararajan, T. Computational Fluid Flow and Heat Transfer, Narosa Publishing. House (1995). **2.** Computational Fluid Dynamics and Heat Transfer by P S Ghosdastidar (Publisher: Cengage Learning India) **3.** Ranade, V.V., Computational flow modeling for chemical reactor engineering, Academic Press (2002).

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9044	**Project Engineering and Management**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
--		CT+EA					

Course Outcomes	• Understand different project management aspects such as planning, tracking, risk, customer, resource, time management and closure. • Appreciate the varying concepts and life cycles of a project such as integration, scope, cost, quality, communication, risk, procurement and stakeholder management. • Leverage globally-recognised project management frameworks to meet real-world business challenges and achieve a competitive advantage • Learn how to plan, implement, monitor and evaluate best practices to tackle the complexity and uncertainty of varied-size projects.
Topics Covered	**Module 1** **Introduction to Project Management** Linking Strategy to Project Management, Portfolio Approach to Project Management, Project/ Portfolio Selection & Organisational Strategy Harvard Business Simulation – Project Management, Project Life Cycle & Initiation. **(10 hours)** **Module 2** **Project Planning & Scope** Project Scheduling, Project Cost Estimation, Project Quality Management. Theory of constraints & Critical Chain, Project Management. **(10 hours)** **Module 3** **Project Monitoring** Project Monitoring: Time & Cost Evaluation, Adaptive & Agile Projec Management, Project Stakeholder & Communication Management Risk Analysis of Projects, Project Procurement & Contract Management Integration-based Project Delivery and Closure. **(10 hours)** **Module 4** **Behavioural & Leadership aspects of Project Management** Negotiation Skills, Emerging Trends in Project Management, Design Thinking in Project Management, Reflections/ PMP Tips & Tricks. **(12 hours)**
Text Books, and/or reference material	**Text Books:** 1. Sammy G. Sinha, “Engineering Project Management for the Global High Technology Industry” 1st Edition, 2013, McGraw-Hill Education. 2. Neil G. Siegel, “Engineering Project Management” 2019, ISBN: 978-1-119-52579-0, Wiley.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9045	**Hazard Analysis and Risk Management in Chemical Industry**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• Identify, classify and characterize different hazardous materials and wastes • Implementation of the rules and regulations pertaining to the handling and management of hazardous materials and wastes • Develop the emergency preparedness and response plans and programs with the ability to identify hazard and risk assessment • Cover the basic aspect of the occupational health and safety management systems and their essential elements.
Topics Covered	**Module 1** **Hazards identification** Introduction of safety, health and environment impact in chemical plants, Necessity of safety in chemical plants, Major chemical plant accidents in India and abroad and lesson learned from them Hazards identifications: Different types of hazards associated in chemical plant chemical hazards, Fire and explosion hazards, toxic gas release hazard, electrical & electromagnetic hazards, mechanical hazards, health hazards, environmental hazards. **(10 hours)** **Module 2** **Risk associated with these hazards and statutory framework** **Risk associated with these hazards**– definition, causes, potential & adverse effects of these hazards on safety, health and environment **statutory framework** – key provisions of factories act, environmental protection act, manufacture, storage & import of hazardous chemical rules, static & mobile pressure vessels rules, NFPA specifications, OSHA regulations **(10 hours)** **Module 3** **Safety barriers available to prevent these hazards:** Safe design, Inherent safe technology, Emergency interlock, Safe standard operating and maintenance procedures, safe practices, personal protective equipment, emergency preparedness, safety audit, safety culture, safety mindset. **(10 hours)**

	Module 4 **Hazard Analysis and prevention** Risk assessment, Incident scenarios, residual risk, concept hazard analysis, preliminary process hazard analysis, HAZOP, Fault Tree Analysis (FTA), Event Tree Analysis (ETA), sneak analysis, Failure Mode and Effect Analysis (FMEA), Human Reliability Analysis (HRA), Cause Consequence Analysis (CCA), Real life case studies of hazop, Prevention techniques: OSHAS occupational health and safety management systems and their essential 14 elements **(12 hours)**
Text Books, and/or reference material	**Text Books:** 1. "Hazard identification and risk assessment" by Geoff Wells, Institution of Chemical Engineers, Davis Building, UK 2. "Occupational health and safety guidelines" by Environmental Department, The World Bank, Washington DC 3. "Environmental Impact Assessment" by Larry W.Canter **Reference Books:** 1. D.A. Crowl and J.F. Louvar, Chemical Process Safety (Fundamentals with Applications), Prentice Hall, 2011. Reference Books: 2. R.K. Sinnott, Coulson & Richardson's, Chemical Engineering, Vol. 6, Elsevier India, 2006. 3. 6. Fawcett H.H. and W.S. Wood, Safety and accident prevention in Chemical operations 2 nd edition John Wiley and Sons Inc. (1982).

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9046	**Nanotechnology**	PEL	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basic knowledge of Chemistry, Physics and Mathematics	CE+EA
Course Outcomes	• CO1: Acquire the concept of nanoscience and nanotechnology at the basic level to apply for different application. • CO2: Acquire the concept of synthesis and characterization of nanomaterials. • CO3: Acquire the idea how to apply nanotechnology in different fields (catalysis, energy and environment) for better efficiency.
Topics Covered	**Module 1** Introduction, History of Nanomaterials synthesis approach of nanomaterials, various kind of nanostructures. **(10 hours)** **Module 2** Synthesis of nanomaterials: Physical Methods, Chemical Methods and Biological Methods.

	Properties of Nanomaterials: Mechanical, Structural, Thermal, Electrical and Optical properties. **(11 hours)** **Module 3** Characterization techniques of nanomaterials: Spectroscopy, XRD, BET, TGA, SEM, TEM and XPS. **(11 hours)** **Module 4** Application of the nanomaterials in different fields. Nanolithography, Nanocomposites. Nanoparticles as catalyst Nanoparticles in energy and environment application. Nanoparticles in biomedical application. **(10 hours)**
Text Books, and/or reference material	**Text Books:** **1.** Dieter Vollath, Nanomaterials: An introduction to synthesis, properties and application, Wiley-VCH Verlag GmbH & Co. Weinheim, Germany, 2008. **2.** CNR Rao, PJ Thomas, GU Kulkarni, Nanocrystals: Synthesis, Properties and Applications, Springer-Verlag Berlin Heidelberg 2007. **3.** T. Pradeep, Nano: The Essentials, Understanding Nanoscience and Nano Technology, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2007. **Reference Books:** 1. Goddard III, WA, Brenner, DW, Lyshevski, SE, Iafrate, GJ. Handbook of nanoscience, Engineering and Technology, 2nd Edition, CRC Press. 2. Nanotechnology: Principles & Practices; Sulabh K. Kulkarni, Capital Publishing Company, Kolkata 3. In some cases research articles.

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours (H)</td></tr>
<tr><td>CH 9046</td><td>Computer Aided Process Engineering</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">--</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• Learn about fundamentals of Mathematical modelling, simulations and process design
• Learn to develop modelling of different unit operations
• Design & analyze of different of processes equipment
• Learn the analysis and solving methods of mathematical modelled equation
• Complete process model of chemical unit operations through assignment / group task</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1
Overview of Process engineering, modelling, Simulation and Design
Fundamental of process engineering, Concept of Mathematical model, simulation and process analysis. Scopes and uses of simulation in process engineering. Fundamentals of model building. Classification uses of mathematical models. Formulation of mathematical models. Reviews of continuity equation - energy equation-momentum equation-equation of state-equilibrium-kinetics, Difference between Process modelling, simulation and Process design, Phenomenological modelling, data driven black box modelling, Grey box modelling
(8 hours)
Module 2
Introduction to process simulators
Use of simulation, basis of Flow sheet simulation, Advantage of simulation, Understanding the simulation problem, Approaches to flowsheet simulation, Sequential modular and equation oriented, Structure of a process simulator, features of commercial simulators, Flow sheet tropology level, Unit operation models and physical property models, Steps in Aspen simulation. Run the first Aspen Simulation., Physical property environment, Use of method assistant to know the physical property method, Workshop on property analysis in Aspen.
(8 hours)
Module 3
Process engineering calculations related to Fluid Mechanics
Process engineering calculations related to Friction Factor, Flow of Fluids in Pipes, Friction Loss, Overall Pressure Drop, Flow through Tank, Compressible Fluid Flow in Pipes, Two-Phase Flow in Pipes, Flow through Packed Beds, use of Aspen simulators to design and simulations of Pumps</td></tr>
</table>

	and compressors, pressure drop in pipeline **(8 hours)** **Module 4** **Design and simulations of Distillation columns** Process engineering calculations related to Diffusion, Unsteady-State Mass Transfer, Multiple-Effect Evaporators, Design and simulations of distillation columns in commercial simulators: Short cut Distillation design, Short cut Distillation rating, Rigorous Binary and multicomponent Distillation design and rating, Hydraulic calculations of distillation towers, Complete Plant/manufacturing set up design, Solvent recovery plants. **(8 hours)** **Module 5** **Design and simulations of Heat exchanger** Overview of Heat exchanger modules available in Aspen, Heat exchanger simulations by simplified model in commercial simulators, Rigorous heat exchanger design by EDR module. **(8 hours)**
Text Books, and/or reference material	**Text Books:** **1.** Applied Mathematics in Chemical Engineering: Mickley TMH **2.** Mathematical Methods in Chemical Engineering: S. Pushpavanam, PHI **3.** Numerical methods for Mathematics, Science and Engineering: John H. Mathews, PHI **4.** Applied Numerical Methods: Alkis Constantinides, McGraw Hill **5.** Luyben, et al., Process modeling simulation and Control, McGraw Hill **6.** Henley and Seader, Multistage separation, McGraw Hill

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9048	**Advanced Water and Wastewater Technology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• The fundamental concepts in environmental engineering dealing with water, air, and land pollution. • Learn a solid foundation in mathematics, sciences, and technical skills needed to analyze and design water engineering systems. • Graduates will be familiar with current and emerging environmental engineering and global issues, and have an understanding of ethical and societal responsibilities. • The necessary qualifications for employment in environmental engineering and related professions, for entry into advanced studies, and for assuming eventual leadership roles in their profession.
Topics Covered	**Module 1** Introduction, Introduction to the Issues of Access to Safe Drinking Water, Worldwide Temporal and Spatial Variation of Water Resources, Water-Quality Standards and Sources and Classification of Pollutants, Introduction to Water Resource Management Approaches **(5 hours)** **Module 2** Physicochemical and Chemical Treatment Technology Introduction, Coagulation–Flocculation–Precipitation–Filtration, Physicochemical Treatment Technology Based on Coagulation–Flocculation–Settling, Adsorption Principles, Adsorption-Based Technology Aeration, Chemical Neutralization, Chemical Oxidation, Chemical Precipitation, Ion Exchange, Disinfection of Water, Advanced Oxidation Technology **(8 hours)** **Module 3** Water Treatment by Membrane-Separation Technology Introduction, Classification of Membrane-Based Processes, Membrane-Separation Terminology, Flow Modes, Membrane Materials, Membrane Modules, Transport Mechanisms in the Membrane-Separation Process, Transport Modeling in Nanofiltration, Selection of Membrane Technology in Water Treatment, Microfiltration Technology in Water Treatment, Ultrafiltration Technology in Water Treatment, Nanofiltration Technology in Water Treatment, Pervaporation Technology in Water Treatment, Reverse Osmosis Technology in Water Treatment, Forward Osmosis Technology in

	Water Treatment, Integrated Membrane Technology in Groundwater and Wastewater Treatment, Forward Osmosis Technology In Power Generation, Membrane Distillation Technology in Water Treatment **(10 hours)** **Module 4** Biological Treatment Technology Introduction to Biological Treatment Technologies, Wastewater Biodegradability: Selection of Treatment Technology, Microbial Growth Kinetics: Unstructured model, Bioreactor Configurations of Biological Treatment Technologies, Biological Treatment Using Fluidized-Bed Reactor Technology, Conventional Biological Treatment Technologies, Advances in Biological Treatment Technologies, Case Studies. **(7 hours)** **Module 5** Industry-Specific Water Treatment: Case Studies **(5 hours)** **Module 6** Nanotechnology in Water Treatment Introduction, Nanomaterials as Adsorbent in Water Treatment, Nanomaterials in Water Purification as Membrane, Nanomaterials in Photocatalytic Degradation of Water Pollutants, Nanomaterials in Disinfection of Contaminated Water. **(7 hours)**
Text Books, and/or reference material	**Text Books:** Parimal Pal, "Industrial Water Treatment Process Technology" 1st Edition, 2017, Elsevier.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH 9049	**Biofuel Technology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• CO1: Students know details biofuel production, they can calculate energy balance of biofuel production students know principles and thermodynamics of gasification processes • CO2: students know advanced power plants concepts (IGCC, chemical looping) • CO3: students know details of gas-to-liquid processes, Fischer Tropsch process • CO4: students know details of carbon dioxide capture and storage, they can calculate energy requirement students know details of desulfurization process
Topics Covered	**Module: 1** Fundamental concepts in understanding biofuel/bioenergy production; Climate Change & the Impact of Carbon Dioxide; History of Biofuels; Renewable Biomass feedstocks and its production; Feedstocks availability, characterization and attributes for biofuel/bioenergy production; Biomass pre-processing: drying, size reduction, and densification. (**10 hours**) **Module: 2** Bio-ethanol, Bio-butanol: 1st Generation Biofuels – Corn Ethanol & Sugarcane Ethanol; 2nd Generation Biofuels – Cellulosic Ethanol; Different enzymes, enzyme hydrolysis, and their applications in ethanol production; 3rd Generation Aquatic Biomass – Cyanobacteria, Diatoms & Algae; Production Processes for Biofuels from Algae. (**9 hours**) **Module: 3** Biodiesel production from oil seeds, waste oils and microalgae, Transesterification process, feedstock processing, Reaction kinetics, Thermodynamics, Parametric optimisation of transesterification, Catalyst and catalyst support development, reusability, characterization of catalyst and biofuel, safe disposal, cost estimation of biofuel and catalyst synthesis. **(9 hours)** **Module: 4** Biogas & Biohydrogen; Microbial fuel cells; Gasification processes Advanced power plant concepts (IGCC); Fischer-Tropsch synthesis, gas to liquid processes. **(8 hours)**

	Module:5 Environmental impacts of biofuel production: Carbon dioxide capture and storage; Chemical Looping, Desulfurization; Value-added processing of biofuel residues and co-products. **(6 hours)**
Text Books, and/or reference material	**Text Books:** 1. Biofuel Technology Handbook, Dominik Rutz, Rainer Janssen, WIP Renewable Energy, Germany, 2003 **Reference Books:** 1. Biofuel Technology: Recent Development, Reza Faryar, Springer Publishers, 2001 2. Biofuel and Bioenergy Technology, Wei-Hsin Chen, Keat Teong Lee, Hwai Chyuan Ong, MDPI, Switzerland, ISBN 978-3-03897-596-0 (Pbk)

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9050	**Colloids and Interface Engineering**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic Chemistry, Physics and Mathematics		CT+EA					
Course Outcomes	• CO1: Acquire an idea about the application of colloidal chemistry, fluid-fluid and solid-fluid interface engineering in different industrial fields. • CO2: To learn the fundamental knowledge of intermolecular forces involved in colloids and interfaces • CO3: Introduction to surface active agent and learn about the application of surface active agents to enhance the efficiency in the process.						
Topics Covered	**Module: 1** Importance and scope of the subject. Overview of colloidal systems, interfaces and surface. Properties and application of the colloids. Colloidal stability factor. Kinetic theory of colloidal systems: sedimentation, centrifugation, diffusion, Domestic and industrial application of colloidal solution. Adsorption at fluid-fluid and fluid-solid interface, Thermodynamics of interfaces, Interfacial rheology and transport process. **(10 hours)** **Module: 2** Surface active agent: Surfactant, Surface and interfacial tension, surface free energy. Surface tension for curved interfaces, Surface excess and Gibbs equation. Theory of surface tension, contact angle, and wetting. Thermodynamics of micelle and mixed micellar formation. Adsorption of single and mixed						

	surfactants at interfaces, Mixed micellar properties, Rheology of surfactant systems. Preparation, mechanistic details of stabilization and relationship between HLB and solubility parameter, characterization and Application **(10 hours)** **Module: 3** Intermolecular forces relevant to colloidal systems: Electrostatic and van der Waals forces. DLVO theory. Measurement techniques of surface tension, contact angle, zeta potential, particle size. **(10 hours)** **Module: 4** Overview of industrial applications of various interfacial phenomena in the industries [Mattress industry (Foam: preparation, characterization, stability), petroleum industry, Mineral processing industry Pesticides, firefighting, personal care formulations] Super hydrophobic surface and self-cleaning surfaces. Case studies related interfacial science. Introduction to Nanotechnology. Application of interfacial engineering concept through the surface modification for the synthesis of nanostructured material by using surface active agent. **(12 hours)**
Text Books, and/or reference material	**Text Books:** 1. P. C. Hiemenz, and R. Rajagopalan, Principle of colloid and surface chemistry, 3rd edition, Mercel Dekher, N. Y. 1997. 2. Pallab Ghosh, Colloid and Interface Science, 1st Edition, PHI Learning, 2009. 3. M. J. Rosen, Surfactants and Interfacial Phenomena, Wiley-Interscience Publication, New York, 2004. **Reference Books:** 1. Drew Myers, Surfaces, Interfaces and Colloids, 3rd Edition, Wiley, 2006. 2. Tharwat F. Tadros, Applied Surfactants Principles and Applications, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2005. 3. Israelachvili, Intermolecular and Surface Forces, Academic Press, New York, 1992.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9051	**Pinch Technology in Process Industry**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Heat Transfer		CT+EA					

Course Outcomes	• CO1: Acquire an idea to optimize the process heat recovery and reducing the external utility loads. • CO2: To achieve financial saving by constructing the best process heat integration.
Topics Covered	**Module 1:** Introduction to process Intensification and Process Integration (PI). Areas of application and techniques available for PI, onion diagram. Overview of Pinch Technology: Introduction, Basic concepts, How it is different from energy auditing, Roles of thermodynamic laws, problems addressed by Pinch Technology. Key steps of Pinch Technology: Concept of ΔT_{min}, Data Extraction, Targeting, Designing, Optimization-Supertargeting Basic Elements of Pinch Technology: Grid Diagram, Composite curve, Problem Table Algorithm, Grand Composite Curve. Targeting of Heat Exchanger Network: Energy Targeting, Area Targeting, Number of units targeting, Shell Targeting and Cost targeting. **(12 hours)** **Module 2:** Designing of HEN: Pinch Design Methods, Heuristic rules, stream splitting, and design of maximum energy recovery (MER). Use of multiple utilities and concept of utility pinches, Design for multiple utilities pinches, Concept of threshold problems and design strategy.Network evolution and evaluation-identification of loops and paths, loop breaking and path relaxation. **(12 hours)** **Module 3:** Design tools to achieve targets, Driving force plot, remaining problem analysis, diverse pinch concepts, MCp ratio heuristics. Targeting and designing of HENs with different ΔT_{min} values, Variation of cost of utility, fixed cost, TAC, number of shells and total area with ΔT_{min} Capital-Energy trade-offs. Process modifications-Plus/Minus principles, Heat Engines and appropriate placement of heat engines relative to pinch. Heat pumps, Appropriate placement of heat pumps relative to pinch. Steam Rankin Cycle design, Gas turbine cycle design, Integration of Steam and Gas turbine with

	process. Refrigeration systems, Stand alone and integrated evaporators. Heat integrations and proper placement of Reactors for batch Processes as well as continuous processes. **(12 hours)** **Module 4:** Case studies on heat integration by pinch technology **(6 hours)**
Text Books, and/or reference material	**Text Books:** 1. Shenoy U. V.; "Heat Exchanger Network Synthesis", Gulf Publishing Co. 2. Smith R.; "Chemical Process Design", McGraw-Hill. 3. 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. **Reference Books:** 1. Ian C. Kemp, Pinch Analysis and Process Integration: A User Guide on Process Integration for the Efficient Use of Energy, 2nd Edition, ISBN: 9780750682602, Butterworth-Heinemann, 2016.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours (H)	
CH9052	**Catalysis in Chemical Industry**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• Provide good knowledge of the adsorption process on the solid catalyst • Provide understanding of the principles of common methods for characterization of solid catalyst • Provide good understanding of the reaction mechanism of heterogeneous catalysis reaction and application of these reactions in different industrial fields.
Topics Covered	**Module 1** Basic concepts on catalytic chemistry, Importance of catalysis reaction, Types of the catalysis reaction, Classification of different industrial catalysis technology. Basic concept of homogeneous and heterogeneous catalysis reactions **(6 hours)** **Module 2** **Homogeneous Catalysis** Different types of homogeneous catalysis reaction, Mechanism and kinetics of the reaction, enzyme catalysis reaction, and industrial application of homogeneous catalysis reaction **(6 hours)**

	Module 3 **Heterogeneous Catalysis** Introduction to heterogeneous catalysis reaction, Types of solid catalysis, different steps involved in catalysis reaction, Synthesis methods and characterization technique of different solid catalysts, Physical and chemical properties of catalysts, Mechanism and kinetics of the reaction, Adsorption **(15 hours)** **Module 4** **Different Heterogeneous catalyst for Industrial application** Metal oxide supported catalyst, Porous support materials, Metallic catalyst, Zeolite catalyst, polymerization catalyst, Semiconductor character – photocatalyst, Acidic and Basic oxide catalysts, Sulfide based catalysts, **(15 hours)**
Text Books, and/or reference material	**Text Books:** 1. B. Viswanathan, S. Sivasanker , A.V. Ramaswamy, "Catalysis : Principles & Applications" CRC Press. 2. Chakrabarty and Viswanathan, “Heterogeneous Catalysis” New Age International Publishers, 2011. 3. Advanced Catalysts and Nanostructured Materials: Modern Synthetic Methods Edited by William R. Moser (Worcester Polytechnic Institute). Academic Press: San Diego, CA, 1996. **Reference Books:** 1. Nanostructured Catalysts, Edited by Sussanath L. Scott, Cathleen M. Crudden and Chritopher W. Jones, Kluwer Academic Publishers, New York, 2005. 2. Dieter Vollath, Nanomaterials: An introduction to synthesis, properties and application, Wiley-VCH Verlag GmbH & Co. Weinheim, Germany, 2008. 3. J. M. Smith, "Chemical Engineering Kinetics" McGraw-Hill Book Company. 4. C. H. Bartholomew and R. J. Farrauto "Fundamentals of Industrial catalytic Processes", Wiley- VCH. 5. In some cases research articles.

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit (C)</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (S)</td><td>Total Hours (H)</td></tr>
<tr><td>CH 9054</td><td>Membrane Technology for Environment Protection</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">--</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Learning the basics of membranes materials and membrane-based technologies
• CO2: Learning to apply understanding of membranes and modules in synthesis of membranes, developing modules and application in abating environmental pollution
• CO3: Gaining knowledge in developing membrane-based technology solution</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module 1: Membrane materials, membrane-based processes and membrane modules. (6 hours)
Module 2: Introduction to membrane-based technology, application potentials of micro, ultra, nano, reverse osmosis, forward osmosis and other integrated membrane processes in water treatment, bio separation, biofuel production, air pollution control, green chemical production. (5 hours)
Module 3: Introduction to modelling membrane separation, modelling microfiltration, ultrafiltration, nanofiltration, reverse osmosis, forward osmosis, membrane distillation and integrated processes. (6 hours)
Module 4: Introduction to Membrane-based technologies in air pollution control. Membrane technology in controlling particulates, and gaseous pollutants (SO_x, NO_x, CO_2, CO). (5 hours)
Module 5: Membrane-based technologies in groundwater treatment, surface water treatment, industrial wastewater treatment, turning waste to wealth through membrane technology, closed loop wastewater treatment using multistage membrane separation. (10 hours)
Module 6: Introduction to development of green technology using membranes, green chlor-alkali production, green biofuel production, green biochemical production. Process intensification through membrane technology, analysis of space intensification, energy reduction, eco-friendly production through adoption of membrane technology. (10 hours)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Membrane-based Technologies for Environmental Pollution control, Parimal Pal, Elsevier Sci.
Reference Books:
1. Industrial Water Treatment Process Technology, Parimal Pal, Elsevier
2. Groundwater Arsenic Remediation: Treatment Technology & Scale Up, Parimal Pal, Elsevier Sci.</td></tr>
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