Syllabus for M.Tech (Chemical Engineering)
First Year & Second Year (Proposed)

Revised Syllabus of M.Tech CHE (for the students who were admitted in Academic Session 2025-2026)

MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY, WEST BENGAL

1st Year-Semester I

S/L	Code	Theory	Contact Hours /Week				Cr. Points
A. THEORY							
			L	T	P	Total	
1	ChE101	Advanced Heat Transfer	3	1	0	4	4
2	ChE102	Advanced Process Control	3	1	0	4	4
3	ChE103	Advanced fluid dynamics	3	1	0	4	4
4	ChE104	Adv. Num. Methods in Chem. Engg	3	1	0	4	4
5	ChE105A/ ChE105B/ChE105C	Elective I: Research Methodology, Ethics & IPR/ Green technology/Petroleum Ref. Engineering	3	1	0	4	4
		Total of Theory				**20**	**20**
B. PRACTICAL							
6	ChE191	Process Control Lab	0	0	3	3	2
7	ChE192	Petroleum Eng. Lab	0	0	3	3	2
C. SESSIONAL							
8	ChE181	Seminar I	0	0	0	0	1
		Total of Practical				**8**	**5**
		Total of Semester				**28**	**25**

1st Year-Semester II

S/L	Code	Theory	Contact Hours/Week				Cr. Points
A. THEORY							
			L	T	P	Total	
1	ChE201	Adv. Reactor Design & Analysis	3	1	0	4	4
2	ChE202	Advanced Mass Transfer	3	1	0	4	4
3	ChE203	Adv. Chemical Engg. Thermodynamics	3	1	0	4	4
4	ChE204	Management Principles	3	1	0	4	4
5	ChE205A/ChE205B/ ChE205C/ ChE205D	Elective II: Polymer & Engg Materials/ Petrochemical Technology/ Sustainable Energy Engineering/ Computer Aided Process Design	2	1	0	3	3
		Total of Theory				**19**	**19**
B. PRACTICAL							
6	ChE291	Instrumental Methods of Analysis Lab	0	0	3	3	2
7	ChE292	Advanced Numerical Lab	0	0	3	3	2
C. SESSIONAL							
8	ChE281	Seminar II	0	0	0	0	2
		Total of Practical				**6**	**7**
		Total of Semester				**25**	**26**

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MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY, WEST BENGAL

2nd Year-Semester III

S/L	Code	Theory	Contact Hours/Week				Cr. Points
			L	T	P	Total	
A. THEORY							
1	ChE301	Advanced Statistical Analysis	3	1	0	4	4
2	ChE302A/ChE302B/ ChE302C	Elective III: Adv. Transport Phenomena/Safety In Process Industry/Project Engineering	3	1	0	4	4
Total of Theory						**8**	**8**
B. SESSIONAL							
3	ChE381	Thesis part-I	0	0	0	0	10
4	ChE382	Project Viva	0	0	0	0	4
Total of Practical						**15**	**14**
Total of Semester						**23**	**22**

2nd Year-Semester IV

S/L	Code	Theory	Contact Hours/Week				Cr. Points
			L	T	P	Total	
A. SESSIONAL							
1	ChE481	Final Thesis	0	0	0	24	14
2	ChE482	Project Viva voce	0	0	0	0	8
3	ChE483	Comprehensive Viva Voce	0	0	0	0	4
Total of Practical						**0**	**26**
Total of Semester						**0**	**26**

TOTAL CREDIT

First Year First Semester	25
First Year Second Semester	26
Second Year Second Semester	23
Second Year Second Semester	26
Total Credit	**100**

Syllabi for M.Tech Course in Chemical Engineering

SEMESTER – I

Paper: Advanced Heat Transfer

Code: ChE101

Total Hours: 60

Credits: 4

Course Objectives	
1. Understand and solve complex steady and unsteady heat conduction problems using analytical and numerical methods. 2. Analyze advanced convective heat transfer in free and forced flow systems through dimensional analysis and analogies. 3. Examine phase-change heat transfer phenomena such as boiling and condensation in engineering applications. 4. Design and optimize advanced heat exchangers using LMTD and NTU methods. 5. Apply radiation heat transfer principles, including view factors and combined heat transfer modes, to real-world systems.	
Course Content	
Module I: Advanced Conduction Heat Transfer	
Unit 1:	Steady state conductive heat transfer with heat generation. Unsteady state heat transfer in different coordinates. Solution of unsteady state partial differential heat transfer equation using analytical and numerical methods. **Hours Allotted: 10**
Unit 2:	Formulation of transient heat conduction equation; initial and boundary conditions for different geometries. Analytical solutions: separation of variables, Fourier series method, and use of dimensionless parameters (Biot and Fourier numbers). Application to one-dimensional transient conduction problems in slabs, cylinders, and spheres. **Hours Allotted: 5**
Module II: Free and Forced Convection with Transfer Analogies	
Unit 3:	Free convective heat transfer under different situations and application of dimensional analysis to estimate the convective heat transfer coefficients. Study of natural convection under various geometries and boundary conditions. Application of dimensional analysis using Rayleigh and Grashof numbers. Estimation of convective heat transfer coefficients through empirical correlations.

	Hours Allotted: 5
Unit 4:	Concepts of forced convection; flow regimes based on Reynolds number – laminar, transitional, and turbulent. Development of velocity and thermal boundary layers in internal and external flows. Heat transfer correlations for laminar and turbulent flows in pipes and over flat plates. Effect of fluid properties, surface roughness, and flow velocity on convective heat transfer coefficient.Heat transfer factor: Reynold's no. plot. **Hours Allotted: 5**
Unit 5:	Concept of analogies between heat, mass, and momentum transfer; Reynolds, Prandtl, and Chilton–Colburn analogies. Application of analogy equations to determine convective heat transfer coefficients. **Hours Allotted: 5**
Module III: Boiling, Condensation, and Heat Exchanger Design	
Unit 6:	Boiling heat transfer with particular reference to Nucleate and film boiling and estimation of boiling heat transfer coefficient. Theory of vapour bubble formation: Homogeneous and heterogeneous nucleation. Bubble Growth Models. **Hours Allotted: 5**
Unit 7:	Heat transfer from condensing vapors. Nusselt equation for film type condensation of vapors over vertical surfaces and inclined tubes. Mechanisms of condensation: filmwise and dropwise modes. Condensation heat transfer over vertical plates and inclined tubes. Influence of surface tension, viscosity, and orientation on condensate film behavior. **Hours Allotted: 5**
Unit 8:	Selection and design of condensers, single pass and multipass heat exchangers. Heat transfer in packed bed. Introduction to compact heat exchangers. **Hours Allotted: 5**
Module IV: Thermal Radiation and Combined Heat Transfer Modes	
Unit 9:	Fundamentals and governing laws of thermal radiation; emissive power, absorptivity, and radiosity concepts; estimation of view factors and emissivity factors for various geometrical configurations such as parallel plates, concentric cylinders, and enclosures; application of radiation networks for heat exchange analysis; role and design of radiation shields to minimize radiative heat loss; errors in temperature measurement due to radiation effects in pyrometry and corrective techniques for accurate readings. **Hours Allotted: 10**
Unit 10:	Combined conduction, convection and radiation heat transfer. Formulation of combined heat transfer equations and overall heat transfer coefficients. Convection and radiation furnaces – design considerations.

	Hours Allotted: 5

Course Outcomes
By the end of this course, students will be able to: 1. To enhance the understanding of heat transfer processes and their relevance to industrial problems. 2. To understand the derivation and physical meaning of energy transport equations. 3. To strengthen analytical, numerical and computational skills to solve complex heat transfer problems. 4. To provide experience in treating multimode heat transfer effects and in solving realistic engineering problems

Suggested Textbooks:

1. Bird, R.B,Stewart, W.E. and Lightfoot, E.N., Transport Phenomena, Wiley, 2001.

2. Heat Transfer Principles and Application, B. K. Dutta, PHI.

3. Unit Operations – McCabe W L and Smith J L (McGraw Hill).

Paper: Advanced Process Control

Code: ChE102

Total Hours: 60

Credits: 4

Course Objectives
To provide a detailed understanding of advanced control concepts and their application in chemical process industries. To enable students to design and analyze various process control schemes using modern control techniques. To familiarize students with multivariable, model predictive, and statistical control approaches for complex process systems. To develop the ability to model, simulate, and tune controllers for dynamic chemical processes.
Course Content
Module I: Process Dynamic Behaviour and Single-Loop Control

Unit 1:	Process Modeling and Dynamic Behavior:– Basic Elements of Dynamic Models, Mathematical Description of Chemical Processes, State-Space models, Transform Domain Models, Lumped Parameter and Distributed Parameter Systems **Hours Alloted: 5**
Unit 2:	Dynamic Behaviour of Linear Systems, Inverse-Response Systems, Time-Delay Systems, Dynamic Behaviour of Nonlinear Systems, Feedback Controllers:- Single-Loop Control of Feedback Control Systems, Features of P, PI, PID Controllers, On-off Controllers **Hours Alloted: 5**

Module II: Stability of Closed Loop Control Systems and Introduction to Advanced Control Strategies	
Unit 3:	Behaviour and Stability of Closed Loop Control Systems, Controller Design and Tuning, Control System Design based on Frequency Response Analysis, Bode Criteria and Nyquist Criteria **Hours Alloted: 10**
Unit 4:	Smith compensator for systems with large dead-time and inverse response, Basics of Feedforward Control, Ratio Control, Cascade Control, Inferential Control, Selective and Split-Range Control **Hours Alloted: 5**
Module III: Complex Control Structures and Multivariable Process Control	
Unit 5:	Design of Complex Control Structures:– Processes with multiple outputs controlled by single input, Processes with single output controlled by multiple inputs **Hours Alloted: 10**
Unit 6:	Multivariable Process Control:– Nature of Multivariable systems, Multivariable Process Models, Open Loop and Closed Loop Dynamic Analysis, Interaction Analysis and Loop Pairing, Relative Gain Array (RGA), Loop Pairing using RGA **Hours Alloted: 10**
Module IV: Special Topics in Chemical Engineering Process Control	
Unit 7:	Fundamental concept of Model Predictive Control (MPC) and its predictive optimization approach; formulation involving objective function, constraints, and receding horizon strategy; principles of Dynamic Matrix Control (DMC) and its role in implementing MPC using linear dynamic models; overview of tuning, stability, and performance aspects; qualitative review of commercial MPC schemes; applications in chemical and process industries. **Hours Allotted: 10**
Unit 8:	Fundamental principles of optimal control theory; formulation of objective functions and performance criteria; constraints and optimization techniques for process control; introduction to statistical process control (SPC) and its role in maintaining product quality; concept of control charts, process variation, and detection of assignable causes; fundamentals of digital control systems, sampling, discretization; integration of optimal, statistical, and digital control for improved process efficiency and automation. **Hours Allotted: 5**

Course Outcomes

By the end of this course, students will be able to:

1. Determine the control structures in chemical processes
2. Understand Multiple-Input- Multiple-Output (MIMO) systems and their dynamical interactions
3. Determine stability of MIMO systems
4. Understand cascade, inferential, and ratio control philosophies
5. Understand the general principles of Model Predictive Control and Statistical Process Control

Suggested Textbooks:

1. D.E. Seborg, T.F. Edgar, E.A. Mellichamp, F. J. Doyle, Process Dynamics and Control, 3rd edition, John Wiley&Sons, NY.
2. B.A. Ogunnaike and W.H. Ray, 1994, Process Dynamics, Modeling, and Control, OxfordUniversity Press

Paper: Advanced Fluid Dynamics

Code: ChE103

Total Hours: 60

Credits: 4

Course Objectives	
1. To understand the fundamental and advanced concepts of fluid flow in various engineering applications. 2. To apply Navier-Stokes equations to analyze laminar and turbulent flow systems. 3. To explore the boundary layer theory, transition to turbulence, and modeling of non-Newtonian fluids. 4. To study the principles and industrial applications of fluidization and multiphase flow systems. 5. To design and analyze fluidized bed reactors and understand heat and mass transfer in multiphase systems.	
Course Content	
Module I: Fluid Kinematics and Boundary Layer Theory	
Unit 1:	Velocity potential, rotational and irrotational flow; Navier-Stokes equation, Poiseuille flow, creep flow, and Couette flow; Boundary layer theory: integral momentum analysis; Turbulent boundary layer: turbulence and mixing; Stream function–vorticity formulation – for solving 2D incompressible flows. **Hours Allotted: 5**
Unit 2:	Similarity solutions of boundary layer equations – e.g., Blasius solution, Falkner–Skan equation; Compressible flow fundamentals – Mach number, continuity, and energy relations; Flow past immersed bodies – drag and lift, boundary layer separation; Dimensional analysis and scaling laws – Buckingham π theorem applied to fluid mechanics; Computational Fluid Dynamics (CFD) introduction – finite difference and finite volume methods basics **Hours Allotted: 10**
Module II: Turbulence and Non-Newtonian Flow	
Unit 3:	Universal velocity profile; Stability analysis of laminar flow, Orr-Sommerfeld solution, transition to turbulence; Detailed modeling of turbulent flow; Laminar and turbulent flow of non-Newtonian fluid, Rheological characteristics, consistency measurement; Viscometric flow, pipe and annular flow, pipeline design equations; Reynolds-averaged Navier–Stokes (RANS) modeling – k–ε and k–ω models; **Hours Allotted:5**

Unit 4:	Large Eddy Simulation (LES) and Direct Numerical Simulation (DNS) – modern turbulence approaches; Viscoelastic and thixotropic fluid models – e.g., Oldroyd-B, Bingham plastic, Herschel–Bulkley; Power-law fluid correlations for heat transfer – Nusselt and friction factor correlations; Micro- and nanofluidics – flow behavior at small scales; Non-isothermal non-Newtonian flow – temperature-dependent viscosity effects. **Hours Allotted: 10**
Module III: Fluidization Phenomena	
Unit 5:	The phenomena of fluidization and its industrial application; Characteristics of particles and principle of fluidization; Mapping of various regimes and two-phase theory of fluidization; Bubbles in fluidized bed, Entrainment and Elutriation, Fast fluidized bed; Minimum fluidization velocity correlations – Ergun and Wen–Yu equations. **Hours Allotted: 10**
Unit 6:	Pressure drop and bed expansion correlations – experimental and empirical methods; CFD simulation of fluidized beds – Euler–Euler and Euler–Lagrange approaches; Circulating fluidized beds (CFB**) – hydrodynamics and applications in combustion; Spouted bed systems – flow regimes and design principles; Electrostatic and cohesive particle behavior in fluidized **Hours Allotted: 5**
Module IV: Multiphase Flow and Fluidized Bed Design	
Unit 7:	Mixing, segregation and gas dispersion; Heat and mass transfer in fluidized bed; Solid-liquid fluidized bed and three-phase fluidized bed. **Hours Allotted: 5**
Unit 8:	Design of fluidized bed reactors: (1) Gas–liquid–solid contactors – bubble column and slurry reactor hydrodynamics; (2) Residence time distribution (RTD) analysis in fluidized systems(3) Heat transfer coefficients in bubbling and turbulent fluidized beds; (4) Modeling of catalytic fluidized bed reactors – with reaction–transport coupling; (5) Design of circulating fluidized bed reactors (CFBRs) – chemical looping and FCC systems; (6) Environmental and energy applications – CO2 capture, biomass gasification, waste-to-energy. **Hours Allotted: 10**

Course Outcomes

By the end of this course, students will be able to:

1. Apply Navier-Stokes equations to analyze laminar and turbulent flow systems.
2. Explore boundary layer theory, transition to turbulence, and model non-Newtonian fluids.
3. Study the principles and industrial applications of fluidization and multiphase flow systems.
4. Design and analyze fluidized bed reactors and understand heat and mass transfer in multiphase systems.

5. Utilize CFD methods and scaling laws for solving complex fluid dynamics problems.

Suggested Textbooks:

1. Unit operations of Chemical Engineering: McCabe, Smith and Harriot,TMH, 6th Edn.
2. R. B. Bird, W. E. Stewart, and E. S. Lightfoot. Transport Phenomena, 2nd ed., Wiley India Pvt.Ltd., 2002.

Paper: Advanced Numerical Methods in Chemical Engineering

Code: ChE104

Total Contact Hours: 60

Credits: 4

Course Objectives	
1. To equip students with the mathematical prowess to formulate and solve complex chemical engineering problems that is intractable by analytical means. 2. To develop a deep understanding of the principles of numerical methods, including error analysis, stability, and convergence, as applied to linear and non-linear systems. 3. To provide hands-on experience in implementing numerical algorithms for solving ordinary and partial differential equations that model transport phenomena, reaction kinetics, and process dynamics. 4. To familiarize students with modern computational tools and techniques, enabling them to simulate and analyze chemical processes effectively.	
Course Content	
Module I: Fundamentals of Numerical Analysis and Linear Systems	
Unit 1	**Error Analysis and Matrix Theory**–Types of errors: Truncation error, round-off error, chopping-off error, loss of significance, Error propagation and accumulation in iterative processes, Matrices, norms and inner products, Gram-Schmidt orthonormalization process, Fredholm alternative theorem, Rayleigh's quotient and applications, Condition numbers and ill-conditioning **Hours allotted:5**
Unit 2	**Solution of Linear Algebraic Equations** – Direct methods: Gauss elimination, LU decomposition, Tri-Diagonal Matrix Algorithm (TDMA), Iterative methods: Jacobi and Gauss-Seidel iterations, Successive Over-Relaxation (SOR), Matrix inversion techniques, Eigenvalue problems: Power method, QR algorithm, Applications: Heat transfer in fins, multi-component material balances, fitting polynomials, steady-state reactor networks

	Hours allotted: 5
Unit 3	**Nonlinear Algebraic Equations** –Newton-Raphson method for single and multiple equations, Secant method and Regula-Falsi method, Convergence criteria and stability analysis, Applications: Thermodynamic property calculations (EOS), bubble point and dew point calculations, stability analysis of non-isothermal CSTR, friction factor calculations in fluid flow **Hours allotted: 5**
Module II: Interpolation, Optimization, and Approximation	
Unit 4	**Interpolation and Curve Fitting**–Lagrange and Newton interpolation, Spline interpolation: Linear, cubic, and B-splines, Least squares regression and polynomial fitting,multi-dimensional interpolation,Applications: Physical property estimation, experimental data correlation **Hours allotted: 5**
Unit 5	**Numerical Optimization**–Unconstrained optimization: Golden section search, Newton's method, Quasi-Newton methods, Constrained optimization: Linear programming, Sequential, Quadratic Programming (SQP), Multi-objective optimization basics,Applications: Parameter estimation, reactor design optimization, process optimization **Hours allotted: 5**
Unit 6	**Numerical Differentiation and Integration**–Finite difference approximations: Forward, backward, and central differences, Richardson extrapolation, Numerical integration: Trapezoidal rule, Simpson's rules, Gaussian quadrature, Applications: Reaction rate calculations from concentration profiles, thermodynamic property integration **Hours allotted: 4**
Module III: Ordinary Differential Equations (ODEs)	
Unit 7	**Initial Value Problems (IVPs)**– Euler's method: Forward and modified Euler, Runge-Kutta methods: 2nd, 4th order, adaptive RK methods, Predictor-corrector methods: Adams-Bashforth, Adams-Moulton, Step size selection and stability analysis, Stiff ODEs and Gear's method, Applications: Batch reactor dynamics, unsteady-state heat transfer, transient CSTR behavior **Hours allotted: 5**
Unit 8	**Boundary Value Problems (BVPs)**–Shooting methods for linear and nonlinear systems, Finite difference methods for BVPs, Method of weighted residuals: Collocation, Galerkin, and least squares, Orthogonal collocation method, Introduction to finite element methods for ODEs, Applications: Tubular reactor with axial dispersion, steady-state heat conduction with generation, catalyst effectiveness

	factor **Hours allotted: 5**
Unit 9	**Advanced Topics in ODEs** –Nonlinear ODEs: Phase plane analysis, limit cycles, Stability of solutions: Liapunov methods, Theory of bifurcation in chemical systems, Regular perturbation methods for singular problems, System of ODEs: Matrix differential equations, Applications: Multiple steady states in CSTRs, oscillatory reactions, stability analysis of process control systems **Hours allotted: 5**
Module IV: Partial Differential Equations (PDEs)	
Unit 10	**Classification and Solution Methods for PDEs** –Classification: Elliptic, parabolic, and hyperbolic PDEs, Finite difference methods: Explicit and implicit schemes, Crank-Nicolson method for parabolic PDEs, Alternating Direction Implicit (ADI) method, Stability analysis: Von Neumann stability criterion, Applications: Unsteady-state diffusion, transient heat conduction **Hours allotted: 4**
Unit 11	**Advanced Methods for PDEs** –Finite volume technique for PDEs, Steady-state and unsteady convection-diffusion equations, PDEs with linear and nonlinear source terms, Method of weighted residuals for PDEs, Orthogonal collocation for PDEs, Finite element methods for PDEs, Similarity transformation and dimensional analysis,Applications: Plug flow reactor with dispersion, packed bed reactor analysis, simultaneous heat and mass transfer **Hours allotted: 4**
Unit 12	**Integral Transforms and Green's Functions** – Fourier transforms and Fourier series solutions, Laplace transforms for PDE solutions,Introduction to wavelet transforms,Green's function methods for PDEs, Superposition principle, Moving boundary problems (Stefan problem), Applications: Transient diffusion in semi-infinite media, dissolution/crystallization problems **Hours allotted: 4**
Unit 13	**Computational Implementation and Case Studies**– Introduction to MATLAB/Python programming for numerical analysis, Built-in functions for linear systems, ODEs, and PDEs, Symbolic computation and automatic differentiation, Visualization and data analysis, Implementation of custom algorithms, Introduction to fuzzy logic and genetic algorithms in optimization, Case studies from chemical engineering:Friction factor and pressure drop calculations in pipe networks, Multicomponent distillation (shortcut and rigorous methods)Multiple-effect evaporator design, Catalytic reactor modelling and parameter estimationTwo-phase flow calculations, Practice sessions: Solving chemical engineering problems using computational tools, Integration of numerical methods in process simulation

	Hours allotted: 4

Suggested Textbooks:

1. Pushpavanam, S., 1998. Mathematical methods in chemical engineering. PHI Learning Pvt. Ltd.

2. Dutta, B.K., 2016. Mathematical methods in chemical and biological engineering. CRC Press.

Paper: Research Methodology, Ethics & IPR

Code: ChE105A

Total Contact Hours: 60

Credits: 4

Course Objectives	
1. Understand the concept, sources, and characteristics of research problems and their formulation. 2. Develop skills in data collection, analysis, interpretation, and use of research instruments. 3. Conduct effective literature reviews while maintaining ethical standards and avoiding plagiarism. 4. Gain proficiency in technical writing, report preparation, and proposal development. 5. Comprehend the fundamentals, processes, and emerging trends of Intellectual Property Rights (IPR) and patenting.	
Course Content	
Module I: Research Problem Identification and Formulation	
Unit 1:	Understanding the concept and significance of a research problem; identifying potential sources such as literature, industrial needs, or societal challenges; essential criteria and attributes of a well-defined research problem; common mistakes made during problem selection; and defining the scope, objectives, and expected outcomes to ensure clarity and feasibility in research formulation. **Hours Allotted: 10**
Unit 2:	Systematic approaches to research investigation; experimental, analytical, and simulation-based methods; formulation of methodology and selection of appropriate techniques; primary and secondary data collection methods; statistical and computational data analysis; result interpretation and validation of hypotheses; requirement and selection of suitable instruments; precision, calibration, and reliability of measurement tools; integration of analytical and

	computational instruments for enhanced accuracy and reproducibility. **Hours Allotted: 5**
Module II: Research Methodology, Literature Review, and Technical Writing	
Unit 3:	Literature survey techniques, identification of research gaps, review structuring, data extraction and synthesis, critical analysis of published work, citation and referencing methods, database search tools (Scopus, Web of Science, ScienceDirect), keyword formulation, organization of reviewed materials, conceptual framework development, plagiarism awareness, types of plagiarism, ethical use of sources, paraphrasing and quotation standards, use of plagiarism detection tools, authorship and contribution ethics, data integrity and transparency, confidentiality in research, publication ethics, conflict of interest, intellectual property rights, code of conduct for researchers, and responsible dissemination of research findings. **Hours Allotted:5**
Unit 4:	Principles of clear and concise technical writing, structure and organization of technical documents, grammar and style in scientific communication, data presentation using tables, figures, and graphs, report writing format and layout, executive summary and conclusion drafting, citation and referencing techniques, stages of research proposal development, formulation of research objectives and hypotheses, identification of research problems and methodology design, budget estimation and timeline preparation, proposal formatting as per funding agency guidelines, review and revision process, plagiarism check and ethical writing practices, journal paper structure (abstract, introduction, methodology, results, discussion, conclusion), and effective communication of technical content to academic and industrial audiences. **Hours Allotted: 10**
Module III: Fundamentals and Processes of Intellectual Property Rights	
Unit 5:	Concept and importance of intellectual property in technological advancement, types of intellectual property rights (IPR) including patents, industrial designs, trademarks, and copyrights, scope and legal protection under each category, criteria for patentability – novelty, inventive step, and industrial applicability, stages in the process of patenting – idea generation, prior art search, drafting, filing, examination, and grant, role of technological research and innovation in creating patentable inventions, commercialization and technology transfer mechanisms, significance of patent databases in R&D, patent infringement and licensing, and strategies for IP management in academic and industrial research environments. **Hours Allotted: 10**
Unit 6:	Overview of international frameworks for intellectual property protection and cooperation among nations, role of organizations like WIPO and WTO-TRIPS in harmonizing IP laws, procedure for obtaining patents in multiple countries through the Patent Cooperation Treaty (PCT), stages of PCT filing – international application, search, publication, and national phase entry, advantages of PCT for global patent protection, and significance of international collaboration in promoting innovation and technology transfer.

	Hours Allotted: 5
Module IV: Advanced IPR Concepts, Licensing, and Emerging Issues	
Unit 7:	Scope and extent of patent rights including exclusivity, duration, and territorial limitations; concepts of patent ownership, assignment, and infringement; technology licensing and transfer mechanisms between academia and industry; use of patent information systems and databases for prior art search and innovation tracking; significance of Geographical Indications (GI) in protecting region-specific products; recent developments in IPR policies, digital patent filing systems, global harmonization efforts, and modernization of patent administration for efficient processing and transparency. **Hours Allotted: 10**
Unit 8:	Emerging areas of IPR protection for biotechnology, genetic resources, and computer software; legal and ethical challenges in patenting living organisms and algorithms; preservation and recognition of traditional knowledge through documentation and benefit-sharing frameworks; and illustrative case studies highlighting conflicts and success in modern IPR applications. **Hours Allotted: 5**
Course Outcome	
By the end of this course, students will be able to: 1. Identify and define appropriate research problems based on scope and feasibility. 2. Apply systematic research methodologies for data analysis and result interpretation. 3. Prepare quality research reports, papers, and proposals with academic integrity. 4. Demonstrate understanding of IPR types, patenting procedures, and recent developments in IPR and technology transfer.	

Suggested Textbooks:

1. Kothari, C.R., 2004. Research methodology: Methods and techniques. New Age International.
2. Irish, V., 2005. Intellectual property rights for engineers (Vol. 22). IET.

Paper: Green Technology

Code: ChE105B

Total Hours: 60

Credits: 4

Course Objectives	
1. Introduce the principles of green chemistry and green engineering for developing sustainable chemical processes. Develop understanding of designing environmentally benign chemicals, safer solvents, and energy-efficient processes. Emphasize the use of renewable feedstocks, catalytic routes, and waste minimization techniques. Familiarize students with real-time pollution monitoring, process intensification, and inherently safer process design. Enable students to evaluate environmental performance and implement sustainability-driven decisions in process industries.	
Course Content	
Module I: Fundamental Principles of Green Chemistry	
Unit 1:	Introduction to green technology and sustainability concepts, Principles of green chemistry and green engineering, Sustainable Development Goals, General principles for assessing environmental performance of chemical processes and products, , Environmental, economic, and social dimensions of sustainability, Global and industrial perspectives **Hours Alloted: 6**
Unit 2:	Role of innovation and design in achieving sustainability, Less hazardous chemical synthesis — replacement of toxic reagents and safer synthesis routes, Designing safer chemicals — molecular design for reduced toxicity and persistence, Safer solvents and auxiliaries — supercritical fluids, ionic liquids, water-based and solvent-free systems **Hours Alloted: 9**
Module II: Sustainable Feedstocks and Catalytic Systems	
Unit 3:	Design for energy efficiency — alternative energy sources, process integration, and energy targeting, Comparison between renewable and non-renewable raw materials, Biomass as a sustainable carbon source, Case studies: fermentation-based processes, bio-based polymers, CO_2 utilization, Reduction of derivatives **Hours Alloted: 8**
Unit 4:	Advantages of catalytic systems, Types of catalysts: homogeneous, heterogeneous, enzymatic, Phase-transfer catalysis, Organocatalysis, Biocatalysis, Catalyst recovery and recyclability, Concepts of Environmental persistence and biodegradability **Hours Alloted: 7**
Module III: Real-Time Monitoring and Pollution Prevention	
Unit 5:	Principles of degradable materials (bioplastics, biodegradable surfactants), On-line and in-process monitoring, Process Analytical Technology (PAT) concepts, Role of sensors, spectroscopy, and automation **Hours Alloted: 7**

Unit 6:	Pollution prevention hierarchy and waste minimization approaches, recycle, and reuse strategies, Cleaner production technologies and industrial symbiosis, Process emission control and zero liquid discharge, Concept of zero-waste operation, Waste-to-resource systems **Hours Alloted: 8**
Module IV: Inherently Safer Design and Sustainability Assessment	
Unit 7:	**Inherently safer chemistry for accident prevention —** substitution, minimization, moderation, and simplification, Risk analysis and hazard identification (HAZOP and FMEA), Methodology of Life Cycle Assessment (LCA), Sustainability indices **Hours Allotted: 6**
Unit 8:	Economic and environmental performance metrics (eco-efficiency, NPV, payback), Integration of green chemistry and process systems engineering, Process intensification and retrofitting for sustainability, Case study from chemical, petrochemical, and pharmaceutical industries, Future directions: circular economy, carbon neutrality **Hours Allotted: 9**
Course Outcomes	
By the end of this course, students will be able to: 1. Explain the fundamental principles of green chemistry and engineering. 2. Design safer and energy-efficient chemical synthesis routes. 3. Utilize renewable feedstocks, catalysts, and degradable materials for sustainable production. 4. Apply tools for real-time pollution prevention and risk minimization. 5. Propose inherently safer chemical processes through systematic analysis and case studies.	

Suggested Textbooks:

1. Anastas, P.T. & Warner, J.C., Green Chemistry: Theory and Practice, Oxford University Press, 1998.
2. Allen, D.T. & Shonnard, D.R., Green Engineering: Environmentally Conscious Design of Chemical Processes, Prentice Hall, 2002.
3. Sikdar, S.K. & Glavic, P., Sustainable Engineering: Drivers, Metrics, Tools, and Applications, Springer, 2010.

Reference Materials**:** Selected papers from Green Chemistry, Journal of Cleaner Production, Chemical Engineering Journal.

Paper: Petroleum Refinery Engineering

Code: ChE105C

Total Contact Hours: 60

Credits: 4

Course Objectives
1. Understand the origin, composition, and properties of crude oil and its evaluation methods. 2. Analyze the design and operation of primary refining units such as atmospheric and vacuum distillation columns. 3. Comprehend the principles and applications of secondary refining and conversion processes. 4. Learn the production process of lube oil base stocks and understand associated refinery equipment. 5. Evaluate the environmental impacts of refining operations and explore mitigation strategies.

Course Content

Module I: Origin, Evaluation, and Characterization of Crude Oil	
Unit 1:	Origin of petroleum crude oil. Evaluation of crude oil, evaluation and characterization of crude oil: TBP and other distillation tests. Petroleum products, their properties, specification and testing. **Hours Allotted: 10**
Unit 2:	Different properties like flashpoint, fire point, smoke point, aniline point, carbon residue, kinematic viscosity, pour point, freezing point etc. **Hours Allotted: 5**
Module II: Primary Refining Processes: Atmospheric and Vacuum Distillation	
Unit 3:	Use of crude book data. Petroleum refinery distillation, pre-fractionation and atmospheric distillation of crude. Process design for atmospheric distillation. Stabilization of naphtha. Vacuum distillation of RCO. Reforming of naphtha. **Hours Allotted: 10**
Unit 4:	Production of finished petroleum goods like, LPG, Kerosene, Petrol, Diesel, Lubricating Oil, Bitumen, environmental norms of products. **Hours Allotted: 5**
Module III: Secondary Conversion and Treatment Processes	
Unit 5:	Other secondary processes like Vis-breaking, Furfural/Phenol/NMP extraction, Solvent dewaxing, propane deasphalting. Delayed coking process. FCC unit. Hydro treatment processes in refining: hydro-desulfurisation, hydro finishing, Hydrocracking. **Hours Allotted: 10**
Unit 6:	Reforming: process, catalyst, reactor design configuration, alkylation, isomerization, lube oil manufacturing process, solvent, de-asphalting, solvent de-waxing. **Hours Allotted: 5**

Module IV: Lube Oil Production, Refinery Equipment, and Environmental Aspects	
Unit 7:	Production of lube oil base stock. Refinery equipment: furnaces, distillation columns, reactors, pumps, compressors and piping. **Hours Allotted: 10**
Unit 8:	Air pollution: emission of CO_2, CO, SO_x, NO_x, VOCs, and particulate matter; greenhouse gas contribution. Water pollution: discharge of oily wastewater, phenols, sulfides, and suspended solids; contamination of surface and groundwater. Soil contamination: leakage and spillage of hydrocarbons and chemicals; sludge disposal issues. Noise and thermal pollution: operation of compressors, pumps, furnaces, and cooling systems. Ecological impacts: harm to aquatic and terrestrial ecosystems; bioaccumulation of toxic substances. Waste generation: solid and hazardous wastes from catalysts, sludge, and spent chemicals. Control measures: effluent treatment plants (ETP), air pollution control devices, waste minimization, and environmental monitoring programs. **Hours Allotted: 5**
Course Outcome	
By the end of this course, students will be able to: 1. Characterize crude oils and petroleum products based on key physical and chemical properties. 2. Design and analyze distillation units used for crude oil fractionation.	

Suggested Textbooks:

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

Paper: Process Control Lab.

Code: ChE191

Credits: 2

Laboratory 1	**Course Code PG ChE191**	**Process Control Lab.**	**Credits: 2 L-T-P: 0-0-3**
Total contact hours = 60			
COURSE OBJECTIVE			
1. To familiarize students with the dynamic behavior of first-order and second-order (interacting and non-interacting) process systems.			

2. To understand and evaluate the performance of various types of controllers (P, PI, PID) in process control applications. 3. To develop practical skills in measuring and controlling process variables such as flow, level, temperature, and pressure using industrial instrumentation. 4. To expose students to the design, calibration, and operation of fluid flow and heat exchange devices relevant to process control systems. 5. To integrate process simulation tools for analyzing and optimizing industrial process dynamics and control strategies.	
EXPERIMENT 1	Time Constant Determination of a Thermometer
EXPERIMENT 2	Response of a single-tank system (First Order System) to step input
EXPERIMENT 3	To study the characteristics of Non-interacting Two Tank System
EXPERIMENT 4	To study the characteristics of Interacting tank system
EXPERIMENT 5	To study the characteristics of PID controllers.
EXPERIMENT 6	To determine the liquid level by air purge method.
EXPERIMENT 7	Study of Proportional (P) controller using a PID controller
EXPERIMENT 8	Study of Proportional (PI) controller using a PID controller
EXPERIMENT 9	Study of Proportional (PID) controller using a PID controller
EXPERIMENT 10	To study the characteristics of control valve.
EXPERIMENT 11	Case study of Simulation of an industrial process plant
COURSE OUTCOME	1. Demonstrate understanding of the dynamic response of single and multi-tank systems and analyze their transient behavior. 2. Apply and tune different types of controllers (P, PI, PID) to achieve desired control performance in laboratory-scale processes. 3. Operate and calibrate process control equipment such as level, flow, and temperature measurement systems using standard industrial techniques. 4. Design and simulate control strategies for integrated process units such as heat exchangers, evaporators, and complete process plants.

Paper: Petroleum Eng. Lab

Code: ChE192

Credits: 2

<table>
<tr><td>Laboratory 1</td><td>Course Code PG
ChE192</td><td>Petroleum Eng.
Lab</td><td>Credits: 2
L-T-P: 0-0-3</td></tr>
<tr><td colspan="4">Total contact hours = 60</td></tr>
<tr><td colspan="4">COURSE OBJECTIVE</td></tr>
<tr><td colspan="4">1. To develop an understanding of the physical and chemical properties of fuels, lubricants, and petroleum products through standard testing methods.
2. To familiarize students with experimental techniques for determining viscosity, flash point, fire point, and aniline point of petroleum samples.
3. To enable students to perform proximate and ultimate analyses of solid fuels and evaluate their suitability for industrial use.
4. To provide hands-on experience in determining calorific values, distillation characteristics, and carbon residue of fuels.
5. To introduce thermodynamic and equilibrium data generation techniques for process design and simulation in petroleum and chemical industries.</td></tr>
<tr><td>EXPERIMENT 1</td><td colspan="3">Viscosity measurement of crude oil and lubricating oils (using Saybolt / Redwood / Engler viscometer).</td></tr>
<tr><td>EXPERIMENT 2</td><td colspan="3">Flash point determination of petroleum products (Pensky–Martens)</td></tr>
<tr><td>EXPERIMENT 3</td><td colspan="3">Fire point determination of petroleum products (Abel apparatus)</td></tr>
<tr><td>EXPERIMENT 4</td><td colspan="3">Aniline point test for petroleum fractions (aromaticity indication).</td></tr>
<tr><td>EXPERIMENT 5</td><td colspan="3">Carbon residue determination (Conradson / Ramsbottom method).</td></tr>
<tr><td>EXPERIMENT 6</td><td colspan="3">Proximate analysis of coal.</td></tr>
<tr><td>EXPERIMENT 7</td><td colspan="3">Ultimate analysis of coal.</td></tr>
<tr><td>EXPERIMENT 8</td><td colspan="3">Atmospheric Distillation of a petroleum product.</td></tr>
<tr><td>EXPERIMENT 9</td><td colspan="3">Determination of calorific value of solid and liquid fuel by Bomb Calorimeter</td></tr>
<tr><td>EXPERIMENT 10</td><td colspan="3">Thermodynamic and fluid property calculations</td></tr>
<tr><td>EXPERIMENT 11</td><td colspan="3">Vapor Liquid and Liquid Liquid Equilibrium Data generation</td></tr>
<tr><td>COURSE OUTCOME</td><td colspan="3">1. Determine and interpret key physical properties of petroleum products such as viscosity, flash point, and fire point using standard test methods.</td></tr>
</table>

	2. Conduct chemical analyses of solid and liquid fuels to assess composition, quality, and performance characteristics. 3. Analyze calorific value, carbon residue, and distillation behavior to understand the combustion and refining properties of fuels. 4. Generate and utilize thermodynamic and phase equilibrium data (VLE/LLE) for process modeling and design in petroleum engineering applications.

Paper: Seminar I

Code: ChE181

Credits: 1

Laboratory 1	Course Code PG ChE181	Seminar I	Credits: 1 L-T-P: 0-0-1
COURSE OBJECTIVE			
1. To develop students' ability to research, analyze, and present technical topics effectively using credible scientific sources. 2. To enhance communication, critical thinking, and presentation skills through regular seminar and peer discussion sessions. 3. To encourage independent learning and confidence in delivering lectures on advanced or emerging areas of chemical/process engineering.			
• Students will give oral presentation on research topics. • Students need to give at least 1 presentation in the semester			
COURSE OUTCOME	1. Identify, review, and summarize relevant literature on selected research topics using scientific databases and journals. 2. Prepare and deliver structured technical presentations with clarity, logical flow, and audience engagement. 3. Demonstrate improved verbal communication, confidence, and depth of understanding through interactive discussions and Q&A sessions.		

SEMESTER – II

Paper: Advanced Reactor Design & Analysis

Code: ChE201

Total Hours: 60

Credits: 4

Course Objectives	
1. To understand the behavior of non-ideal reactors through RTD analysis and flow models To analyze catalytic reactions, reactor design, and catalyst effectiveness. To study the dynamics, stability, and optimization of chemical reactors. To understand gas–solid reactions, multiphase reactor modeling, and reactor scale-up principles.	
Course Content	
Module I: Residence Time Distribution (RTD) and Non-Ideal Reactors.	
Unit 1:	RTD of non-ideal reactors, interpretation of RTD data, flow models for non-ideal reactors – axial dispersion, N tanks in series, and multiparameter models. Compartment models – modeling complex flow structures (bypassing, dead zones), RTD in multiphase systems (gas–liquid and gas–solid reactors). Tracer techniques and experimental RTD determination (radioactive, conductivity, and dye tracers). Use of CFD for RTD analysis – numerical simulation of residence time distribution. **Hours Allotted: 5**
Unit 2:	Diagnosing the ills of reactors; influence of RTD and micro-mixing on conversion; application of RTD in reactor performance evaluation. Macro- and micromixing interplay in non-ideal flow reactors. Model discrimination and parameter estimation from RTD data. RTD under transient operating conditions (startup and shutdown effects). **Hours Allotted: 10**
Module II: Heterogeneous Catalysis and Reactor Design	
Unit 3:	Development of rate equations for solid catalyzed fluid phase reactions; estimation of kinetic parameters; external mass and heat transfer in catalyst particles. Internal diffusion and effectiveness factor modeling for complex geometries (e.g., pellets, monoliths). Intraparticle temperature gradients and internal heat transfer limitations. Modeling catalyst deactivation kinetics (coking, sintering, poisoning). Dynamic modeling of catalyst regeneration (e.g., FCC regeneration). Membrane reactors – coupling reaction. **Hours Allotted:10**

Unit 4:	Catalyst characterization – measurement of surface area and pore size; effectiveness factor, selectivity, and catalyst deactivation; design of packed bed, slurry, trickle bed, and fluidized bed reactors. Structured catalysts (monoliths, foams, microreactors) and design considerations. Microchannel and millireactors for process intensification. Photocatalytic and electrocatalytic reactor systems – emerging technologies. Slurry-phase hydrogenation and oxidation reactor modeling**.** **Hours Allotted: 5**
Module III: Reactor Dynamics and Stability	
Unit 5:	Optimum operation policy of batch reactors; optimal temperature progression; analysis of multibed adiabatic reactors and autothermal operation. Dynamic modeling of semibatch and fed-batch reactors. Control strategies for unstable reactors – feedback, feedforward, and cascade control. Non-isothermal reactor dynamics and bifurcation analysis. Parametric sensitivity and process safety using stability maps. **Hours Allotted: 5**
Unit 6:	Steady-state multiplicity in CSTR, stability and transient behavior of CSTR, hotspot formation, and runaway criteria. Reactor startup, shutdown, and transient response modeling Use of MATLAB/Simulink or Aspen Dynamics for reactor simulation. Integration of reaction and heat exchange networks (reactor heat exchangers). Data-driven modeling for dynamic systems (AI/ML-based reactor control). **Hours Allotted: 10**
Module IV: : Non-Catalytic and Multiphase Reactor Modeling	
Unit 7:	Non-catalytic gas–solid reactions; mass transfer with chemical reactions – principles and design. Shrinking core and grain models for solid–fluid reactions (diffusion vs. chemical control). Fluid–solid reaction kinetics under mixed control. Gas–liquid–solid reactors with mass transfer resistances (triple-phase reactors). Population balance modeling (PBM) for multiphase and polymerization reactors. **Hours Allotted: 5**
Unit 8:	Modeling of multiphase reactors, reactor optimization, dynamic behavior, and scale-up considerations. Reactor scale-up methodologies – geometric, kinematic, and dynamic similarity. Use of dimensionless groups (Re, Da, Pe, We, Bi, etc.) for scale-up analysis. CFD modeling of multiphase reactors (Euler–Euler and Euler–Lagrange frameworks). Bioreactor modeling – gas–liquid mass transfer, oxygen transfer rate (OTR). Process intensification and hybrid reactor systems (e.g., reactive distillation, reactive extraction). **Hours Allotted: 10**

Course Outcomes
By the end of this course, students will be able to: 1. Apply RTD models and flow patterns to analyze and design non-ideal reactors. 2. Develop and evaluate rate expressions for catalytic and non-catalytic systems. 3. Design heterogeneous reactors with considerations of heat and mass transfer limitations. 4. Analyze the stability and transient behavior of chemical reactors for safe operation. 5. Model and optimize multiphase reactors for scale-up and industrial application.

Suggested Textbooks:

1. Levenspiel, O. Chemical Reaction Engineering, 3rd Edition, Wiley, 1999.
2. Fogler, H. S. Elements of Chemical Reaction Engineering, 6th Edition, Prentice Hall, 2020.

Paper: Advanced Mass Transfer

Code: ChE202

Total Contact Hours: 60

Credits: 4

Course Objectives
1. Understand the theory and design of multicomponent distillation systems using graphical and analytical methods. 2. Analyze multicomponent absorption and extraction operations, including systems involving chemical reactions. 3. Explain the principles, modelling, and performance parameters of different membrane-based separation processes. 4. Evaluate and design various membrane module configurations for industrial applications. 5. Explore advanced separation technologies such as electric field enhanced processes, gas separation, and pervaporation.

Course Content	
Module I: Multicomponent Distillation and Design Methods	
Unit 1:	Multicomponent Distillation vapour-liquid equilibria, key components, Underwood’s methods for minimum reflux, product distribution at total reflux. **Hours Allotted: 5**

Unit 2:	Theoretical Plate calculation by Lewis-Matheson, Thiele-Gieddes and Relaxation method, sum rates method, Naphthali-Sandholm method. Multiple feeds and multiple product streams. **Hours Allotted: 10**
Module II: Multicomponent Absorption and Liquid–Liquid Extraction	
Unit 3:	Multicomponent gas absorption: Edmister's method for plate calculation Multicomponent adsorption equilibrium; Intrapellet mass transfer- Pore Diffusion surface diffusion; Governing equation of adsorption process in batch, fixed bed and fluidized bed. Absorption with chemical reaction. **Hours Allotted: 5**
Unit 4:	Multicomponent liquid-liquid extraction. Extraction with chemical reaction. stage wise calculations for multicomponent. **Hours Allotted: 5**
Unit 5:	Mass transfer with chemical reaction: Application towards Absorption, Distillation, Liquid –Liquid extraction, adsorption. **Hours Allotted: 5**
Module III: Membrane Separation Principles and Module Design	
Unit 6:	Basic overview membrane separation processes, terminologies: MWCO, concentration polarization, rejection coefficient, backwash, Basic principles of membrane processes with modeling of equations: reverse osmosis, nano-filtration, ultra- filtration, micro-filtration, Osmotic controlled filtration, gel layer-controlled filtration, dialysis. **Hours Allotted: 5**
Unit 7:	Detailed module design: dead end and crossflow mode, tubular, flat plate, spiral wound and hollow-fiber modules. Principle of membrane reactors with affinity binding. Hybrid processes and novel applications; Selected Environmental applications involving for water reuse and material recovery. **Hours Allotted: 10**
Module IV: Advanced and Electrically Enhanced Separation Techniques	
Unit 8:	Electric field enhanced separation processes: zeta potential, electric double layer. Basic modeling of electric field enhanced filtration. Liquid membrane and its concept. Basic modeling of gas separation and pervaporation processes, Industrial application of membrane principles. **Hours Allotted: 10**
Unit 9:	Surfactant based separation process, centrifugal separation process, electrophoretic separation methods, supercritical fluid extraction. **Hours Allotted: 5**

Course Outcome
By the end of this course, students will be able to: 1. Apply mathematical and graphical methods to design multicomponent distillation systems. 2. Perform design and analysis of absorption and extraction operations involving multiple components. 3. Model and evaluate different membrane separation processes and module configurations. 4. Demonstrate understanding of advanced separation mechanisms including electric field enhanced and hybrid membrane processes.

Suggested Textbooks:

1. Mass Transfer in Multicomponent Mixtures, J. A. Wesselingh, R. Krishna
2. Adsorption Calculations and Modelling, Chi Tien.
3. Richard W. Baker Membrane Technology and Applications 2012.

Paper: Advanced Chem. Eng. Thermodynamics

Code: ChE203

Total Contact Hours: 60

Credits: 4

Course Objectives	
1. To provide a molecular-level understanding of thermodynamic principles using statistical and classical approaches. 2. To apply thermodynamic laws to complex multicomponent systems in equilibrium, phase behavior, and reaction systems. 3. To analyze thermodynamic properties of mixtures, real fluids, and solutions using equations of state and activity models. 4. To understand the thermodynamic principles governing refrigeration, liquefaction, and cryogenic processes.	
Course Content	
Module I: Introduction & Statistical Thermodynamics	
Unit 1:	Concepts of microstates and macrostates and their significance in describing molecular systems; derivation and application of Boltzmann distribution law to predict molecular energy populations; formulation and interpretation of partition functions for translational, rotational, vibrational, and electronic modes; connection between molecular behavior and macroscopic thermodynamic properties; molecular interpretation of entropy based on probability and disorder in a system. **Hours Alloted: 5**

Unit 2:	Revisiting the First, Second, and Third Laws of Thermodynamics through the framework of statistical mechanics; microscopic interpretation of energy, work, and heat transfer; entropy as a measure of molecular disorder and probability; statistical justification of the Second Law through Boltzmann's equation; connection between absolute zero and molecular energy states in the Third Law. **Hours Alloted: 5**
Unit 3:	Concept and significance of fugacity and activity coefficients in real mixtures; methodsof determination from experimental data and equations of state; empirical and theoretical correlations for predicting non-ideal behavior; application to vapor–liquid and liquid–liquid equilibria; thermodynamic consistency tests to validate experimental and calculated equilibrium data; importance in phase equilibrium modeling and chemical process design. **Hours Alloted: 5**
Module II: Chemical Equilibrium & Equations of State	
Unit 4:	Criteria for chemical equilibrium based on Gibbs free energy minimization; definition and application of reaction coordinates for complex reacting systems; concept of extent of reaction and its role in quantifying reaction progress; equilibrium constant expressions derived from thermodynamic principles; interrelation between equilibrium composition, temperature, and pressure; and applications to multicomponent chemical reaction systems in processes. **Hours Alloted: 5**
Unit 5:	Thermodynamic relationships describing the variation of equilibrium constants with temperature; derivation and application of the Van't Hoff equation; interpretation of enthalpy and entropy changes from temperature dependence; connection between Gibbs free energy, equilibrium composition, and thermal effects. **Hours Alloted: 5**
Unit 6:	Equations of State and Compressibility Factor – cubic equations (van der Waals, Redlich-Kwong, Peng-Robinson), virial equation, residual properties **Hours Alloted: 5**
Module III: Solution Thermodynamics & VLE	
Unit 7:	Concept of partial molar properties and their significance in mixture behavior; derivation and application of the Gibbs–Duhem equation for thermodynamic consistency; interpretation of the Lewis–Randall rule for ideal solutions; graphical representation and determination of excess and residual properties; and their role in describing non-ideal mixing behavior in chemical and process systems. **Hours Alloted: 5**
Unit 8:	Definition and importance of excess Gibbs energy and activity coefficients in quantifying non-ideality; development and application of empirical and semi-theoretical models such as Margules, van Laar, Wilson, NRTL, and UNIQUAC equations; determination of binary and multicomponent interaction parameters. **Hours Alloted: 5**
Unit 9:	Fundamentals of phase rule and its application to binary and multicomponent systems; derivation and use of Raoult's law and modified Raoult's law for ideal and non-ideal mixtures; analysis of azeotropy and its industrial implications; introduction to fugacity concepts in mixtures. **Hours Alloted: 5**
Module IV: Refrigeration, Liquefaction, and Cryogenics	
Unit 10:	Thermodynamic principles underlying refrigeration and gas liquefaction processes; analysis of the Carnot refrigeration cycle and its limitations; understanding the Joule–Thomson effect and its application in cooling and gas expansion.

	Hours Alloted: 5
Unit 11:	Comparative study of vapor compression, absorption, and gas liquefaction cycles; energy and exergy analysis for performance evaluation; impact of working fluids and system parameters on coefficient of performance (COP); cycle modifications for improved efficiency; and thermodynamic optimization in large-scale refrigeration and cryogenic systems. **Hours Alloted: 5**
Unit 12:	Overview of cryogenic process design and operation; production, liquefaction, and storage of low-temperature fluids such as nitrogen, oxygen, and hydrogen; thermophysical considerations in cryogenic insulation and material selection. **Hours Alloted: 5**

Course Outcomes

By the end of this course, students will be able to understand:

1. Explain the molecular basis of thermodynamics using statistical concepts and interpret classical laws through statistical mechanics.
2. Determine fugacity, activity coefficients, and equilibrium conditions for multicomponent systems.
3. Apply equations of state and solution thermodynamics models to evaluate real gas and mixture properties.
4. Analyze vapor–liquid equilibrium and perform thermodynamic consistency and correlation of data.
5. Evaluate and design refrigeration, liquefaction, and cryogenic systems based on thermodynamic principles.

Suggested TextBooks:

1. Smith, J.M., Van Ness, H.C., and Abbott, M.M., Introduction to Chemical Engineering Thermodynamics, 8th Ed., McGraw Hill.

2. Sandler, S.I., Chemical, Biochemical, and Engineering Thermodynamics, 5th Ed., Wiley.

3. Cengel, Y.A. and Boles, M.A., Thermodynamics: An Engineering Approach, McGraw Hill.

Paper: Management Principles

Code: ChE204

Total Contact Hours: 60

Credits: 4

Course Objectives
To introduce students to classical and modern schools of management thought and their relevance to engineering organizations. To understand production, human resource, and conflict management principles through mathematical, analytical, and case-based approaches.

To apply modern quality management and technology management tools for enhancing productivity and innovation. To develop the ability to use statistical quality control and decision tools for continuous process improvement in engineering and manufacturing contexts.	
Course Content	
Module I: Fundamentals of Management and Organizational Structure	
Unit 1	**Evolution and Schools of Management Thought -** Classical School – scientific management (Taylor, Fayol), administrative and bureaucratic principles, Behavioral School – motivation, leadership, group dynamics, Hawthorne studies, Quantitative School – management science, operations research, decision theory, Contingency School – situational approaches, system thinking, socio-technical systems, Comparative analysis of schools and their modern-day application in process industries. **Hours allotted:5**
Unit 2	**Organization Structure and Design**–Concepts of organization – objectives, elements, and levels.Formalization, centralization, and decentralization; departmentalization by function, product, geography, and matrix form, Span of management and delegation of authority, Organizational effectiveness and efficiency; criteria and measurement, Organizational life cycle – birth, growth, maturity, and decline stages; implications for engineering firms, Case study: Evolution of organizational structures in chemical process industries. **Hours allotted: 5**
Unit 3	**Managerial Roles and Decision-Making**–Functions of management: planning, organizing, leading, and controlling. Managerial roles (Mintzberg classification), Decision-making process: problem identification, alternative generation, decision tree analysis, Quantitative decision-making tools: cost–benefit analysis, sensitivity analysis, simulation-based decision support. **Hours allotted: 5**
Module II: Production, Human Resource, and Conflict Management	
Unit 4	**Principles of Production and Operations Management**–Production system types: job, batch, mass, and continuous, Production planning and control (PPC): forecasting, scheduling, dispatching, expediting, and maintenance planning, Application of linear programming and network analysis (PERT/CPM) in production planning, Case study: Resource optimization in refinery scheduling. **Hours allotted: 6**
Unit 5	**Human Resource Management and Development**–Role and importance of HRM in industrial organizations, Human resource planning process: recruitment, selection, placement, and retention, Training and development: need assessment, methods (on-the-job, simulation, e-learning), evaluation techniques, Job evaluation and incentive schemes in engineering organizations, HR analytics introduction: workforce productivity measurement. **Hours allotted: 4**
Unit 6	**Conflict and Negotiation Management**–• Understanding conflict – nature, sources, and types, Conflict management techniques: avoidance, accommodation, compromise, collaboration, and competition, Negotiation process – preparation, bargaining, closure, and implementation, Creative conflict management: transforming conflict into innovation, Mini-case: Managing multidisciplinary team conflict in EPC (Engineering–Procurement–Construction) projects. **Hours allotted: 5**
Module III: Quality and Technology Management Tools	

Unit 7	**Tools and Techniques for Quality Management**– Evolution of quality – from inspection to assurance to total quality management (TQM), Contributions of quality gurus: Deming's 14 points, Juran's trilogy, Crosby's zero defects, Ishikawa's quality circles, TQM philosophy and continuous improvement principles, Kaizen, 5S, and benchmarking in process industries, Case study: Implementation of Kaizen in a petrochemical plant. **Hours allotted: 5**
Unit 8	**Quality Control and Improvement Techniques**–Type A and Type B problem-solving tools, Seven QC tools: check sheets, stratification, histograms, Pareto analysis, cause–effect diagrams, scatter plots, control charts, Advanced tools: affinity diagrams, tree diagrams, matrix data analysis, Application of brainstorming and SWOT analysis for quality enhancement, Mini-project: Quality improvement plan for an engineering service firm. **Hours allotted: 5**
Unit 9	**Technology Management and Stress Management**–Components of technology: hardware, software, humanware, and infoware; Technology acquisition, diffusion, and transfer models; Intellectual property rights and technology protection mechanisms; Managing human stress: physiological and psychological aspects; Stress diary technique, work-life balance, and burnout prevention, Case study: Managing technological change and employee stress during digital transformation. **Hours allotted: 5**
Module IV: Statistical Quality Control and Acceptance Sampling	
Unit 10	**Statistical Quality Control (SQC)**–Concept and importance of process capability, tolerance limits, and control limits; Control charts for variables: $\bar{X}$–R, $\bar{X}$–S charts; Control charts for attributes: p-chart, np-chart, c-chart, u-chart; Interpretation of control charts – assignable and chance causes; Real-world examples from chemical and pharmaceutical manufacturing. **Hours allotted: 5**
Unit 11	**Acceptance Sampling and Reliability**–Basic concept of acceptance sampling and its industrial applications; Probability models in sampling inspection – binomial, Poisson, and hypergeometric; Single and double sampling plans: OC curve and AOQL concepts; Chain sampling and multiple sampling plans; Overview of Dodge–Romig and MIL-STD sampling plans; Reliability metrics – MTBF, MTTR, system availability, and life testing. **Hours allotted: 5**
Unit 12	**Integrated Quality and Productivity Systems**– Linking SQC with Lean Six Sigma approaches; Statistical process control (SPC) in continuous manufacturing; Role of ERP and MIS in quality data analytics; Total productive maintenance (TPM) and 5S integration; Emerging trends: Industry 4.0, digital twins, and predictive quality management. **Hours allotted: 5**

Course outcome

By the end of this course, students will be able to:

1. Explain the evolution and relevance of classical, behavioral, quantitative, and contingency schools of management thought, and relate them to modern engineering and process organizations.
2. Analyze organizational structures, managerial roles, and decision-making processes to improve operational efficiency in engineering contexts.

3. Apply principles of production, human resource, and conflict management to solve practical problems in industrial operations using analytical and case-based approaches. 4. Utilize quality management philosophies, statistical quality control tools, and technology management strategies to enhance productivity, reliability, and innovation. 5. Integrate Lean, Six Sigma, and Industry 4.0 concepts for continuous improvement and sustainable performance in manufacturing and service systems.

Suggested Textbooks:

1. Principles of Management" by Harold Koontz,

2. Principles and Practice of Management" by L.M. Prasad, and "Principles of Management" by Neeru Vasishth Principles of Management by Sultan Chand & Sons

Paper: Polymer and Engineering Materials

Code: ChE205A

Total Contact Hours: 45

Credits: 3

Course Objectives	
1. Understand the mechanisms and reactor design principles involved in various polymerization processes. 2. Analyze rheological behavior and mechanical responses of polymeric materials under different conditions. 3. Study polymer morphology and its influence on material properties and processing behavior. 4. Learn the principles and applications of mixing, extrusion, moulding, and forming operations in polymer processing. 5. Explore the composition, properties, and performance of composite and engineering polymer materials.	
Course Content	
Module I: Polymerization Processes, Catalysts, and Reactor Engineering	
Unit 1:	Fundamental concepts of polymers, classification of polymers, polymerization methods, Polymer Molecular weight, molecular weight distribution, polydispersity index, Properties of polymers, Effect of temperature : Glass transition temperature, effect of chemical structure on Polymers. Measurement of molecular weight and its distribution. **Hours Allotted: 5**
Unit 2:	Polymerization Processes, Catalysts, and Reactor Engineering. **Hours Allotted: 5**
Module II: Polymer Rheology, Kinetics and Morphology	
Unit 3:	Step growth and chain growth Polymerization, Stereoregular polymerization and role of Zieglar-Natta catalyst, Bulk, solution, suspension and emulsion Polymerization. Kinetic of polymerization Definition of moments and Population balance model for Polymerization **Hours Allotted: 5**
Unit 4:	Polymer Rheology: Visco-elastic non-Newtonian flow phenomena and material functions, Power law, relaxation & hysteresis, Deformation and fracture behaviour of polymers, Polymer Morphology. **Hours Allotted:5**
Module III: Polymer Processing: Mixing, Extrusion, and Moulding Techniques	

Unit 5:	Rubbery State and compounding of natural and synthetic rubber, classification of polymer forming operations. **Hours Allotted: 5**
Unit 6:	Mixing: Characterization of mixed state, Dispersive and distributive mixing, Importance of processing, Extruders, Extrusion Dies, Film blowing, Multilayer Extrusion, Fibre spinning, Moulding and forming: Injection and Jet moulding, Thermoforming **Hours Allotted: 10**
Module IV: Composite and Engineering Polymer Materials	
Unit 7:	Composite Materials: Plastic Composites, Metal-matrix Composites, Ceramic-matrix Composites, Nano-composites, Engineering polymers, Polymer blends, Engineering Ceramics. **Hours Allotted: 5**
Unit 8:	Engineering alloys; Service Performance: Corrosion and Fatigue **Hours Allotted: 5**

Course Outcomes

By the end of this course, students will be able to:

1. Explain polymerization mechanisms, catalysts, and reactor configurations used in polymer production.
2. Evaluate viscoelastic and non-Newtonian flow behavior of polymers for processing applications.
3. Apply knowledge of processing operations to design and analyze polymer product manufacturing techniques.
4. Demonstrate understanding of advanced polymer composites, blends, and engineering materials for industrial use.

Suggested Books:

1. Fundamentals of Polymer Science and Engineering: Anil Kumar and S.K. Gupta
2. Polymer Processing: B.R. Gupta
3. Rheology of Polymers: B.R. Gupta
4. Principles of Material Science and Engineering: William F.Smith
5. Elements of Material Science and Engineering: Lawrence H.Van Black
6. Material Science and Metallurgy: S.V. Kodgiri and V.D.Kodgiri
7. Properties and Applications of Engineering Materials: NIIT Publication

Paper: Petrochemical Technology

Code: ChE205B

Total Contact Hours: 45

Credits: 3(L-T-P: 3-0-0)

Course Objectives

1. To provide comprehensive knowledge of petrochemical feedstocks and their conversion processes for producing basic building blocks of the chemical industry.

2. To enable students to understand the manufacturing processes of various important petrochemical intermediates and their industrial applications.
3. To familiarize students with the production technologies of synthetic polymers, fibers, and elastomers derived from petrochemical sources.
4. To develop awareness about process intensification, emerging technologies, safety practices, and sustainable approaches in the petrochemical industry.

Course Content

Module I: Petrochemical Feedstocks and Basic Building Blocks	
Unit 1	**Feedstock and Olefin Production -** Petrochemical feedstock: Types, sources, and characterization Process of naphtha cracking: Thermal and catalytic cracking Steam cracking technology and reactor design Production of olefins: Ethylene, propylene, butadiene Process variables affecting olefin yield and selectivity C4 fraction processing Cryogenic separation techniques Applications: Polymerization feedstock, chemical intermediates **Hours allotted:5**
Unit 2	**Aromatics and Synthesis Gas**–Separation of aromatics: Benzene, toluene, xylenes (BTX) Catalytic reforming for aromatics production Solvent extraction and crystallization processes Isomerization and transalkylation processes Uses of synthesis gas (syngas): Composition and production methods Steam reforming and partial oxidation Fischer-Tropsch synthesis Methanol synthesis from syngas Applications: Fuel production, chemical synthesis **Hours allotted: 5**
Module II: Petrochemical Intermediates and Derivatives	
Unit 3	**Acetate and Acid Derivatives - Part I**–Manufacture of acetic anhydride: Carbonylation of methyl acetate Process chemistry and catalysis Manufacture of adipic acid: Oxidation of cyclohexane/cyclohexanol Nitric acid oxidation process Process flow diagrams and reactor design Manufacture of aniline: Nitrobenzene hydrogenation Catalytic processes and reaction mechanisms Quality specifications and applications **Hours allotted: 6**
Unit 4	**Acetate and Acid Derivatives - Part II**–Manufacture of ethyl acetate: Esterification process Reactive distillation technology Manufacture of maleic anhydride: Oxidation of benzene or n-butane Fixed bed catalytic reactor design Manufacture of benzoic acid: Liquid phase oxidation of toluene Manufacture of Pure terephthalic acid (PTA): Oxidation of p-xylene Mid-Century (MC) and Amoco processes Manufacture of phthalic anhydride: Oxidation of naphthalene or o-xylene Manufacture of butyl acetate: Esterification processes Applications in polyester, plasticizer, and solvent industries **Hours allotted: 6**
Module III: Polymers, Fibers, and Elastomers	

Unit 5	**Synthetic Polymers and Fibers**– Manufacture of Urea-formaldehyde resin: Polymerization chemistry Reaction kinetics and process parameters Manufacture of ABS plastic (Acrylonitrile-Butadiene-Styrene): Emulsion and bulk polymerization Process technology and grade variations Manufacture of Acrylic fiber: Polyacrylonitrile production Wet spinning and dry spinning processes Manufacture of Carbon fiber: PAN-based and pitch-based processes Oxidation, carbonization, and graphitization Properties and applications in aerospace and automotive industries **Hours allotted: 6**
Unit 6	**Synthetic Elastomers**–Manufacture of Styrene-Butadiene Rubber (SBR): Emulsion and solution polymerization Hot and cold polymerization processes Reactor design and polymerization kinetics Manufacture of chloroprene (Neoprene): Free radical polymerization Properties and vulcanization Comparison with natural rubber Quality control and testing methods Applications: Tire manufacturing, adhesives, industrial products **Hours allotted: 5**
Module IV: Advanced Topics and Safety	
Unit 7	**Process Intensification and Emerging Technologies**–Process intensification in petrochemical industry: Concepts and principles Microreactor technology and compact heat exchangers Reactive separation processes Membrane-based separation technologies Emerging technologies: Bio-based petrochemicals Green chemistry approaches in petrochemicals Catalytic innovations and process optimization Digitalization and Industry 4.0 in petrochemical plants Circular economy and waste valorization **Hours allotted: 6**
Unit 8	**Safety and Transportation**–Transportation of hazardous materials: Classification and regulations Packaging, labeling, and documentation requirements Tank car and pipeline transportation Emergency response procedures Health and safety in petrochemical industries: Occupational hazards Personal protective equipment (PPE) Safety management systems Process safety management (PSM) Accident case studies: Bhopal, Flixborough, Texas City Risk assessment and mitigation strategies Environmental regulations and compliance **Hours allotted: 6**

Course Outcomes

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

1. Explain the processes for production of olefins, aromatics, and synthesis gas from petrochemical feedstocks
2. Analyze manufacturing processes for various petrochemical intermediates including acids, anhydrides, and esters
3. Evaluate production technologies for synthetic polymers, fibers, and elastomers
4. Apply process intensification techniques and assess emerging technologies in the petrochemical industry

5. Design safety protocols and risk management strategies for petrochemical operations

Text Books:

1. Speight, J. G. (2019). *Petrochemical Processes: Technology and Economics*. CRC Press.
2. Chauvel, A., & Lefebvre, G. (1989). *Petrochemical Processes: Technical and Economic Characteristics*. Editions Technip.
3. Weissermel, K., &Arpe, H. J. (2003). *Industrial Organic Chemistry*. Wiley-VCH.

Reference Books:

1. Meyers, R. A. (Ed.). (2005). *Handbook of Petrochemicals Production Processes*. McGraw-Hill.
2. Matar, S., & Hatch, L. F. (2001). *Chemistry of Petrochemical Processes*. Gulf Professional Publishing.
3. Albright, L. F. (2009). *Albright's Chemical Engineering Handbook*. CRC Press.
4. Rase, H. F. (2000). *Handbook of Commercial Catalysts*. CRC Press.

Paper: Sustainable Energy Engineering

Code: ChE205C

Total Contact Hours: 45

Credits: 3(**L-T-P**: 3-0-0)

Course Objectives	
1. To develop understanding of global energy challenges, climate change issues, and the need for sustainable energy transitions. 2. To provide comprehensive knowledge of catalytic processes for converting biomass and waste materials into clean transportation fuels and green energy. 3. To familiarize students with catalyst design, characterization techniques, and kinetics of heterogeneous and enzymatic catalytic reactions. 4. To enable students to understand the principles and applications of renewable energy technologies including solar, hydro, and emerging energy systems. 5. To develop skills in designing and evaluating photocatalytic, electrocatalytic, and other advanced processes for sustainable energy production.	
Course Content	
Module I: Energy Landscape and Green Chemistry	
Unit 1	**Global Energy Challenges and Green Energy Concepts -** Overview of energy use and related issues: Current global energy consumption patterns Major energy options: Fossil fuels, nuclear, and renewables Issues of supply and demand: Energy security and resource depletion Concept of Green Energy: Definition, principles, and scope Global climate change issues and responses: IPCC reports and international agreements Greenhouse gas emissions and potential effects: Carbon footprint analysis Concept of Energy Transition: Decarbonization pathways Energy sources for a more sustainable future: Technology roadmaps Sustainable development goals and energy access **Hours allotted:5**

Unit 2	**Catalysis for Green Energy** –Separation of aromatics: Homogeneous catalysis towards green energy: Organometallic catalysts Advantages and limitations of homogeneous systems Heterogeneous catalysis towards green energy: Solid catalysts and their advantages Comparison of homogeneous vs. heterogeneous catalysis Green chemistry principles in catalytic processes Catalyst selectivity and activity Life cycle assessment of catalytic processes Industrial examples: Hydrogenation, oxidation, and reforming reactions **Hours allotted: 4**
Module II: Alternative Fuels and Biomass Conversion	
Unit 3	**Alternative Cleaner Transportation Fuels**–Case study: Biodiesel production Transesterification process and catalysts Feedstock selection and quality parameters Case study: Green diesel (Hydrotreated Vegetable Oil - HVO) Hydro processing technology Comparison with biodiesel Case study: Upgraded bio-oil Pyrolysis oil upgrading techniques Hydrodeoxygenation processes Case study: Bioethanol production Fermentation technology First and second-generation processes Case study: Bio jet fuel Fischer-Tropsch synthesis Alcohol-to-jet (ATJ) and oil-to-jet pathways Fuel properties and engine compatibility Economic and environmental assessment **Hours allotted: 5**
Unit 4	**Industrial Catalytic Processes for Green Fuels - Part I**–Hydro-processing for green fuels: Hydrocracking and hydrotreating Catalyst design for bio-oil upgrading Conversion of biomass to fuel - Thermochemical processes: Pyrolysis: Fast pyrolysis, catalytic pyrolysis Reactor designs: Fluidized bed, rotating cone Product distribution and optimization Gasification: Air, oxygen, and steam gasification Syngas cleaning and conditioning Tar removal technologies Biomass to liquid (BTL) processes: Integrated gasification and Fischer-Tropsch Coal to liquid (CTL) processes: Direct and indirect liquefaction Process economics and scale-up challenges **Hours allotted: 5**
Unit 5	**Industrial Catalytic Processes for Green Fuels - Part II**– Conversion of CO2 to green fuel: CO2 hydrogenation to methanol Reverse water-gas shift reaction CO2 methanation (Sabatier process) Electrochemical CO2 reduction Conversion of lignocellulosic biomass to fermentable sugar: Pretreatment methods (physical, chemical, biological) Enzymatic hydrolysis Simultaneous saccharification and fermentation (SSF) Conversion to drop-in biofuels: Catalytic upgrading pathways Lignin conversion processes for biofuel: Depolymerization techniques Catalytic cracking and hydrogenolysis Fuel additives/drop-in fuels production Enhanced engine performance and emission improvements

	Octane and cetane enhancers Oxygenated fuel additives **Hours allotted: 5**
Module III: Catalyst Fundamentals	
Unit 6	**Process Intensification and Emerging Technologies** –Introduction to preparation of solid catalysts: Precipitation, impregnation, sol-gel methods Support materials and their properties Metal dispersion and loading optimization Characterizations of solid catalysts: BET surface area analysis X-ray diffraction (XRD) Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) Temperature programmed techniques (TPR, TPD, TPO) Spectroscopic methods (FTIR, Raman, XPS) Survey of catalytic conversion processes: Cracking, reforming, isomerization Conversion efficiency and rate considerations: Selectivity and yield optimization Space velocity and residence time effects **Hours allotted: 5**
Unit 7	**Reaction Kinetics and Biocatalysis**–Reaction kinetics in heterogeneous catalysis: Langmuir-Hinshelwood mechanism Eley-Rideal mechanism Mars-van Krevelen mechanism Basic mechanisms of surface kinetics: Adsorption, surface reaction, desorption Rate-determining steps Kinetics of catalyst decay: Fouling, poisoning, sintering Coking mechanisms Regeneration: Oxidative regeneration, steam treatment Catalyst reactivation strategies Introduction to biocatalysts: Enzymes as catalysts Enzyme structure and function Kinetics of enzyme-catalyzed reactions: Michaelis-Menten kinetics Enzyme inhibition and activation Immobilized enzymes for biofuel production **Hours allotted: 4**
Module IV: Renewable Energy Technologies	
Unit 8	**Basic Principles and Applications of Renewable Energy**– Hydropower: Types of hydroelectric plants (run-of-river, storage, pumped storage) Turbine types: Pelton, Francis, Kaplan Hydropower potential and environmental considerations Small-scale and micro-hydro systems Solar Energy: Solar radiation fundamentals and availability Solar thermal technologies: Flat plate collectors, concentrated solar power (CSP) Parabolic trough, power tower, dish-Stirling systems Photovoltaic (PV) technology: Silicon-based and thin-film solar cells Solar cell efficiency and performance parameters Solar energy storage systems Grid integration challenges Economic analysis and policy incentives **Hours allotted: 4**
Module V: Emerging Catalytic Technologies	

Unit 9	**Photocatalysis and Electrocatalysis**– Photocatalysts: Design principles and material selection Semiconductor photocatalysts (TiO_2, ZnO, CdS) Band gap engineering and visible light activation Applications in water splitting: Photocatalytic hydrogen production Z-scheme and S-scheme photocatalysis Solar photocatalysis: Pollutant degradation Self-cleaning surfaces CO_2 photo reduction: CO_2 to CO, methane, and methanol Reaction mechanisms and efficiency enhancement Electrocatalysis in fuel cells: Basic principles of fuel cells Types of fuel cells: PEM, SOFC, AFC, MCFC Catalyst materials: Platinum-based and non-precious metal catalysts Anodic reactions: Hydrogen oxidation, methanol oxidation Cathodic reactions: Oxygen reduction reaction (ORR) Methanol oxidation kinetics and catalyst development Durability and degradation mechanisms **Hours allotted: 4**
Unit 10	**Other Emerging Processes**– Other emerging processes for green energy production: Bioelectrochemical systems (microbial fuel cells) Photoelectrochemical water splitting Artificial photosynthesis Thermochemical water splitting Supercritical water gasification Plasma-assisted conversion processes Integrated multi-generation systems Energy storage technologies: Batteries, supercapacitors, hydrogen storage Future trends and research directions Techno-economic analysis of emerging technologies **Hours allotted: 4**

Course Outcomes

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

1. To define green energy and describe the need of mitigating Global climate change through sustainable energy
2. To understand the synthesis and characterization of catalysts and evaluate the kinetics of catalytic conversion processes
3. To explain the application of industrial catalytic processes for the production of green energy and appraise their performance
4. To understand the basic principles and applications of Geothermal Energy, Nuclear Energy, Hydropower, Ocean Energy, Solar Energy
5. To design, develop and assess photocatalysis, electrocatalysis and other emerging processes

Text Books:

1. Crocker, M. (Ed.). (2010). *Thermochemical Conversion of Biomass to Liquid Fuels and Chemicals*. Royal Society of Chemistry.

2. Demirbas, A. (2016). *Biodiesel: A Realistic Fuel Alternative for Diesel Engines*. Springer.

3. Chorkendorff, I., &Niemantsverdriet, J. W. (2017). *Concepts of Modern Catalysis and Kinetics*. Wiley-VCH.

Reference Books:

1. Luque, R., & Speight, J. G. (Eds.). (2015). *Gasification for Synthetic Fuel Production: Fundamentals, Processes and Applications*. Woodhead Publishing.

2. Armor, J. N. (2011). *Catalysis and the Hydrogen Economy*. Catalysis Letters.

3. Twidell, J., & Weir, T. (2015). *Renewable Energy Resources*. Routledge. 4.Serrano, D. P. (Ed.). (2010). *Synthesis Techniques for Zeolitic Materials*. RSC Publishing.

4. Sheldon, R. A., & Arends, I. (Eds.). (2007). *Green Chemistry and Catalysis*. Wiley-VCH.

Paper: Computer Aided Process Design

Code: ChE205D

Total Contact Hours: 45

Credits: 3

Course Objectives	
1. Introduce students to modern computational tools used in chemical process design and optimization. 2. Develop the ability to simulate, analyze, and design chemical processes using commercial software. 3. Teach systematic methods for process synthesis, flowsheet development, and economic evaluation. 4. Enable students to apply computational methods for process integration, energy optimization, and design of sustainable processes. 5. Bridge theory with practice through case studies and hands-on exercises using software such as Aspen Plus / HYSYS / DWSIM / MATLAB / Excel / Python	
Course Content	
Module I: Introduction to Computer-Aided Process Design for Chemical Engineers	
Unit 1:	Evolution of process design methodologies, Role of computers in chemical process design, Overview of commercial simulation packages (Aspen Plus, HYSYS, DWSIM, etc.), Structure of process simulators, Hierarchial approach to Conceptual Design **Hours Allotted: 5**
Unit 2:	Introduction to Integrated Process Design, Sustainable Process Design, Production-integrated Environmental Protection, Review of Engineering Economics, Measures of Process Profitability **Hours Allotted: 5**
Module II: Economic Decision Making and Process Synthesis	
Unit 3:	Economic Decision Making with case studies, Equipment Design Considerations and Rules of Thumb **Hours Allotted: 6**
Unit 4:	Process Synthesis and Basis of Process Design, Economic, Plant and Size Data, Safety considerations, Patents, Input/Output Analysis: Design Variables, Economic Potential, Basics of Reactor/Separation/Recycle Structure and Separation System Design, Concepts of Process Integration **Hours Allotted:9**
Module III: Development of Process Design and Process Optimization	
Unit 5:	Batch vs. Continuous, Recycle Structure of Flowsheets, Separation System Design cases, Heat Exchanger Networks, Concepts of Pinch-point Analysis **Hours Allotted: 5**

Unit 6:	Preliminary Process Optimization with case studies, Concepts of Process Retrofits, General Structure of Computer Aided Design Programs, Superstructure optimization **Hours Allotted: 5**
Module IV: Process Economic Evaluation and Case Studies	
Unit 7:	Process Design Case Study on any one of the following: Phenol Hydrogenation to Cyclohexanone, or Alkylation of Benzene by Propylene to Cumene, or Vinyl Chloride Monomer Process, Bioethanol Production **Hours Allotted: 5**
Unit 8:	Simulation-based case study using computational tools, Sensitivity analysis and risk assessment, Report preparation **Hours Allotted: 5**

Course Outcomes

By the end of this course, students will be able to:

1. Apply computer-aided tools for simulation of chemical processes.
2. Design and optimize process flowsheets systematically.
3. Analyze heat and mass integration for improving process efficiency.
4. Evaluate process economics and perform sensitivity and optimization studies.
5. Develop and present complete process design reports using simulation data

Suggested Textbooks:

1. J.M. Douglas**.,** Conceptual Design of Chemical Processes*,* McGraw Hill, 1988.
2. Dimian, A.C. and Bildea, C.S., Chemical Process Design: Computer-Aided Case Studies, Wiley , 2008

Paper: Instrumental Methods of Analysis Lab

Code: ChE291

Credits: 2

Laboratory 1	**Course Code PG ChE291**	**Instrumental Methods of Analysis Lab**	**Credits: 2 L-T-P: 0-0-2**
Total contact hours = 80			
COURSE OBJECTIVE			

	1. To understand the working principles and applications of analytical instruments such as UV–Visible spectrophotometer, colorimeter, pH meter, and turbidimeter. 2. To provide hands-on experience in measurement of key process variables like temperature, pressure, load, and concentration using transducers and sensors. 3. To enable students to determine and analyze physicochemical parameters of liquids and suspensions such as TDS and TSS. 4. To study the effect of various parameters on adsorption processes relevant to water and wastewater treatment. 5. To develop data analysis, calibration, and interpretation skills for quantitative estimation and process optimization.
EXPERIMENT 1	UV-Visible Spectroscopy – Determination of λ_{max} and concentration of a colored compound (Beer–Lambert's Law).
EXPERIMENT 2	Measurement Using load cell.
EXPERIMENT 3	Temperature Measurement using RTD
EXPERIMENT 4	Determination of unknown concentration of a colour solution by using colorimetry.
EXPERIMENT 5	Determination of unknown pressure by Dead weight Pressure Gauge.
EXPERIMENT 6	To settle down the Total suspended solid by using Centrifuge.
EXPERIMENT 7	To determine the Total dissolve solids by using Turbidimetry.
EXPERIMENT 8	To determine the pH of a solution by using pH meter.
EXPERIMENT 9	Effects of pH on adsorption capacity
EXPERIMENT 10	Effects of adsorbent loading on adsorption capacity
EXPERIMENT 11	Effects of adsorbate concentration on adsorption capacity
COURSE OUTCOME	1. Demonstrate understanding of principles and operation of analytical and process measuring instruments. 2. Perform experimental measurements for temperature, pressure, load, and solution concentration with accuracy and calibration. 3. Evaluate water quality parameters such as total dissolved solids and suspended solids using appropriate techniques. 4. Examine the influence of pH, adsorbent loading, and adsorbate concentration on adsorption performance for pollution control applications.

Paper: Advanced Numerical Lab

Code: ChE292

Credits: 2

Laboratory 1	Course Code PG ChE292	Advanced Numerical Lab	Credits: 2 L-T-P: 0-0-2
Total contact hours = 80			
COURSE OBJECTIVE			

1. To develop a strong understanding of fundamental numerical techniques used for solving linear and nonlinear algebraic equations, differential equations, and boundary value problems relevant to engineering.

2. To introduce numerical approaches for solving ordinary and partial differential equations governing heat transfer, fluid flow, and reaction kinetics.

3. To enable students to apply iterative and direct methods such as Gauss–Seidel, Successive Over-Relaxation (SOR), and matrix inversion for solving systems of linear equations.

4. To impart knowledge on interpolation, curve fitting, and numerical integration techniques for experimental data analysis and engineering modeling.

5. To build computational proficiency in implementing numerical algorithms using programming tools for solving practical chemical and thermal engineering problems.

EXPERIMENT 1	Matrix inversion and eigen value–eigenvector computation.
EXPERIMENT 2	Bisection method**,** Newton–Raphson method**,** and Secant method for solving equations.
EXPERIMENT 3	Solution of first-order ODEs using Euler's method and Modified Euler's method**.**
EXPERIMENT 4	Runge–Kutta methods (RK2, RK4) for ODEs.
EXPERIMENT 5	Finite difference method for solving 1D heat conduction equation**.**
EXPERIMENT 6	Gauss-Seidel and Successive Over-Relaxation (SOR) Methods
EXPERIMENT 7	Polynomial Interpolation and Curve Fitting
EXPERIMENT 8	Numerical Integration Techniques
EXPERIMENT 9	Shooting Method for Boundary Value Problems
EXPERIMENT 10	Crank–Nicolson Method for Transient Heat Conduction
EXPERIMENT 11	Matrix inversion and eigenvalue–eigenvector computation.
COURSE OUTCOME	1. Apply numerical techniques such as bisection, Newton–Raphson, and secant methods to find roots of algebraic and transcendental equations. 2. Solve ordinary differential equations (ODEs) using Euler's, Modified Euler's, and Runge–Kutta (RK2, RK4) methods for engineering system modeling. 3. Analyze and simulate heat transfer and diffusion problems using finite difference and Crank–Nicolson methods for steady and transient cases.

	4. Utilize matrix-based methods like matrix inversion, eigen value–eigen vector computation, and iterative solvers (Gauss–Seidel, SOR) for linear systems. 5. Perform polynomial interpolation, curve fitting, and numerical integration for engineering data interpretation, optimization, and process analysis.

Paper: Seminar II

Code: ChE281

Credits: 2

Laboratory 1	Course Code PG ChE281	Seminar II	Credits: 2 L-T-P: 0-0-2
COURSE OBJECTIVE			
4. To develop students' ability to research, analyze, and present technical topics effectively using credible scientific sources. 5. To enhance communication, critical thinking, and presentation skills through regular seminar and peer discussion sessions. 6. To encourage independent learning and confidence in delivering lectures on advanced or emerging areas of chemical/process engineering.			
• Students will give oral presentation on research topics. • Students need to give at least 2 presentation in the semester			
COURSE OUTCOME	4. Identify, review, and summarize relevant literature on selected research topics using scientific databases and journals. 5. Prepare and deliver structured technical presentations with clarity, logical flow, and audience engagement. 6. Demonstrate improved verbal communication, confidence, and depth of understanding through interactive discussions and Q&A sessions.		

SEMESTER – III

Paper: Advanced Statistical Analysis

Code: ChE301

Total Contact Hours: 60

Credits: 4

Course Objectives
1. To provide an in-depth understanding of statistical concepts, tools, and methods applicable to engineering research and data analysis.

To enable students to model, interpret, and make inferences from experimental and process data. To develop proficiency in using hypothesis testing, regression, and multivariate analysis for problem-solving in engineering systems. To familiarize students with techniques for data visualization and analysis. To cultivate the ability to design statistically sound experiments and analyze uncertainty in engineering and scientific studies	
Course Content	
Module I: Basics of Descriptive Statistics and Probability	
Unit 1:	History of Statistics, Subdivisions within Statistics, Grouping of Data, Frequency Distributions, Summary Statistics, Measures of Central Tendency and Dispersion in Frequency Distributions **Hours Allotted: 5**
Unit 2:	Basics of Probability, Probabilities under conditions of Statistical Independence and Statistical Dependence, Probability Distributions- Normal, Binomial, Poisson **Hours Allotted: 5**
Module II: Concepts of Inferential Statistics	
Unit 3:	Sampling, Estimation and Hypothesis Testing:-Random Sampling, Non-random Sampling, Basics of Design of Experiments, Interval Estimates, Confidence Intervals, Interval estimates using t-Distribution, Testing Hypothesis: One-Sample and Two-Sample Tests **Hours Allotted: 10**
Unit 4:	Chi-square Test, Analysis of Variance, Inferences about a Population Variance, Inferences about Two-Population Variances, Simple Regression and Correlation Analysis **Hours Allotted:5**
Module III: Concepts of Nonparametric Statistics and Introduction to Multivariate Statistics	
Unit 5:	Introduction to Nonparametric Statistics, Sign Test for Paired Data, Rank Sum Tests, Rank Correlation, Kolmogorov-Smirnov Test **Hours Allotted: 8**
Unit 6:	Introduction to Multivariate Analysis, Classification and Types of Multivariate Techniques, Concepts for Examining Data- Missing Data, Outliers, Normality, Homoscedasticity, Linearity **Hours Allotted: 7**
Module IV: Multivariate Data Analysis: Interdependence and Dependence Techniques	
Unit 7:	Interdependence Techniques: Exploratory Factor Analysis- General principles, Objectives, Design, Assumptions, Assessment of Overall Fit, Interpretation, and Validation, Additional use for Data Reduction; Cluster Analysis as a Multivariate Technique with simple example **Hours Allotted: 10**
Unit 8:	Dependence Techniques:Introduction to Multiple Regression Analysis, Multiple Regression in the era of Big Data, Objectives, Design, Assumptions, Assessment of Overall Fit, Interpretation, and Validation, Concepts of Logistic Regression **Hours Allotted: 10**

Course Outcomes
By the end of this course, students will be able to: 1. Apply advanced probability and statistical concepts to engineering and research data. 2. Perform hypothesis testing, regression modeling, and analysis of variance for data interpretation. 3. Design and analyze statistically sound experiments with appropriate sampling and error estimation. 4. Apply concepts of multivariate, and nonparametric data analyses 5. Interpret and communicate statistical findings for informed engineering and research decisions.

Suggested Textbooks:

1. Joseph F. Hair Jr, William C. Black, Barry J. Babin, Rolph E. Anderson, Multivariate Data Analysis, Eighth Edition, CENGAGE
2. Richard I Levin, David S. Rubin, Masood Husain Siddiqui, Sanjay Rastogi, Statistics for management, Eighth Edition, Pearson India

Paper: Advanced Transport Phenomena

Code: ChE302A

Total Contact Hours: 60

Credits: 4

Course Objectives	
Course Objectives • To provide an in-depth understanding of momentum, heat, and mass transport from first principles. • To develop mathematical models for transport phenomena in complex geometries and flow systems. • To correlate microscopic transport mechanisms with macroscopic behavior. • To apply transport equations to real engineering systems involving non-Newtonian fluids, turbulent flows, and multiphase systems.	
Course Content	
Module I: Momentum Transport (Fluid Mechanics)	
Unit 1:	Differential and integral forms of momentum balance; derivation and physical interpretation of continuity and Navier–Stokes equations for incompressible Newtonian fluids; stress tensor formulation; application of vector and tensor notation in fluid mechanics; governing equations in Cartesian and cylindrical coordinates. **Hours Allotted: 5**
Unit 2:	Solutions of Navier–Stokes equations for simple systems – steady laminar flow in pipes, between parallel plates, and around spheres. development of velocity profiles and shear stress distributions; pressure drop calculations; flow resistance and friction factor evaluation; analysis of creeping flow and boundary layer approximations in simplified geometries. **Hours Allotted: 5**
Unit 3:	Non-Newtonian fluid behavior; classification and characterization of time-independent and time-dependent fluids; rheological models such as Bingham plastic, power-law, and Herschel–Bulkley; experimental determination of flow curves; Rheological models; Boundary layer theory and dimensionless analysis, Reynolds number and scaling laws in

	fluid mechanics. **Hours Allotted: 5**
Module II: Energy Transport (Heat Transfer)	
Unit 4:	Fourier's law, heat conduction equation in Cartesian, cylindrical, and spherical coordinates; Boundary conditions**,** derivation of the general heat conduction equation in Cartesian, cylindrical, and spherical coordinates; formulation of boundary and initial conditions; physical meaning of thermal conductivity and temperature gradients; one-dimensional steady-state conduction with variable properties. **Hours Allotted: 5**
Unit 5:	Analytical and numerical solutions for steady/unsteady conduction; ; transient conduction in solids; use of Heisler and Gurney–Lurie charts; Extended surfaces (fins) – types, efficiency, effectiveness, and temperature distribution in fins; introduction to numerical techniques for conduction problems. **Hours Allotted: 5**
Unit 6:	Convective heat transfer – principles and mechanisms; dimensional analysis using Buckingham π theorem; derivation of similarity parameters (Re, Pr, Nu, Gr); empirical and theoretical correlations for laminar and turbulent flow over flat plates, inside tubes, and across cylinders; forced and free convection applications. **Hours Allotted: 5**
Module III: Mass Transport (Mass Transfer)	
Unit 7:	Fick's laws of diffusion; molecular diffusion in stationary and moving media; determination of diffusion coefficients; diffusion through membranes and thin films; steady and unsteady diffusion models; analogy with electrical resistance and flux-driven processes in binary and multicomponent systems. **Hours Allotted: 5**
Unit 8:	Convective mass transfer, mass transport mechanisms in boundary layers; analogies between momentum, heat, and mass transfer (Reynolds, Chilton–Colburn analogies); derivation and application of mass transfer coefficients; development of empirical correlations for different flow geometries and interfaces. **Hours Allotted: 5**
Unit 9:	Interphase mass transfer, film and penetration theories for gas–liquid and liquid–liquid systems; models of absorption, stripping, and evaporation; concept of equilibrium and driving force; estimation of overall mass transfer coefficients; relevance to industrial operations such as distillation and absorption towers. **Hours Allotted: 5**
Module IV: Coupled Transport and Applications	
Unit 10:	Simultaneous heat and mass transfer physical coupling mechanisms and industrial relevance; processes involving drying, condensation, and evaporation; formulation of governing equations; graphical representation of combined transfer coefficients; examples from chemical and environmental engineering.

	Hours Allotted: 5
Unit 11:	Transport in turbulent and multiphase flow systems; analysis of turbulence models and eddy diffusivity concepts; flow and transport in gas–solid, liquid–solid, and gas–liquid systems; Introduction to micro- and nano-scale transport phenomena including slip flow, rarefied gas effects, and size-dependent transport properties. **Hours Allotted: 5**
Unit 12:	Dimensionless analysis and scaling of transport equations; Introduction to computational approaches (CFD concepts) **Hours Allotted: 5**

Course Outcomes

By the end of this course, students will be able to:

1. Formulate and solve differential equations for momentum, heat, and mass transport.
2. Analyze transport phenomena in laminar and turbulent regimes.
3. Apply analogies between momentum, heat, and mass transfer to simplify complex problems.
4. Evaluate transport behaviour in non-Newtonian and multiphase systems.
5. Employ dimensionless parameters and scaling methods for transport modelling.
6. Apply transport principles to industrial and environmental engineering processes.

Paper: Safety in Process Industry

Code: ChE302B

Total Contact Hours: 60

Credits: 4(**L-T-P**: 3-1-0)

Course Objectives

1. To provide comprehensive understanding of engineering aspects of industrial safety and scientific principles governing safe operations in chemical process industries.
2. To enable students to design safe plant layouts and implement preventive measures for fire, explosion, and toxic hazards.
3. To familiarize students with systematic tools and methodologies for hazard identification, risk assessment, and quantitative risk analysis.
4. To develop competency in implementing engineering controls, safety systems, and disaster management protocols in chemical plants.

Course Content

Module I: Fundamentals of Industrial Safety

Unit 1	**Engineering and Scientific Principles of Safety-** Engineering aspects of industrial safety: Definition, scope, and importance Historical perspective of major industrial accidents Scientific principles of industrial safety: Thermodynamics and kinetics of hazardous reactions Material and energy balance considerations Safety in relation to economic aspects: Cost-benefit analysis of safety measures Loss prevention economics Safety in relation to operational aspects: Process optimization vs. safety trade-offs

	Human factors in process safety Safety regulations: OSHA (Occupational Safety and Health Administration) EPA (Environmental Protection Agency) regulations International safety standards (ISO, IEC) Industry-specific regulations (NFPA, API) Compliance and enforcement mechanisms **Hours allotted: 5**
Unit 2	**Fire and Explosion Hazards**–Hazards due to fire: Classification of fires (Class A, B, C, D, K) Fire chemistry and combustion fundamentals Flammability limits (LFL and UFL) Flash point, fire point, and auto-ignition temperature Fire triangle and fire tetrahedron: Elements required for combustion Oxygen, fuel, ignition source, and chemical chain reaction Fire prevention strategies based on fire triangle Explosion hazards: Deflagration vs. detonation Vapor cloud explosions (VCE) Boiling Liquid Expanding Vapor Explosion (BLEVE) Dust explosions and their prevention Pressure wave effects and blast damage Explosion severity parameters: Maximum explosion pressure (Pmax) Rate of pressure rise (dP/dt) Deflagration index (KSt) **Hours allotted: 5**
Unit 3	**Toxic Chemical Hazards and Runaway Reactions -** Hazards due to toxic chemicals: Routes of exposure (inhalation, dermal, ingestion) Acute vs. chronic toxicity Dose-response relationships Threshold Limit Values (TLV) and Permissible Exposure Limits (PEL) Immediately Dangerous to Life or Health (IDLH) concentrations Toxic gas dispersion modeling Emergency response planning for toxic releases Runaway reactions: Thermal runaway mechanisms Adiabatic temperature rise calculations Critical temperature and pressure Detection and prevention of runaway reactions Reactor relief system design Case studies: Seveso dioxin release, Bhopal gas tragedy Chemical reactivity hazards and compatibility **Hours Allotted: 5**
Module II: Plant Design and Hazard Identification	
Unit 4	**Industrial Plant Layout and Safety Design**–Industrial plant layout: Principles of safe plant layout Spacing requirements and segregation of hazardous areas Site selection criteria Process unit arrangement and equipment placement Storage tank farm layout Control room location and design Access routes and emergency exits Ventilation systems: Types of ventilation (natural, mechanical, local exhaust) Ventilation design calculations Air change rate requirements Hazardous area classification and ventilation Lighting requirements: Adequate illumination standards Emergency lighting systems Explosion-proof lighting in hazardous areas

	Importance of visibility for safety **Hours allotted: 5**
Unit 5	**Electrical Safety and Fire Prevention**–Electric system fire prevention: Electrical hazard classifications Area classification (Class, Division, Group) Intrinsically safe equipment design Grounding and bonding practices Static electricity generation and control Electrical equipment selection for hazardous areas Circuit protection devices Electrical safety audits Lightning protection systems Electrical failure modes and preventive maintenance Arc flash hazards and protection Lockout/Tagout (LOTO) procedures **Hours allotted: 5**
Unit 6	**Tools for Hazard Identification - Part I**– Introduction to hazard identification: Systematic approach to safety analysis Preliminary Hazard Analysis (PHA) What-If analysis technique Checklist method HAZOP (Hazard and Operability) study: HAZOP methodology and procedure Guide words and parameters Node selection and boundary definition Team composition and facilitation HAZOP documentation and follow-up Application examples: Continuous processes Batch processes Utility systems Case studies from chemical industries **Hours allotted: 5**
Unit 7	**Tools for Hazard Identification - Part II**– Fault Tree Analysis (FTA): Basic concepts and logic gates Construction of fault trees Qualitative and quantitative analysis Minimal cut sets Importance measures Event Tree Analysis (ETA): Event tree construction Success and failure paths Consequence assessment Integration of FTA and ETA Bow-tie analysis: Combining FTA and ETA Preventive and mitigative barriers Barrier management Failure Modes and Effects Analysis (FMEA): FMEA procedure and ranking Criticality analysis (FMECA) Layer of Protection Analysis (LOPA): Independent Protection Layers (IPLs) Risk reduction calculations **Hours allotted: 5**
Module III: Risk Assessment and Indexing Methods	
Unit 8	**Fire and Explosion Indices**–Dow Fire and Explosion Index (F&EI): Methodology and calculation procedure Material Factor (MF) determination General Process Hazards Special Process Hazards Fire and Explosion Index calculation

	Radius of exposure and exposure areas Loss estimation and business interruption Risk management strategies based on F&EI Mond Index (now ICI Mond Index): Mond Index methodology Comparison with Dow F&EI Toxicity and reactivity considerations Application in chemical plant design Limitations of indexing methods Other hazard indices: Chemical Exposure Index (CEI) Rapid Ranking Method **Hours allotted: 5**
Unit 9	**Risk Analysis Methodology**–Risk concept and measurement: Definition of risk (frequency × consequence) Individual risk vs. societal risk Risk matrices and risk ranking F-N curves (Frequency-Number curves) Risk perception and communication Risk acceptance criteria: ALARP (As Low As Reasonably Practicable) principle Tolerable and intolerable risk regions Risk acceptance criteria in different countries Regulatory risk criteria Cost-benefit analysis in risk reduction Quantitative Risk Analysis (QRA): Systematic QRA methodology Hazard identification and scenario selection Consequence modeling: Dispersion, fire, and explosion models Frequency analysis: Historical data and fault tree analysis Risk calculation and presentation Sensitivity and uncertainty analysis **Hours allotted: 5**
Module IV: Engineering Controls and Safety Management	
Unit 10	**Engineering Control of Chemical Plant Hazards**– Engineering control strategies: Hierarchy of controls (elimination, substitution, engineering, administrative, PPE) Intensification and attenuation of hazardous materials: Inherently safer design principles Minimization of inventory Substitution with less hazardous materials Moderation of operating conditions Simplification of design Process intensification for safety Engineering controls for specific hazards: Containment systems Pressure relief devices (safety valves, rupture disks) Flare and vent systems design Scrubbers and vapor recovery systems Dikes and secondary containment Blast-resistant structures Fire protection systems: Active fire protection (sprinklers, foam systems, deluge systems) Passive fire protection (fireproofing, fire barriers) **Hours allotted: 5**
Unit 11	**Fire Prevention and Personnel Protection**– Fire prevention strategies: Elimination of ignition sources Inerting and blanketing Hot work permits Housekeeping and maintenance practices Fire detection systems: Smoke, heat, and flame detectors Automatic fire alarm systems Fire suppression systems: Water-based systems (sprinklers, hydrants, monitors) Foam systems for hydrocarbon fires CO2 and Halon systems

	Dry chemical systems Personnel protection devices: Respiratory protection (air purifying vs. air supplying) Selection based on hazard assessment Protective clothing: Chemical protective suits, flame-resistant clothing Eye and face protection Hearing protection Fall protection equipment Emergency shower and eyewash stations Personal gas detectors **Hours allotted: 5**
Unit 12	**Safety Systems and Disaster Management**– Other Safety instrumented systems (SIS): Safety Integrity Level (SIL) concept SIL determination and verification Safety lifecycle (IEC 61511) Emergency shutdown systems (ESD) Interlocks and permissives Alarm management: Alarm rationalization and prioritization Abnormal situation management Safety management systems: Process Safety Management (PSM) elements Management of change (MOC) Pre-startup safety review (PSSR) Incident investigation and root cause analysis Safety performance indicators Disaster management: Emergency preparedness and response planning On-site and off-site emergency plans Mutual aid agreements Emergency drills and training Crisis communication Business continuity planning Post-incident recovery Case studies: Piper Alpha, Deepwater Horizon, Flixborough **Hours allotted: 5**

Course Outcomes

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

1. Explain the engineering and scientific principles of industrial safety and evaluate safety regulations and compliance requirements
2. Analyze fire, explosion, and toxic hazards in chemical processes and design preventive measures Apply systematic tools such as HAZOP, FTA, and ETA for hazard identification and risk assessment
3. Calculate and interpret Dow F&EI, Mond Index, and conduct quantitative risk analysis for chemical plants
4. Design engineering controls, safety systems, and disaster management protocols for safe chemical plant operations

Text Books:

1. Crowl, D. A., &Louvar, J. F. (2011). *Chemical Process Safety: Fundamentals with Applications*. Prentice Hall.

2. Lees, F. P., & Mannan, S. (2012). *Lees' Loss Prevention in the Process Industries* (4th ed.). Butterworth-Heinemann.

3. Sanders, R. E. (2015). *Chemical Process Safety: Learning from Case Histories*. Butterworth-Heinemann.

Reference Books:

1. CCPS (Center for Chemical Process Safety). (2008). *Guidelines for Hazard Evaluation Procedures*. Wiley-AIChE.

2. Kletz, T. A., &Amyotte, P. (2010). *Process Plants: A Handbook for Inherently Safer Design*. CRC Press.

3. Khan, F. I., & Abbasi, S. A. (1999). *Major Accidents in Process Industries and an Analysis of Causes and Consequences*. Journal of Loss Prevention.

4. Mannan, S. (Ed.). (2012). *Lees' Process Safety Essentials*. Butterworth-Heinemann.

5. NFPA Standards: *NFPA 30 (Flammable and Combustible Liquids Code)*, *NFPA 70 (National Electrical Code)*.

Paper: Project Engineering

Code: ChE302C

Total Contact Hours: 60

Credits: 4

Course Objectives	
1. To provide a systematic understanding of the various stages in process development and chemical plant design. 2. To introduce methods of plant costing, depreciation, and project evaluation for industrial decision-making. 3. To impart knowledge on optimum design principles for process equipment and systems. 4. To develop competence in project scheduling and management using network analysis tools (PERT/CPM).	
Course Content	
Module I: Basis of Chemical Plant Design	
Unit 1:	Systematic approach to process development from laboratory research to pilot and semi-commercial plant design; feasibility surveys for assessing technical and economic viability; methodology of scale-up and scale-down techniques; challenges in translating laboratory results to industrial operation; integration of process safety and sustainability considerations during design development. **Hours Alloted: 5**
Unit 2:	Factors influencing site selection – raw material availability, market proximity, transportation, utilities, environmental impact, and safety regulations; principles of plant layout design for efficient workflow, minimal material handling, and optimum land use; concepts of block layout, flow diagrams, and functional zoning of process units; case examples of modern chemical plant layouts. **Hours Alloted: 5**
Unit 3:	Classification of utilities – steam, water, air, power, refrigeration, and fuel systems; design considerations for sizing and integration of utilities; environmental and safety clearances for plant commissioning; overview of statutory and regulatory requirements in process industries related to emissions, noise, and waste management. **Hours Alloted: 5**
Module II: Costing, Depreciation and Financial Analysis	

Unit 4:	Fundamental concepts and importance of depreciation in chemical plant accounting; methods such as straight-line, declining balance, sinking fund, and MACRS; comparative analysis of methods with examples; impact on profitability, taxation, and asset valuation. **Hours Alloted: 5**
Unit 5:	Capital and operating cost components in process plants; techniques for preliminary and detailed cost estimation; equipment cost correlations and use of cost indices; effect of inflation and escalation on cost estimates; introduction to Lang factors and cost adjustment for capacity changes. **Hours Alloted: 5**
Unit 6:	Economic analysis of process investment decisions using present worth, discounted cash flow, rate of return, and payback period methods; concepts of perpetuity and capitalized cost; formulation of cash flow diagrams; decision-making under economic uncertainty; interpretation of results for project feasibility. **Hours Alloted: 5**
Unit 7:	Evaluation of risk and return in chemical project investments; understanding liabilities, assets, and equity; financial ratio analysis including liquidity ratios, defensive interval ratio, capital structure ratios, debt-equity ratio, and profitability indicators; introduction to Du-Pont chart for performance evaluation and financial health analysis. **Hours Alloted: 5**
Module III: Optimum Design and Design Strategy	
Unit 8:	Definition and significance of optimization in process design; formulation of objective functions and constraints; economic criteria for design selection; influence of process variables on cost and performance; graphical and analytical methods of optimization; trade-offs between cost, efficiency, and safety. **Hours Alloted: 5**
Unit 9:	Concept of break-even point and its importance in process economics; relationship between cost, revenue, and production volume; determination of optimum production rate for maximizing profitability; graphical representation and sensitivity analysis for different market conditions. **Hours Alloted: 5**
Unit 10:	Techniques for determining optimum economic pipe diameter, flow rate in condensers, and column design parameters; cost–energy balance considerations; empirical and analytical optimization of heat exchangers and separation units; linking process design with sustainability and energy efficiency objectives. **Hours Alloted: 5**
Module IV: Project Scheduling and Network Analysis	
Unit 11:	Introduction to scheduling techniques for project management; preparation of bar charts, Gantt charts, and milestone charts; visualization of sequential and parallel activities; planning timelines for procurement, construction, and commissioning; use of software tools in project scheduling. **Hours Alloted: 5**
Unit 12:	Principles of network-based planning; concepts of nodes, events, and activities; construction and numbering of networks; relationship between events and dependencies; fundamentals of PERT and CPM for project planning and monitoring; illustration through simple project examples. **Hours Alloted: 5**
Unit 13:	Application of statistical distributions in PERT; estimation of optimistic, most likely, and pessimistic times; calculation of earliest and latest event times; concept of slack and float; identification of critical path for project optimization; interpretation of scheduling outputs for decision-making.

	Hours Alloted: 5
Course Outcomes	
By the end of this course, students will be able to: 1. Explain the fundamental steps of process development and apply principles of plant location, layout, and utility design considering safety and environmental aspects. 2. Estimate capital and operating costs, apply various depreciation methods, and perform financial evaluations of chemical projects. 3. Analyze project profitability using economic indicators such as present worth, rate of return, and payback period. 4. Apply the principles of optimum design and economic criteria to determine optimum operating and equipment design conditions. 5. Develop and interpret project schedules using tools like Gantt charts, PERT, and CPM to identify critical paths and optimize project timelines.	

Textbooks and References

1. Peters, M. S. and Timmerhaus, K. D., Plant Design and Economics for Chemical Engineers, McGraw Hill.
2. Sinnott, R. K. and Towler, G., Chemical Engineering Design, Elsevier.
3. Vilbrandt, F. C. and Dryden, C. E., Chemical Engineering Plant Design, McGraw Hill.
4. Perry, R. H. and Green, D. W., Perry's Chemical Engineers' Handbook, McGraw Hill.
5. Humpreys, K. K., Project and Cost Engineers' Handbook, Marcel Dekker.

Paper: Thesis part I

Code: ChE381

Credits: 10

Project	**Course Code PG ChE381**	**Thesis part I**	**Credits: 10 L-T-P: 0-0-10**
COURSE OBJECTIVE			
1. To enable students to identify a relevant research problem through comprehensive literature review and formulate clear research objectives and methodology. 2. To develop skills in experimental design, data collection, modeling, and analysis for solving complex engineering problems. 3. To cultivate independent research ability, critical thinking, and scientific writing skills leading to the			

preparation of a research progress report and presentation.
1. Thesis Structure Template 1. Title Page 2. Acknowledgement 3. Abstract (250–300 words) 4. Table of Contents 5. List of Figures & Tables 6. Introduction 7. Literature Review 8. Proposed Methodology 9. Discussion 10. References 11. Appendices
2. Detailed Guidelines 1. Introduction: State research objectives, scope, and significance. 2. Literature Review: Summarize prior work, identify gaps, and justify project need. 3. Proposed Methodology: Describe proposed methods, tools, materials, datasets, and workflow. 4. Discussion: Planning of experimental setup, material selection, and process conditions and preliminary testing or model validation for feasibility analysis

COURSE OUTCOME	1. Identify and define a suitable research problem with clear objectives and scope based on critical literature survey. 2. Design and implement an appropriate research methodology involving analytical, experimental, or computational approaches. 3. Collect, analyze, and interpret preliminary data to assess the feasibility and potential outcomes of the proposed work. 4. Prepare and present a comprehensive research progress report demonstrating technical understanding, innovation, and academic writing skills.

Assessment Rubric (100 Marks)

Criteria	**Marks**	**Descriptors**
Title, Abstract & Presentation	10	Clarity of title, concise abstract, professional formatting and structure.
Introduction & Problem Definition	15	Clear background, motivation, objectives, problem statement.
Literature Review	15	Depth of analysis, relevance, synthesis of sources, identification of research gap.
Research gap identification	20	Proper literature review, recent technical exposure, clarity in gap finding
Proposed Methodology	20	Appropriateness, clarity, justification of proposed methods.

Discussion on Work plan	10	Critical evaluation, insightfulness, alignment with objectives, future plan of action.
Referencing & Academic Integrity	5	Correct citation style, use of credible sources..
Viva Voce / Defense	5	Understanding, clarity of explanation, response to questions.

Paper: Project Viva

Code: ChE382

Credits: 4

Project	Course Code PG ChE382	Project Viva	Credits: 4 L-T-P: 0-0-4

COURSE OBJECTIVE

1. To assess the student's understanding of the research problem, literature review, objectives, and methodology developed during Thesis Part–I.
2. To evaluate the student's analytical, presentation, and communication skills in explaining research progress and preliminary findings.
3. To encourage critical thinking, defense of ideas, and technical discussion on research outcomes and future work.

COURSE CONTENTS

1. Project Viva Voce

1. Panel Introduction and Verification of Student Details
2. Student presentation (8-10minutes) of literature review summary and identified research gaps.
3. Explanation of research objectives, hypothesis, and problem formulation.
4. Detailed Question-Answer Session
5. Assessment of Subject Knowledge and Project Understanding
6. Assessment of proposed methodology, design of experiments, or model development.
7. Assessment of Communication, Professionalism, and Ethics
8. Feedback-based refinement of research plan for Final Thesis Part.

2. Expectations from Students

1. Project Mastery: Students should be able to clearly explain every stage of their project including the rationale behind choices.

2. Fundamental Knowledge: Ability to link core academic concepts with project work. 3. Technical Competence: Understanding of tools, algorithms, processes, instruments, and data handling. 4. Critical Thinking: Ability to analyze, justify decisions, evaluate alternatives, and interpret results. 5. Professional Behaviour: Confidence, ethics, honesty, punctuality, and respectful conduct.		
COURSE OUTCOME	1. Present and defend the research problem, objectives, and methodology with clarity and confidence. 2. Demonstrate comprehensive understanding of literature, theoretical background, and experimental/modeling progress. 3. Respond effectively to technical queries, showing depth of knowledge and analytical reasoning. 4. Identify gaps, limitations, and the future direction of the ongoing research work.	

Detailed Rubric for Viva Assessment (100 Marks)

Criteria	Excellent (A)	Good (B)	Average (C)	Poor (D)
Understanding of Project Work (30 marks)	Demonstrates thorough understanding; able to explain objectives, research gaps and proposed methods clearly with deep insight.	Shows good understanding with minor gaps; explanation mostly clear.	Shows partial understanding; some confusion in explaining gaps/methoology.	Lacks understanding; unable to explain key aspects of the project.
Subject Knowledge & Fundamentals (25 marks)	Strong conceptual clarity; accurately relates fundamentals to project work.	Good conceptual understanding with occasional errors.	Basic understanding; difficulty connecting theory with project.	Weak fundamentals; major conceptual gaps.
Proposed methodology (20 marks)	Fully justifies proposed methods; demonstrates possibility of problem-solving.	Justifies most choices; good literature review and technical approach with moderate reasoning.	Limited justification; basic technical approach.	Unable to justify choices; poor technical understanding.
Communication & Presentation Skills (15 marks)	Clear, confident, well-structured; excellent visual/technical presentation.	Good clarity and structure; some hesitation.	Acceptable communication with noticeable gaps in structure.	Unclear, disorganized, lacks confidence.
Attitude, Engagement & Academic Integrity (10 marks)	Highly professional, honest, attentive, and respectful.	Generally professional, minor issues in engagement.	Inconsistent engagement; mild disciplinary concerns.	Unprofessional behavior or signs of academic dishonesty.

SEMESTER IV

Paper: Final Thesis

Code: ChE481

Credits: 14

Final Thesis	Course Code PG ChE481	Final Thesis	Credits: 14 L-T-P: 0-0-14
COURSE OBJECTIVE			
1. To provide an opportunity for students to carry out independent, original, and application-oriented research addressing a significant problem in chemical or process engineering. 2. To enable students to analyze, interpret, and validate experimental or simulation data, drawing meaningful conclusions and proposing innovative solutions. 3. To evaluate the ability to prepare a comprehensive dissertation report and present findings effectively before an expert committee. 4. To strengthen research communication, technical defense, and the ability to link results with real-world applications and future research potential.			
COURSE CONTENTS			
1. Thesis Structure Template 1. Title Page 2. Certificate 3. Declaration 4. Acknowledgement 5. Abstract (250–300 words) 6. Table of Contents 7. List of Figures & Tables 8. Introduction 9. Literature Review 10. Methodology 11. Results & Analysis 12. Discussion 13. Conclusion & Future Work 14. References 15. Appendices			
2. Detailed Guidelines 5. Introduction: State research problem, objectives, scope, and significance. 6. Literature Review: Summarize prior work, identify gaps, and justify project need. 7. Methodology: Describe methods, tools, materials, datasets, and workflow. 8. Results & Analysis: Present findings with tables, graphs, and interpretation. 9. Discussion: Explain implications, limitations, and comparison with literature.			

10. Conclusion: Summarize contributions and propose future directions.	
COURSE OUTCOME	1. Execute the proposed research plan, including experimental work, simulation, or analytical modeling, with appropriate documentation. 2. Analyze and interpret data critically to validate hypotheses and generate reliable conclusions supported by evidence. 3. Prepare a well-structured dissertation report following scientific writing standards, including discussion, results, and references. 4. Present and defend the complete research work confidently in a formal viva–voce examination. 5. Demonstrate innovation, depth of knowledge, and professional ethics in presenting and communicating research outcomes.

Assessment Rubric (100 Marks)

Criteria	**Marks**	**Descriptors**
Title, Abstract & Presentation	10	Clarity of title, concise abstract, professional formatting and structure.
Introduction & Problem Definition	15	Clear background, motivation, objectives, problem statement.
Literature Review	15	Depth of analysis, relevance, synthesis of sources, identification of research gap.
Methodology	20	Appropriateness, clarity, reproducibility, justification of methods.
Results & Analysis	20	Accuracy, clarity, depth of analysis, effective use of figures/tables.
Discussion & Conclusion	10	Critical evaluation, insightfulness, alignment with objectives, future scope.
Referencing & Academic Integrity	5	Correct citation style, use of credible sources.
Viva Voce / Defense	5	Understanding, clarity of explanation, response to questions.

Paper: Project Viva Voce

Code: ChE482

Credits: 8

Project Viva Voce	**Course Code PG ChE482**	**Project Viva**	**Credits: 8 L-T-P: 0-0-8**
COURSE OBJECTIVE			

1. To evaluate the student's overall understanding, technical competence, and depth of knowledge gained through the final thesis or project work.
2. To assess the student's ability to present, justify, and defend the research findings and conclusions before an expert evaluation panel.
3. To encourage critical discussion, professional communication, and reflection on research contributions, challenges faced and future scope.

COURSE CONTENTS

1. Project Viva Voce

9. Panel Introduction and Verification of Student Details
10. Student Presentation (8–12 minutes) covering objectives, methodology, results, and conclusions
11. Detailed Question-Answer Session
12. Assessment of Subject Knowledge and Project Understanding
13. Assessment of Technical Competence and Problem-Solving
14. Assessment of Communication, Professionalism, and Ethics
15. Final Scoring and Constructive Feedback

2. Expectations from Students

6. Project Mastery: Students should be able to clearly explain every stage of their project including the rationale behind choices.
7. Fundamental Knowledge: Ability to link core academic concepts with project work.
8. Technical Competence: Understanding of tools, algorithms, processes, instruments, and data handling.
9. Critical Thinking: Ability to analyze, justify decisions, evaluate alternatives, and interpret results.
10. Professional Behaviour: Confidence, ethics, honesty, punctuality, and respectful conduct.

COURSE OUTCOME	1. Present the complete research or project work in a clear, concise, and technically sound manner. 2. Defend the experimental methods, analytical models, or simulation techniques adopted in the project. 3. Demonstrate comprehensive understanding of literature, methodology, results, and their practical implications. 4. Exhibit professional communication, confidence, and clarity during the viva–voce examination.

Detailed Rubric for Viva Voce Assessment (100 Marks)

Criteria	Excellent (A)	Good (B)	Average (C)	Poor (D)
Understanding of Project Work (30 marks)	Demonstrates thorough understanding; able to explain	Shows good understanding with minor gaps;	Shows partial understanding; some confusion in explaining	Lacks understanding; unable to explain key aspects of the project.

	objectives, methods, and results clearly with deep insight.	explanation mostly clear.	methodology/results.	
Subject Knowledge & Fundamentals (25 marks)	Strong conceptual clarity; accurately relates fundamentals to project work.	Good conceptual understanding with occasional errors.	Basic understanding; difficulty connecting theory with project.	Weak fundamentals; major conceptual gaps.
Technical Skills & Application (20 marks)	Fully justifies tool/method choices; demonstrates excellent problem-solving.	Justifies most choices; good technical skills with moderate reasoning.	Limited justification; basic technical knowledge.	Unable to justify choices; poor technical understanding.
Communication & Presentation Skills (15 marks)	Clear, confident, well-structured; excellent visual/technical presentation.	Good clarity and structure; some hesitation.	Acceptable communication with noticeable gaps in structure.	Unclear, disorganized, lacks confidence.
Attitude, Engagement & Academic Integrity (10 marks)	Highly professional, honest, attentive, and respectful.	Generally professional, minor issues in engagement.	Inconsistent engagement; mild disciplinary concerns.	Unprofessional behavior or signs of academic dishonesty.

Paper: Comprehensive Viva Voce

Code: ChE483

Credits: 4

Comprehensive Viva Voce	**Course Code PG ChE483**	**Comprehensive Viva Voce**	**Credits: 4 L-T-P: 0-0-4**
COURSE OBJECTIVE			
1. To integrate and evaluate comprehensive knowledge gained from core chemical engineering subjects. 2. To assess analytical and problem-solving abilities through oral questioning and discussion. 3. To develop confidence, articulation, and clarity in presenting engineering concepts. 4. To encourage interdisciplinary thinking and application of theory to practical industrial situations.			
COURSE CONTENTS			
• Student will appear before external examiner and give a short viva on chemical engineering subjects and research outcomes.			
COURSE	1. Demonstrate conceptual understanding of key chemical engineering principles across		

OUTCOME	core subjects. 2. Apply interdisciplinary knowledge to analyze and solve real-world engineering problems. 3. Communicate technical ideas effectively and respond confidently in oral examinations. 4. Exhibit preparedness for professional interviews, research discussions, and higher studies. 5. Connect theoretical learning with practical and industrial perspectives in chemical process design and operation.

Comprehensive Viva Voce Rubric (100 Marks)

Criteria	Marks	Descriptors
Understanding of the course along with project work	30	Depth of understanding, technical knowledge, clarity of objectives, ability to explain methodology and results.
Subject Knowledge & Fundamentals	25	Accuracy of answers, conceptual clarity, ability to relate fundamentals to project.
Technical Skills & Application	20	Ability to justify tools/methods, problem-solving skills, analytical ability.
Communication & Presentation Skills	15	Clarity, confidence, structure, professional delivery.
Attitude, Engagement & Academic Integrity	10	Honesty, responsiveness, preparedness, respect during interaction.