NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

CURRICULUM

OF

MASTER OF TECHNOLOGY IN AI and DATA ANALYTICS in PROCESS ENGINEERING

OFFERED BY

THE DEPARTMENT OF CHEMICAL ENGINEERING

2025 ONWARD ADMISSION BATCH

V0:

Curriculum and Syllabus Recommended by members of DAC	03.07.2025
Curriculum and Syllabus Recommended by PGAC	29.07.2025
Curriculum and Syllabus Approved by the 74th Senate (Item No. 74.5)	03.08.2025

M.Tech in AI and Data Analytics in Chemical Engineering
Course Curriculum

First Semester

Sl. No.	Subject Code	Name of the Subject	L-T-P	Credits	Hours
1.	CH1021	Basics of Process Engineering	3-1-0	4	4
2.	CH1022	Introduction to AI /ML and data analytics	3-1-0	4	4
3.	CH1023	Computer Aided Process Equipment Design	3-1-0	4	4
4.	CH 90**	Elective-I	3-0-0	3	3
5.	CH 90**	Elective-II	3-0-0	3	3
6.	CH1071	Advanced computing laboratory on AI & Data Analytics -I	0-0-4	2	4
7.	CH1072	Computer Aided Process Engineering Laboratory-I	0-0-4	2	4
Total				**22**	**26**

Second Semester

Sl. No.	Subject Code	Name of the Subject	L-T-P	Credits	Hours
1.	CH2021	Process control and Optimization	3-1-0	4	4
2.	CH2022	Data analytics in Process Industries	3-1-0	4	4
3.	CH 90**	Elective-III	3-0-0	3	3
4.	CH 90**	Elective-IV	3-0-0	3	3
5.	CH 90**	Elective-V	3-0-0	3	3
6.	CH2071	Innovative Mini project through self-learning	0-0-4	2	4
7.	CH2072	Advanced computing laboratory on AI & Data Analytics II	0-0-4	2	4
Total				**21**	**25**

Third Semester

Sl. No.	Subject Code	Name of the Subject	L-T-P	Credits	Hours
1.	CH9071	Audit Lectures / Workshops	0-0-0	0	2
2.	CH3071	Dissertation - I	0-0-24	12	24
3.	CH3072	Seminar –Non-Project / Self-development Project	0-0-4	2	4
Total				**14**	**30**

Fourth Semester

Sl. No.	Subject Code	Name of the Subject	L-T-P	Credits	Hours
1.	CH4071	Dissertation - II	0-0-24	12	24
2.	CH4072	Project Seminar	0-0-4	2	4
Total				**14**	**28**

Total Programme Credit Point: 71

List of Elective Subjects (I, II, III, IV and V)

S. No.	Subject Code	Name of the Subject	L-T-P	Credits
1.	CH9018	Petroleum Refining and Petrochemical Engineering	3-0-0	3
2.	CH9034	Pinch Technology in Process Industry	3-0-0	3
3.	CH9051	Modelling and simulation in Process Engineering	3-0-0	3
4.	CH9052	Bioenergy Engineering	3-0-0	3
5.	CH9053	Application of AI in bioprocess engineering	3-0-0	3
6.	CH9054	Process Intensification	3-0-0	3
7.	CH9055	CFD Applications in process Engineering	3-0-0	3
8.	CH 9056	Project Engineering and Management	3-0-0	3
9.	CH 9057	Hazard Analysis and Risk Management in Process Industry	3-0-0	3
10.	CH 9058	Application of AI in environmental engineering	3-0-0	3
11.	CH 9059	Polymer Science and Engineering	3-0-0	3

First semester

Department of Chemical Engineering							
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	
CH1021	**Basics of Process Engineering**	PCR	3	1	0	4	4
Pre-requisites:		Course Assessment methods (Continuous (CT) and end assessment (EA)):					
		Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination					
Course Outcomes		• CO1: Acquire an idea about the core element of process engineering in the chemical process industry • CO2: Learn the mass and energy balance and their application in chemical process industries • CO3: Learn the fundamental knowledge of fluid, heat, and mechanical engineering and their importance in process engineering					
Topics Covered		**Module I: Introduction to Process Engineering (5 hrs)** • Introduction to Process Engineering, Basic philosophy of a process flow diagram (PFD). Elements of a PFD, Process Engineering Drawings (such as BFD, PFD, P&ID, isometrics) • Introduction to Process Safety in Process Engineering **Module II: Thermodynamics, Mass and Energy Balance in the Process Engineering (12 hours)** • Thermodynamics: Principles of energy, heat, and work, including first and second laws of thermodynamics • Mixture Properties, getting into the behaviour of mixtures. • Material Balance: Calculating material flows and balances in a process • Energy Balance: Calculating energy flows and balances in a process **Module III: Role of fluid dynamics in Process Engineering (12 hours)** • Fundamental Concepts: Definition of Fluid, Terminologies of fluid flow, velocity – local, average, maximum, flow rate – mass, volumetric, velocity field; flow visualization – streamline, path line, streak line, viscosity; Newtonian fluid; Non-Newtonian fluid; Reynold's number—its significance, laminar, transition and turbulent flows. • Fluid Statics: Basic equation of fluid statics; pressure variation in a static field; pressure measuring devices–manometer, U-tube, inclined tube. Introduction; flow of incompressible fluid in circular pipe; laminar flow for					

	Newtonian fluid; Hagen-Poiseullie equation; introduction to turbulent flow in a pipe-Prandtl mixing length; energy consideration in pipe flow, relation between average and maximum velocity, Bernoulli's equation–kinetic energy correction factor. • Fluid moving machines: Introduction; Basic classification of pumps: Mechanical pump: Centrifugal pumps-cavitation, NPSH, Positive displacement pumps (rotary, piston, plunger, diaphragm pumps); Peristaltic pump; Pump specification; Basic characteristics curves for centrifugal pumps. • Valves • Compressors **Module IV: Role of Heat Transfer in Process Engineering (12 hours)** • Fundamental study on different modes of heat transfer: Conduction, Convection, and Radiation. • Steady and unsteady heat transfer analysis through extended surface • Heat Exchangers, the fundamental theory of Heat Exchangers, and design principles of double pipe heat exchangers and shell and tube heat exchangers. • Fundamental study on Evaporation and design principles of evaporator **Module V: Role of Mechanical Operation in Process Engineering (7 hours)** • Particulate solids: Characterization of solid particles, particle shape, particle size, mixed particle sizes and size analysis, specific surface of mixture, average particle size. • Comminution of solids (Size Reduction): Factors affecting comminution, comminution laws: Kick's law, Rittinger's law, and Bond's law and their limitations. Crushing efficiency & power consumption. • Gravity Separations & Separators, the main theory about separation by gravity, practical knowledge about the principle and design specifications of equipment **Module VI: Fundamentals of dimensional analysis and scale-up (8 hours)** • Lab scale to semi commercial • Semi commercial to commercials
Text Books, and/or reference material	**Textbooks:** 1. Marshall Sitting (Ed.), and M. Gopala Rao (Ed.), DRYDEN'S Outlines of Chemical Technology, 3rd Edition, WEP East West Press, 2010. 2. J. M. Smith, H. C. van Ness and M. M. Abbot, "Introduction to Chemical Engineering Thermodynamics," McGraw Hill, 7th Ed., 2005. 3. Process Heat Transfer: D. Q. Kern, MGH

	4. Heat Transfer Principles and Application, B. K. Dutta, PHI. 5. Units Operations of Chemical Engineering: McCabe & Smith and Harriot, MGH **6.** Coulson, J.M., Richardson, J.F., "Chemical Engineering", Volume 2, Third Edition, Pergamon Press, 1977

			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH1022	Introduction to AI /ML and data analytics	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes		CO1 : Acquire an idea about the application of artificial intelligence in chemical process industry CO2 : Learn the fundamental knowledge of Neural network base modelling and their application in chemical process industries CO3: Learn the fundamental knowledge of data analytics					
Topics Covered		**Module – I (08 hrs.)** **Basic concept and introduction** Challenges faced by process industries, Paradigm shift of chemical business, What is artificial intelligence (AI)?, What is advance data analytics (ADA)?, Use of artificial intelligence (AI) and advance data analytics in different fields, Use of AI in chemical process industry and changing business scenario of chemical process industry , Areas where AI have impact on process industry, Different real life case studies of application of AI in process industry , How AI based techniques can be used to increase profit in chemical industry **Module – II (12 hrs.)** **Application of artificial neural network (ANN) for modeling industrial processes** What is process modeling? ,Difference between process design and process simulation , Different process modeling strategy , Comparative advantage and disadvantage of different modeling strategy , Limitations of first principle base modeling , Limitations of commercial simulators to model complex industrial reactors ,Data driven black box or grey box modeling technique and its advantage ,Necessity to build a platform to utilize large number of process data , Artificial neural network (ANN) as effective tool of black box modeling, What is artificial neural network (ANN)?, Network architecture, Back propagation algorithm, How ANN can be used to develop complex industrial processes, Steps in ANN modeling technique ,Modeling of process performance parameters like selectivity, yield, efficiency etc. , Different examples of ANN modeling applied in diverse field of process industries, A step by step matlab based ANN case study for modeling of industrial reactor ,Different aspects of ANN modeling					

	Model –III (6 hrs) Introduction of data Analytics Basic concept of data analytics, various statistical data anlysis, data visualization, Data engineering, Data base decision making, case studies **Module - IV (12 hrs.)** **Artificial intelligence based fault diagnosis in process industry** Development of Fault diagnosis system What is fault diagnosis system?, Features of fault diagnosis system ,How a robust fault diagnosis system can be made by PCA and ANN , Steps to build efficient fault diagnosis system ,Matlab code ,Case study
Text Books, and/or reference material	**Text Books:** • Process plant simulations, B.V. Babu , Oxford University Press 2004, ISBN **0-19-566805-7** • A General Introduction to Data Analytics, João Mendes Moreira, André C. P. L. F. de Carvalho, Tomáš Horváth, Wiley, 2019.

Department of Chemical Engineering							
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	
CH1023	**Computer Aided Process Equipment Design**	PCR	3	1	0	4	4
Pre-requisites							
Fluid flow, heat and mass transfer, reaction, computer programing		CEA-ET					

Course Outcomes	CO1: Students will be familiarised with the design, development and analysis of process equipment by computer programs and codes. CO2: They will test the performances of process equipment under different operating conditions CO3: Computer programs and codes will enable them to scale up, optimize and improve the design of the equipment, as desired. CO4: Students will visualize the process equipment being used in industries.
Topics Covered	**Module 1 (7L):** Introduction to process design methods, degree of freedom, design variables, computer programs and codes for process design, hierarchical structures of the computer codes and the underlying solvers, optimization and sizing of equipment, design standards. **Module 2 (12L):** Computer aided design of fluid flow and heat transfer equipment. Computational methods for pipe line, single-phase and two-phase heat exchangers, heat recovery systems. **Module 3 (12L):** Computer aided design of mass transfer equipment. Computational methods for multistage separation (absorption, stripping, distillation), industrial dryers, cooling towers. **Module 4 (12L):** Computer aided design of reactors. Computational methods for non-isothermal single-phase and two-phase reactors, multiphase reactors, nuclear reactors.

	Module 5 (10L): Computer aided design of energy systems. Computational methods for solar collectors, fuel cell, semiconductors.
Text Books, and/or reference material	**Text Book** 1. G. F. Hewitt, Heat Exchanger Design Handbook (HEDH-1998, three volumes), ed., Begell House, 1998. 2. Standards of Tubular Exchanger Manufacturers Association, Ninth Edition, 2007 3. J. Versteeg, W. Malalasekara, Introduction to Computational Fluid Dynamics, 2nd Edition, Pearson Education India, 2007. 4. .D. Seader, Ernest J. Henley, Separation process principles,John Wiley, 2006 5. J. R. Couper, W. R. Penney, J. R. Fair, S. M. Walas, Chemical Process Equipment: Selection and Design, 2nd edition, Elsevier/Gulf Professional Publishing, 2005 6. Narayanan, C. M. and Bhattacharya, B.C., Computer Aided Design of Chemical Process Equipment, New Central Book Agency, 1992

CO	**Statement**	**Program Outcomes**					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO1	Students will be familiarised with the design, development and analysis of process equipment by computer programs and codes.	3	3	3	3	3	3
CO2	They will test the performances of process equipment under different operating conditions	3	3	3	3	3	3
CO3	Computer programs and codes will enable them to scale up, optimize and improve the design of the equipment, as desired.	3	3	3	3	3	3
CO4	Students will visualize the process equipment being used in industries.	3	3	3	3	3	3
Average		**3**	**3**	**3**	**3**	**3**	**3**

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH1071	Advanced Computing lab on AI & data Analytics -I	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes		• CO1: To solve chemical engg problems using computers					

	• CO2: To use mathematical methods to solving chemical engineering problem
Topics Covered	1. Module I 9 hr 1. Familiarization of programming environment and execution of sample programs 2. Expression evaluation 3. Conditionals and branching 4. Iteration 5. Functions 6. Arrays Module II 9 hr Solution of liner and non-liner algebraic equations System of linear and non-liner algebraic equations Module III 9 hr Initial value ODES using Euler explicit and implicit technique. Non-linear ODEs System of Linear ODEs System of non-liner and Stiff ODEs. Module IV 9 hr The problems related to chemical engineering are given as laboratory assignments. Most of the problems deals with the various numerical methods taught in the Mathematics course. The problems on Phase Equilibrium, Equation of State, Determination of Bubble point and Dew Point calculation.
Text Books, and/or reference material	Suggested Text Books: 1. Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice Hall of India. 2. E. Balaguruswamy, Programming in ANSI C, Tata McGraw-Hill. 3. John H. Mathews, Numerical Methods Using FORTRAN. Prentice-Hall India 4. R. White and V. R. Subramanian, Computational Methods in Chemical Engineering. PHI.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Number of contact hours**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH1072	**Computer Aided Process Engineering Laboratory-I**	PCR	0	0	4	4	2
Pre-requisites: Introduction to Mass Transfer, Heat Transfer	Course Assessment methods (Continuous (CT) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination						
Course Outcomes	CO1: Conceptualization of a chemical process and its simulation needs CO2: Understanding the various thermodynamic property packages for Estimation of Physical Properties and thermodynamic parameters CO3: Understanding the simulation modules and their solution						

	procedure related to process equipment like heat exchanger, reactor, distillation columns CO4: Calculations and their solution methodology related to various simulation methods in commercial simulators
Topics Covered	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. Case study: 1. Estimating pure component property as a function of temperature and pressure of any compound in Aspen simulation. 2. Estimating XY, TXY, PXY, Gibbs energy of mixing curve of a binary system. 3. Estimating ternary maps showing phase envelop, tie lines and azeotrope of ternary system. 4. Mixer, Splitter, Flash separator simulation in Aspen, Overview of library modules of mixer, splitter and flash separation 5. Computer aided Design of distillation column 6. Block, Pump, Compressor, Turbine, Control valve, Pipe line simulation in Aspen. 7. Heat exchanger design, Overview of Heat exchanger modules available in Aspen, Heater model. HeatX model, Rigorous heat exchanger design by EDR module 8. Reactor design: Overview of reactor modules available in Aspen, Yield Reactor, Stoichiometric Reactor, Equilibrium Reactor, Gibbs Reactor, CSTR, CSTR in series, Plug flow Reactor. Batch Reactor 9. Equipment Cost Estimation and Optimization 10. Simulation on industrial Ethyl Acetate Reactor and industrial Ethylene Glycol Reactor
Text Books, and/or reference material	**Textbooks:** 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, 3 rd edition, 2015 5. Mathematical Methods in Chemical & Environmental Engineering: Ajay K.Ray, Thomson Learning, 2000.

Second semester

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total number of contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH2021	**Process Control and Optimization**	PCR	3	1	0	4	4
Pre-requisites: Introduction to AI / ML and Data Analytics (CH1022), Computer-Aided Design (CH1023)		Course Assessment methods (Continuous (CT) and end assessment (EA)):					
		Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination					
Course Outcomes		CO1: **Develop and analyze** mathematical models of dynamic engineering systems. (PO1, PO3, PSO1) CO2: **Design and evaluate** control strategies applicable to multidisciplinary processes. (PO3, PSO2) CO3: **Apply** optimization techniques to improve engineering processes and operations. (PO1, PO3, PSO2) CO3: **Integrate** data-driven techniques, AI/ML tools, and simulation for advanced process control and optimization. (PO1, PO2, PO3, PSO3)					
Topics Covered		**Module I: Foundation for Process Control and Optimization (8 hrs)** • Mathematical modeling of physical systems (mass, energy, momentum balances) • Dynamic system behavior: steady-state vs transient • Introduction to feedback, feedforward, and open-loop systems across disciplines • Basics of optimization: objective functions, constraints • Programming basics for optimization (Python/MATLAB) **(Lecture: 5 hours; Tutorial/Problem Solving: 3 hours)** **Module II: Process Dynamics and System Modeling (12 hrs)** • Classification of systems: linear/nonlinear, lumped/ distributed parameter systems • Transfer function derivation; Laplace Transform techniques • First-order and second-order systems: modeling and behavior • Time-domain analysis: step, ramp, impulse responses • Stability criteria: Routh-Hurwitz criterion, root-locus analysis **(Lecture: 8 hours; Tutorial: 4 hours)** **Module III: Control Strategies and Advanced Tuning (12 hrs)** • PID control: architecture, tuning methods (Ziegler-Nichols, Cohen-Coon) • Cascade control, feedforward control, and ratio control concepts • Introduction to Model Predictive Control (MPC) • Applications: environmental systems, smart grids, water systems, chemical processes **(Lecture: 8 hours; Tutorial: 4 hours)**					

	Module IV: Optimization Theory and Engineering Applications (12 hrs) • Problem formulation: objective functions, constraints, feasible regions • Linear Programming (LP): graphical method, Simplex method • Nonlinear Programming (NLP): Lagrange multipliers, Karush-Kuhn-Tucker (KKT) conditions • Derivative-based methods: Newton-Raphson, Secant, Bisection methods • Application examples from the energy, environment, and manufacturing sectors **(Lecture: 9 hours; Tutorial: 3 hours)** **Module V: Integration of AI, Simulation, and Advanced Optimization (12 hrs)** • Unconstrained optimization: Single-variable methods (region elimination methods) Multivariable direct search (Simplex, Hooke-Jeeves, Powell's method) Multivariable gradient-based methods (Cauchy, Newton, Marquardt) • AI/ML applications in process modeling, optimization, and fault detection • Simulation of dynamic systems and control loops using Python/MATLAB **(Lecture: 9 hours; Tutorial: 3 hours)**
Text Books, and/or reference material	**Textbooks:** 1. Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, Francis J. Doyle III, Process Dynamics and Control. 2. Thomas E. Marlin, Process Control: Designing Processes and Control Systems for Dynamic Performance, McGraw-Hill, 2nd Ed. 3. T. F. Edgar, D. M. Himmelblau, L. S. Lasdon, Optimization of Chemical Processes, 2nd Ed., McGraw-Hill, 2001. **4.** B. V. Babu, Process Plant Simulation, Oxford University Press. **Reference Books:** 1. Babatunde Ogunnaike, W. Harmon Ray, Process Dynamics, Modeling, and Control, Oxford University Press. 2. B.W. Bequette, Process Control: Modeling, Design, and Simulation, Prentice Hall. 3. Singiresu S. Rao, Engineering Optimization Theory and Practice. 4. Raymond H. Myers, Douglas C. Montgomery, Christine M. Anderson-Cook, Response Surface Methodology: Process and Product Optimization Using Designed Experiments, 4th Ed.

CO	Statement	Program Outcomes					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO1	Develop and analyze mathematical models of dynamic engineering systems.	3	1	3	3	1	1

CO2	Design and evaluate control strategies suitable for multidisciplinary processes.	1	1	3	1	3	1
CO3	Apply optimization techniques to improve engineering processes and operations.	3	1	3	1	3	1
CO4	Integrate data-driven techniques, AI/ML tools, and simulation for advanced process control and optimization.	3	2	3	1	2	3
Average		**2.5**	**1.25**	**3**	**1.5**	**2.25**	**1.5**

			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH2022	Data analytics in Process industries	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes		• Enhance problem-solving abilities through hands-on data analysis exercises. • Learn facts and theories for data analysis, statistical analysis, hypothesis testing, and machine learning for foundations of data analytics. • Practical data analysis projects to apply learned skills.					
Topics Covered		• Excel, SQL, and Python for data analysis. Prepare for a career as a data analyst with essential professional skills and knowledge. • A-Z data cleaning and manipulation methods, sorting, sorting and conditional filtering, formulas, and functions, graphs and charts in Excel. • Advanced analysis in PIVOT tables and charts, Data Analysis ToolPak for statistical analysis and interactive dashboard in Excel. • RDBMS fundamentals, covering key concepts such as primary and foreign keys, data types, and the various types of RDBMS and more. • Full stack manipulation of tables, columns, constraints, indices, null values, filtering, joining methods in MySQL or structured query language. • Important Python programming basics such as variables naming, data types, lists, dictionaries, dataframes, sets, loops, functions etc. • Methods and techniques for data cleaning, sorting, filtering,					

	data manipulation, transformation, and data preprocessing in Python. • Python for data visualizations, exploratory data analysis, statistical analysis, hypothesis testing methods and machine learning models. • 50+ practical assignments, 140+ coding exercises,
Text Books, and/or reference material	1 Data Analytics using Python By Bharti Motwani 2 Data Analytics Essentials You Always Wanted To Know By Vibrant Publishers and Dr. Bianca Szasz 3 Data Analytics: Handbook of Formulas and Techniques (Systems Innovation Book Series) by Adedeji B. Badiru

			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
	Advanced computing laboratory on AI & data Analytic II	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes		Hands-on experience of machine learning based model development Hands-on experience of meta- heuristic based optimization techniques					
Topics Covered		Module 1 : overview of machine learning in matlab Module 2 : Coding and development of ANN models for different chemical processes Model 3: Coding and development of Genetic programming models for different chemical processes Module 4 : Coding and optimization of chemical processes by genetic algorithm and PSO Module 5 : Artificial intelligence based fault diagnosis in process industry					
Text Books, and/or reference material		1. Profit Maximization Techniques for Operating Chemical Plants by SK Lahiri (Author)					

Detailed Syllabus of Elective Subjects

Department of Chemical Engineering								
			Total Number of contact hours					
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH9018	**Petroleum Refining & Petrochemical Engineering**	PEL	3	0	0	3	3
Prerequisite:		Course Assessment methods (Continuous (CT) and end assessment (EA))					
CH1021, Fundamentals of separation, purification, Organic Chemistry, Catalysis, Energy utilisation		CT + EA					
Course Outcomes		CO1: Ability of critical thinking and analysis of emerging energy scenario CO2: Ability of independent design, investigation, data analysis and scientific reporting of petroleum refining and petrochemical units CO3: Capacity building towards sustainable fuel processing					
Topics Covered		***Module I: Physico-chemical fundamentals of Petroleum and Petrochemicals*** *8hrs* • Composition, classification and analysis of crude oil; • Physico-chemical properties of petroleum and major petrochemical products; • Analysis of crude and petroleum products and emerging specification standards; • Petrochemical production routes **Module II: Major Petroleum refining Processes** *12hrs* • Refinery configurations, flow sheeting • Material and Energy balance control schemes in distillation • Refluxing techniques and plant utilities • Major refinery operations: distillation, cracking, reforming, alkylation, isomerisation • Production of Kerosene, Jet fuel, Motor gasolene, Diesel, LPG, Lubricating Oil **Module III: Sustainability and Green Technology in Refining** *10 hrs* • Green refinery concepts and energy-efficient operations, eco-friendly fuel • Advanced distillation: Catalytic distillation, Azeotropic distillation, Membrane Distillation • Environmental aspects: sulphur removal and recovery,					

	emissions, wastewater • Use of sustainability metrics (e.g., EII, Solomon benchmarking) • Integration with petrochemical complex • Sustainable fuel beyond Oil and Gas: Methanol, Ethanol and Hydrogen **Module IV: Petrochemical Industry: Production and recycling** *12 hrs* • Feedstock for petrochemicals • Reading and interpreting PFDs of petrochemical units • Production routes for ethylene, propylene, benzene, toluene, xylene, and methanol. • Flow sheets and interconnections between refining and petrochemical plants • Recycling of polymer and microplastic
Text Books, and/or reference material	**Text Books:** • Petroleum Refining Engineering: W.L. Nelson • Petrochemicals Technology: B.K.B. Rao • Petrochemical Process technology: I. D. Mall • Fundamentals of Petroleum Refining, Mohamed A. Fahim, Taher A. Al-Sahhaf, AmalElkilani, Elsevier Science, 2010 **Reference Books:** • Advanced Petroleum Refining: G.M. Sarkar • Environmental Control in Petroleum Refining: J.C. Reis • Petroleum Refining Technology & Economics: J.H. Gary & G.E. Handwerk

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total number of contact hours: 42**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH9034	**Pinch Technology in Process Industry**	PEL	3	0	0	3	3
Pre-requisites:		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination					
Course Outcomes		CO1: Identify the minimum heating and cooling requirements for a process based on thermodynamic knowledge CO2: Evaluate lower-cost solutions for arrangements of heat exchangers CO3: Design optimal heat exchanger networks to improve energy recovery and global energy efficiency of processes					

Topics Covered	**Module I: Introduction to Process Intensification and Pinch Tec (12 hours)** ✓ 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. **Module II: Designing of HEN (10 hours)** ✓ 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. **Module III: Design tools of heat exchanger networks (15 hours)** ✓ 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. **Module IV: Case Studies on Heat Integration (5 hours)** ✓ Case studies on heat integration by pinch technology

Text Books, and/or reference material	**Textbooks:** 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.

CO	**Statement**	**Program Outcomes**					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO1	Identify the minimum heating and cooling requirements for a process based on thermodynamic knowledge.	3	--	3	3	1	1
CO2	Evaluate lower-cost solutions for arrangements of heat exchangers.	2	--	3	1	2	1
CO3	Design optimal heat exchanger networks to improve energy recovery and global energy efficiency of processes.	3	1	3	3	3	3
Average		**2.67**	**0.33**	**3**	**2.33**	**2**	**1.37**

			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH9051	Modeling and Simulation in Process Engineering	PEL	3	0	0	3	3
Pre-requisites		Continuous Assessment (CT) + Midterm (MT) + End Assessment (EA)					
(i) Process Calculations (ii) Engineering Mathematics I–III (iii) Programming Fundamentals (MATLAB recommended)		CT+MT+EA					

Course Outcomes	CO1: Understand and formulate mathematical models based on fundamental conservation laws for chemical process systems. CO2: Apply numerical methods, particularly finite difference techniques, to solve ordinary and partial differential equations arising in process models. CO3: Develop and validate data-driven and hybrid models using artificial intelligence and machine learning techniques for process prediction and control. CO4: Analyze and simulate industrial chemical processes for design, optimization, and fault diagnosis. CO5: Interpret and utilize high-dimensional process data for model calibration, sensitivity analysis, and system diagnostics.
Topics Covered	**Module 1: Fundamentals of Process Modeling and Simulation (12 Hours)** Introduction to Process Modeling, Importance of modeling in process engineering, Types of models: empirical, mechanistic, and hybrid, Role of simulation in process design and optimization, Model Development and Classification, Lumped vs. distributed parameter models, Linear vs. nonlinear models, Steady-state vs. dynamic models, Deterministic vs. stochastic models, Conservation Principles, Mass, energy, and momentum balances, Constitutive relations and thermodynamic principles, Modeling of unit operations: reactors, heat exchangers, distillation columns **Module 2: Numerical Methods and Dynamic Simulation (14 Hours)** Finite Difference Methods, Discretization of differential equations, Stability and convergence analysis, Application to heat and mass transfer problems, Dynamic Simulation Techniques, Time integration methods: Euler, Runge-Kutta, Handling stiff systems, Implementation using MATLAB, Case Studies in Industrial Systems, Dynamic modeling of continuous stirred-tank reactors (CSTR), Simulation of heat exchanger networks, Control strategies for distillation processes **Module 3: Integration of AI and Data Analytics in Process Modeling (13 Hours)** Introduction to AI and Machine Learning, Overview of machine learning algorithms: regression, classification, clustering, Neural networks and deep learning basics, Training, validation, and testing of models, Data-Driven Modeling Approaches, Development of surrogate models, Hybrid modeling combining first-principles and data-driven methods, Applications in process optimization and control, Process Data Analytics, Data preprocessing and feature engineering, Principal component analysis (PCA) and dimensionality reduction, Fault detection and diagnosis using statistical methods, Industrial Applications, Predictive maintenance using machine learning, Real-time optimization of chemical processes, Case studies on AI implementation in process industries

Text Books, and/or reference material	1. William L. Luyben – Process Modeling, Simulation, and Control for Chemical Engineers, 2nd Edition, McGraw-Hill, 1996. 2. B.W. Bequette – Process Dynamics: Modeling, Analysis, and Simulation, Prentice Hall, 1998. 3. S. Pushpavanam – Mathematical Methods in Chemical Engineering, Prentice Hall India, 2001. 4. S.C. Chapra and R.P. Canale – Numerical Methods for Engineers, 7th Edition, McGraw-Hill, 2015. 5. R.E. Precup and S. Preitl – Process Control: Design for Dynamic Performance using Artificial Intelligence Methods, Springer, 2021. 6. Rafael S. Gonçalves & Mario R. Eden – Machine Learning and Data Science in Chemical Engineering, Elsevier, 2023.

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	**Total number of contact hours: 56**				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH9052	**Bioenergy Engineering**	PCR	3	0	0	3	3
Pre-requisites: Fundamentals of energy and fuels, Concept of biomass utilization, Mass and energy balance, Heat transfer, Thermodynamic, Mechanical operation.		Course assessment methods (Continuous (CT) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination					
Course Outcomes		CO1: To obtain an idea about the fundamentals of bioenergy and its need as alternative to petro-fuels () CO2: To learn the concept of biomass utilization on the way to bioenergy synthesis; mass energy balance and their application in biochemical process industries () CO3: To elucidate the fundamental knowledge of heat transfer processes, engineering thermodynamics, process kinetic and mechanical operation and their importance in process industries ()					
Topics Covered		**Module I: Introduction and fundamentals of bioenergy 12 hrs** • Energy consumption and production scenario in the world • Climate change & the impact of carbon dioxide • Alternatives to conventional petro-fuels towards mitigation of energy crisis • Fundamental concepts in understanding biomass utilization and waste valorisation; • Introduction and history of bioenergy and biofuel synthesis • Renewable biomass feedstocks and their production;					

	Feedstocks availability, characterization and attributes for bioenergy and biofuel production **Module II: Various feedstock and their processing 12 hrs** • 1^{st} generation (edible) feedstocks, 2^{nd} generation (non-edible) feedstocks, 3^{rd} generation (Micro/macroalgae, Cyanobacteria) feedstocks, 4^{th} generation (genetically engineered) feedstocks. • Biomass pre-processing: drying, size reduction, grinding/pulverising, carbonization, activation and densification • Production and consumption status in India and world **Module III: Bioenergy and their synthesis 12 hrs** • Biodiesel, Bio-ethanol, Bio-butanol, Biogas, Bio-briquette, Biohydrogen, Microbial fuel cells • Bioenergy synthesis methods: Anaerobic decomposition, Gasification, Pyrolysis, Esterification, Transesterification, Microwave irradiation, Supercritical extraction, Microemulsion, Ultrasonication process, Fischer-Tropsch synthesis. **Module IV: Process optimisation, thermodynamics & kinetics 12 hrs** • Various optimisation approaches • Process parameters and their optimisation • Mass and Energy balance over piece of equipment • Reaction kinetics, Thermodynamics, Catalyst and catalyst support development • Reusability of materials, E-metrics, Turn over frequency • Characterization of bioenergy, fuel properties, cost estimation of biofuel synthesis • Value-added processing of biofuel residues and co-products **Module V: Approaches towards process scale-up 8 hrs** • Environmental impacts of biofuel production • Various approaches for lab-to-land transfer • Analysis of major engineering problems associated • Safe disposal of residues
Text Books, and/or reference material	**Text Books:** 1. Introduction to Bioenergy, (2016), Taylor and Francis, Authors: Vaughn Nelson and Kenneth Starcher 2. Bioenergy Engineering, Editors: Mahendra Rai, Avinash P. Ingle, Publisher: CRC Press, Year: (2020) 3. Advances in Bioenergy Engineering, (2022), Narendra publishing house, Seveda, M.S., Narale P.D., Kharpude S. N. 4. Introduction to Bioenergy (Energy and the Environment), Vaughn C. Nelson, Kenneth L. Starcher, CRC Press, 2016 **Reference Books:**

	1. Bioenergy Engineering: Fundamentals, Methods, Modelling, and Applications, (2023), Publisher: Elsevier Science, Editors: Anjani Ravi Kiran Gollakota, Irem Deniz, Kaustubha Mohanty, Krushna Prasad Shadangi, Prakash Kumar Sarangi 2. Biomass and Bioenergy: Processing and Properties, Editors: Khalid Rehman Hakeem, Muhammad Jawaid, Umer Rashid, Publisher: Springer, (2014) 3. Biofuel Technology Handbook, Dominik Rutz, Rainer Janssen, WIP Renewable Energy, Germany, 2003 4. Biofuel Technology: Recent Development, Reza Faryar, Springer Publishers, 2001 5. Biofuel and Bioenergy Technology, Wei-Hsin Chen, Keat Teong Lee, Hwai Chyuan Ong, MDPI, Switzerland, ISBN 978-3-03897-596-0 (Pbk) 6. Biofuels Engineering Process Technology, Authors: Caye M. Drapcho, Nghiem Phu Nhuan, Terry H. Walker, Publisher: McGraw-Hill, (2008) 7. Biochemical Engineering Fundamentals, James E. Bailey, David F. Ollis, Publisher: McGraw-Hill Education, 1986 8. Handbook of Bioenergy Crop Plants, N. Gopalakrishnan, B. G. Kang, K. V. Raman, Publisher: CRC Press, (2012) 9. Biodiesel Production: Feedstocks, Catalysts, and Technologies, (2022), Wiley, Samuel Lalthazuala Rokhum, Gopinath Halder, Suttichai Assabumrungrat, Kanokwan Ngaosuwan

CO	**Statement**	**Program Outcomes**					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO 1	To obtain an idea about the fundamentals of bioenergy and its need as alternative to petro-fuels	2	1	3	2	1	1
CO 2	To learn the concept of biomass utilization on the way to bioenergy synthesis; mass energy balance and their application in biochemical process industries	1	1	3	3	2	1
CO 3	To elucidate the fundamental knowledge of heat transfer processes, engineering thermodynamics, process kinetic and mechanical operation and their importance in process industries	3	3	3	3	2	2
Average		**2.00**	**1.67**	**3**	**2.67**	**1.67**	**1.33**

<table>
<tr><th colspan="9">Department of Chemical Engineering</th></tr>
<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</td></tr>
<tr><td>CH9053</td><td>Application of AI in Bioprocess 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" rowspan="2">Pre-requisites: Introduction to AI / ML and Data Analytics (CH1022)</td><td colspan="5">Course Assessment methods (Continuous Assessment (CA), Mid-term (MT) and End-term (ET))</td></tr>
<tr><td colspan="5">CA+MT+ET</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Understand the kinetics of different bioprocess for the design of bioreactor. (PO1, PO2, PO3, PO4, PO5, PO6, PSO1)
CO2: Analyze the performance of bioreactors. (PO1, PO2, PO3, PO4, PO5, PO6, PSO1)
CO3: Apply the knowledge of bioprocess for industrial production. (PO1, PO2, PO3, PO4, PO5, PO6, PSO1)
CO4: Apply machine learning and deep learning to solve biological problems. (PO1, PO2, PO3, PO4, PO5, PSO2)</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Module I:
Introduction of Bioprocesses and their importance in process industry, Free enzyme kinetics, Inhibition in enzymatic reactions. Bioreactors for enzymatic reactions. Application of enzymatic reactions in industrial production. Production of HFCS.
[8 hrs.]
Module II:
Cell growth kinetics, Growth models, Inhibition kinetics for cell growth, Reactors for cell growth system. Combination of bioreactors for cell growth. Application of cell growth reactions in industrial production, Wastewater treatment.
[8 hrs.]
Module III:
Downstream processing in bioprocesses, Intra and extracellular product extraction and separation. Industrial application of bioprocesses.
[8 hrs.]
Module IV:
Machine learning and Deep Learning Models in Bioprocesses, Regression models (Linear Regression, SVR), Classification models (Decision Trees, Random Forests, SVMs), Time series analysis for bioprocess monitoring (e.g., LSTM networks). Neural networks for bioprocess prediction, Image-based bioprocess monitoring.
[8 hrs.]
Module V:
Modelling, control and optimization of Bioprocess, Data-driven models for microbial growth, product formation, and substrate utilization. Hybrid models</td></tr>
</table>

	combining mechanistic equations with neural networks. AI based control systems in bioreactors. AI enables multi-variable, multi-objective optimization. [8 hrs.]
Text Books, and/or reference material	<u>Suggested Text Books:</u> 1. M. L. Shuler, F. Kargi, Bioprocess Engineering - Basic Concepts, Second Edition, Prentice Hall of India Private Ltd., New Delhi, 2002. 2. J. E. Bailey, D. F. Ollis, Biochemical Engineering Fundamentals, Second Edition, Mc. Graw Hill Inc., Singapore, 1986. 3. H. W. Blanch, D. S. Clark, Biochemical Engineering, Special Indian Edition, Marcel Dekker Inc. New York, 2007.

Mapping of CO (Course Outcome) with PO (Programme Outcome) and PSO (Programme Specific Outcome)

POs / COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CO 1	3	2	3	2	3	1	-	-	-	-	-	-	3	-	-
CO 2	3	2	3	2	3	1	-	-	-	-	-	-	3	-	-
CO 3	3	2	3	2	3	1	-	-	-	-	-	-	3	-	-
CO 4	3	2	2	2	3	-	-	-	-	-	-	-	-	3	-

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH9054	**PROCESS INTENSIFICATION**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
--		CT+EA					
Course Outcomes		• CO1: Apply process intensification to turn Process Technology Sustainable • CO2: Ability of critical thinking and analysis of real-world problems towards innovative solutions					

	• CO3: Ability of independent design, investigation, data analysis and scientific reporting
Topics Covered	**Module 1:** Basics of Process Intensification, definitions, approaches, benefits, role of process intensification in sustainable development. Twelve principles of green chemistry. Matrices for chemistry: Effective mass yield, carbon efficiency, atom economy, reaction mass efficiency, Environmental factor (E). *14 hrs* **Module 2:** Process Intensification by Multifunctional equipment, Reactive distillation system, Catalytic distillation: principles, design, operation and case studies. Process Intensification through cavitation reactors, monolith reactors, oscillatory baffled reactors, Sono chemical, hydrodynamic cavitation reactors. *14 hrs* **Module 3:** Membrane Technology fundamentals and Process Intensification through Membrane-based technology. Process intensification in Biochemical production sectors, Chlor-alkali sector, industrial waste treatment through Membrane-based technology adoption. 14 hrs
Text Books, and/or reference material	**Suggested Text Book:** 1. Membrane based technologies for environmental pollution control, P. Pal, Elsevier Sci., Amsterdam, 2020. 2. Reengineering the Chemical Process Plants, Process Intensification, Stankiewicz, A. and Moulijn, (Eds.), Marcel Dekker, 2003. **Suggested References Book:** 1. Intensification of bio-based processes, A. Gorak, Andrzej Stankiewicz edited. RSC publication, A.Stankiewicz, J.A. Moulijin, Re-engineering the Chemical Processing Plant, Process intensification, Marcel Dekker, New York (2004) 2. Industrial Water Treatment Process Technology, P. Pal, Elsevier Science, Amsterdam, 2017.

			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH9055	CFD Applications in Chemical Engineering	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
	CT+EA
Course Outcomes	• 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.
Topics Covered	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 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.
Text Books, and/or reference material	**Text Books:** 1. An Introduction to Computational Fluid Dynamics – The Finite Volume Method, H.K. Versteeg, W. Malalasekera, Prentice Hall, 2007 and 2nd Edition. 2. Computational Fluid Dynamics – The Basics with Applications, John D. Anderson, Jr., McGraw Hill Education, 2017 3. Numerical heat transfer and fluid flow by S.V. Patankar, Hemisphere Publishing Corporation, 1980. 4. Introduction to Computational Fluid Dynamics by Anil W. Date, Cambridge University Press, 1st Edition, 2005. 5. 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).					
			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH9056	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		CO1: Understanding the fundamental features of different types of projects CO2: Determining project feasibility and project implementation time CO3: Learning how to do project planning and managing the activities CO4: Learning how to implement a project CO5: Preparing a project report – conceptualization to implementation & conclusion					
Topics Covered		**Module 1: Introduction (4L)** Definition of project and their types, project engineering–responsibilities of project engineers and project managers – projects-process needs-project requirement specification (PRS) **Module 2: Project life cycle (8L)** Definition of stage gate process, Various stages of a project – managing the various stages of project – various approaches of managing the projects **Module 3: Project management (12L)** Project management objectives, work breakdown structure, bar charts, development of networks, critical path method-activity times and activity floats, value engineering, crashing-time-cost tradeoff, limited time resource scheduling , project control and updating, programme evaluations review technique **–** event times and probability of completion, precedence diagramming method, line of balance for repetitive projects **Module 4: Project evaluation (9L)** Estimation of equipment cost – inside battery limit cost, fixed capital investment, working capital, total capital investment, taxes					

	& depreciation, rate on return (ROI), payback period, net present value, feasibility study-economic analysis of profitability, Preparation of bankable DFR. **Module 5: Case study: process design projects (9L)** Life cycle of a process design project, mass balance and energy balance, PFD, equipment sizing, detailed engineering, P&ID, detailed feasibility study, basic engineering package (BEP), technology transfer from lab to land.
Text Books, and/or reference material	**Text Book:** 1. Ernest E. Ludwig, Applied project engineering and management, Gulf Pub. Co., (1988) 2. Max S. Peters, K. D. Timmerhaus, Plant Design and Economics for Chemical Engineers 5th Edition, McGraw Hill Inc 3. Gavin Towler, R K Sinnott, Chemical Engineering Design, Second Edition: Principles, Practice and Economics of Plant and Process Design. Butterworth-Heinemann

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Understanding the fundamental features of different types of projects	3	3	3	3	3	3
CO2	Determining project feasibility and project implementation time	3	3	3	3	3	3
CO3	Learning how to do project planning and managing the activities	3	3	3	3	3	3
CO4	Learning how to implement a project	3	3	3	3	3	3
CO5	Preparing a project report – conceptualization to implementation & conclusion	3	3	3	3	3	3
Average		**3**	**3**	**3**	**3**	**3**	**3**

Department of Chemical Engineering							
			Total Number of contact hours				
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH9057	**Hazard Analysis and Risk Management in Process Industry**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end					

	assessment (EA))
Pre-requisites: CH1021, CH1022	Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination
Course Outcomes	• CO1: **Identify and classify** hazards in process industries using systematic techniques such as HAZOP and FMEA. (PO1, PO3, PSO1) • CO2: **Apply** quantitative and qualitative risk assessment methods to evaluate and mitigate risks. (PO1, PO3, PSO1, PSO2) • CO3: **Design** safety management systems and emergency response plans using computational tools and data analytics, and conduct independent research to communicate findings effectively. (PO1, PO2, PO3, PSO1, PSO2, PSO3)
Topics Covered	**Module I: Fundamentals of Hazard Identification and Risk Assessment (14 hours)** • Introduction to hazard and risk concepts: likelihood, consequence, and risk matrix. • Qualitative hazard identification techniques: HAZOP, What-If Analysis, Checklist Analysis, FMEA (Risk Priority Number). • Quantitative risk analysis methods: Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Bow-Tie Analysis. • Risk mitigation hierarchy: inherently safer design, engineering, and administrative controls. • Introduction to AI/ML in risk prediction: machine learning models for equipment failure prediction. *(Lecture: 12 hours; Assignment/Quiz: 2 hours)* **Module II: Process Safety Management and Regulatory Frameworks (14 hours)** • Principles and elements of Process Safety Management (PSM): OSHA PSM Standard, CCPS Risk-Based Process Safety. • Safety Management Systems (SMS): ISO 45001 and ISO 31000 frameworks. • Legal, regulatory, and environmental aspects: Factories Act, Environmental Protection Act, Major Accident Hazard Control (MAHC) rules. • Process Safety Metrics: Leading and lagging indicators. • Risk communication: Preparation of safety reports, audit reporting, and regulatory submissions. (Lecture: 12 hours; Assignment/Case Study: 2 hours) **Module III: Emergency Response, Simulation Tools, and AI Integration (14 hours)** • Emergency preparedness and response planning: emergency drills, evacuation, recovery procedures. • Computational simulation tools: i) Industry-standard software: PHAST, Safeti for consequence modeling and risk analysis.

	ii) Open-source alternatives: ALOHA, Python-based risk modeling (basic introduction). • Case studies on major process industry disasters and how modern tools could have mitigated them. • Research skills: Literature review techniques, experimental design for safety-related studies, writing technical papers. *(Lecture: 12 hours; Assignment/Project Work: 2 hours)*
Text Books, and/or reference material	**Textbooks:** • Crowl, D. A., & Louvar, J. F. (2011). Chemical Process Safety: Fundamentals with Applications. Prentice Hall. • Kletz, T. A. (1999). Hazop and Hazan: Identifying and Assessing Process Industry Hazards. CRC Press. • CCPS (Center for Chemical Process Safety). (2008). Guidelines for Risk-Based Process Safety. Wiley. **Reference Books:** • ISO 45001:2018 Standard for Occupational Health and Safety Management Systems. • OSHA Process Safety Management (PSM) Guidelines, 29 CFR 1910.119. • Research articles on AI applications in process safety (available via IEEE Xplore, ScienceDirect).

CO	Statement	Program Outcomes					
		PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	Identify and classify hazards in process industries using systematic techniques such as HAZOP and FMEA.	3	1	2	2	1	1
CO2	Apply quantitative and qualitative risk assessment methods to evaluate and mitigate risks.	3	2	3	3	2	2
CO3	Design safety management systems and emergency response plans using computational tools and data analytics, and conduct independent research to communicate findings effectively	3	3	3	3	3	3
Average		**3**	**2**	**2.67**	**2.67**	**2**	**2**

Department of Chemical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total number of contact hours: 56				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CH9058	**Application of AI in environmental engineering**	PEL	2	1	0	3	3
Pre-requisites: CH1022, and Data Analytics, Basic knowledge of Environmental Engineering		Course Assessment methods (Continuous (CT) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination					
Course Outcomes		CO1: Understand the fundamental concepts of environmental engineering, including water and wastewater treatment and air pollution control CO2: Analyze environmental data and assess pollution levels using conventional methods and monitoring tools. CO3: Apply basic artificial intelligence techniques to real-world environmental engineering problems through relevant case studies and develop data-driven solutions.					
Topics Covered		**Module 1: Introduction to Environmental Engineering (6 Hours)** Overview of Environmental Engineering and its importance, Key areas: Water, air, soil, and waste management, Environmental pollution and its impact on health and ecosystems, Pollution control technologies: Wastewater treatment, air pollution control, and waste management, Examples: Basic treatment systems for wastewater and air quality **Module 2: Wastewater Treatment (8 Hours)** Introduction to water treatment: Sources of contamination, purification processes, Types of waste water: Municipal, industrial, and agricultural, Treatment technologies: Physical, chemical, and biological methods, Case studies: Wastewater treatment plants, Advanced Treatment techniques **Module 3: Air Pollution and Control Technologies (6 Hours)** Sources of air pollution and its effects on the environment and human health, Air quality monitoring and control methods, Technologies: Scrubbers, filters, catalytic converters, and green technologies, Case studies: Air quality improvement initiatives in cities, industrial air pollution control **Module 4: AI in Environmental Engineering – Case Studies**					

	(10 Hours) Introduction to AI and ML, Applications in environmental problems, Use of machine learning in air and water quality prediction, Case studies on predicting pollution levels with machine learning models, AI in air pollution modelling, AI models for climate change forecasting and environmental monitoring
Text Books, and/or reference material	**Textbooks:** 1. Environmental Pollution Control Engineering – C S Rao 2. Industrial Water Treatment Process Technology – P Pal 3. Air Pollution Control Engineering, McGraw-Hill - Noel de Nevers 4. The Science of AI in Environmental Engineering - Frank R. Spellman 5. Wastewater engineering, Treatment and Reuse, MetCalf, Eddy, Tata McGrawHill, 2003, 3rd Edition. **Reference Books:** 1. Pollution control in Process industries - Mahajan S P, TMH, New Delhi. 2. Handbook of Air Pollution Prevention and Control - Nicholas P. Cheremisinoff 3. Artificial Intelligence in Environmental Engineering, Elsevier - Deyi Hou

CO	**Statement**	**Program Outcomes**					
		PO1	**PO2**	**PO3**	**PSO1**	**PSO2**	**PSO3**
CO1	Understand the fundamental concepts of environmental engineering, including water and wastewater treatment and air pollution control	2	1	3	1	1	1
CO2	Analyze environmental data and assess pollution levels using conventional methods and monitoring tools.	2	1	3	1	1	2
CO3	Apply basic artificial intelligence techniques to real-world environmental engineering problems through relevant case studies and develop data-driven solutions.	3	1	3	3	3	2
Average		**2.3**	**1**	**3**	**1.6**	**1.6**	**1.6**

Department of Chemical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	Credit
CH 9059	Polymer Science and Engineering	PEL	3	0	0	3	3
Pre-requisites: Basic knowledge of Chemistry		Course Assessment methods (Continuous (CT) and end assessment (EA)): Assignments, Quiz/class test, Mid-semester Examination, and End Semester Examination					
Course Outcomes		CO1: To provide an in-depth understanding of polymer chemistry, structure, and synthesis. CO2: To explore polymer processing, morphology, properties, and engineering applications. CO3: To familiarize students with polymer characterization techniques. CO4: To introduce advanced topics including polymer composites, smart polymers, and sustainability in polymer engineering.					
Topics Covered		**Module 1: Fundamentals of Polymer Science 10 Hrs** **Introduction to Polymers:** Historical development, types of polymers (natural, synthetic, thermoplastics, thermosets, elastomers). **Polymer Structure:** Linear, branched, crosslinked, network polymers; tacticity; molecular weight and its distribution. **Polymerization Techniques:** Step-growth, chain-growth polymerization; free-radical, ionic, and coordination polymerization; copolymerization; emulsion and suspension polymerization. **Kinetics and Mechanisms:** Reaction kinetics and rate expressions for various polymerization mechanisms. **Module 2: Polymer Properties and Characterization 10 Hrs** **Thermal Properties:** TG, Tm, crystallinity, DSC, TGA. **Mechanical Properties:** Stress-strain behavior, tensile strength, toughness, creep, viscoelasticity. **Rheology of Polymers:** Newtonian and non-Newtonian behavior, melt flow index, viscosity. **Characterization Techniques:** GPC/SEC (molecular weight), FTIR, NMR, XRD, SEM, TEM, DMA, UV-Vis spectroscopy. **Module 3: Polymer Processing and Product Engineering 10 Hrs** **Polymer Processing Techniques:** Extrusion, injection molding, blow molding, compression molding, thermoforming, calendaring.					

	Compounding and Additives: Fillers, plasticizers, stabilizers, colorants, flame retardants. **Processing-Structure-Property Relationship:** Effect of processing conditions on morphology and properties. **Design Considerations:** Polymer product design, prototyping, CAD tools in polymer design. **Module 4: Advanced Topics in Polymer Engineering 10 Hrs** **Polymer Blends and Composites:** Thermoplastic and thermoset composites, fiber-reinforced polymers, nanocomposites. **Functional and Smart Polymers:** Conducting polymers, shape memory polymers, stimuli-responsive materials. **Sustainable Polymers and Recycling:** Biodegradable polymers, recycling techniques, life cycle assessment. **Emerging Applications:** Polymers in biomedical engineering, electronics, aerospace, and energy storage.
Text Books, and/or reference material	**Textbooks:** 1. V.R. Gowariker, N.V. Viswanathan, and Jayadev Sreedhar – *Polymer Science*, New Age International Publishers. 2. Premamoy Ghosh – *Polymer Science and Technology of Plastics and Rubbers*, Tata McGraw-Hill. 3. A.K. Bhattacharya – *Polymer Chemistry*, Narosa Publishing House. **References:** 1. F.W. Billmeyer Jr. – *Textbook of Polymer Science*, Wiley. 2. Joel R. Fried – *Polymer Science and Technology*, Prentice Hall. 3. Robert O. Ebewele – *Polymer Science and Technology*, CRC Press. 4. R.J. Young and P.A. Lovell – *Introduction to Polymers*, CRC Press.