First Year Curriculum

Admission Year 2026-27

Master of Technology

Chemical Engineering

Faculty of Engineering & Technology

Parul University

Vadodara, Gujarat, India

Semester 1

a. **Course Name:** Process Modeling & Simulation
b. **Course Code:** 03022001PC01
c. **Prerequisite:** Fundamentals of Chemical Engineering, Mathematics
d. **Rationale:** To equip students with the knowledge and skills to develop, model, and simulate chemical processes using advanced computational tools and techniques. The course aims to provide students with a strong understanding of the underlying principles of process dynamics, steady-state, and dynamic modeling, as well as the ability to apply simulation software to optimize and analyze industrial processes for design, operation, and control.
e. **Course Learning Objective:**

CLOBJ 1	To enable the students to develop models for different chemical processes and systems
CLOBJ 2	To enable the students to differentiate between the structure of modular and equation-oriented mode simulators
CLOBJ 3	To enhance the students to apply various simulation approaches in terms of partitioning and tearing of flow diagrams
CLOBJ 4	To enhance the students to apply various computational tools and simulators for the simulation of chemical processes

f. **Course Learning Outcomes:**

CLO 1	Develop models for different chemical processes and systems
CLO 2	Differentiate between the structure of modular and equation-oriented mode simulators
CLO 3	Apply various simulation approaches in terms of partitioning and tearing of flow diagrams
CLO 4	Apply various computational tools and simulators for the simulation of chemical processes

g. **Teaching & Examination Scheme:**

Teaching Scheme				**Evaluation Scheme**					
				Internal Evaluation			**ESE**		**Total Marks**
L	**P**	**T**	**Credit**	**T**	**P**	**CE**	**T**	**P**	
3	2	-	4	20	20	20	60	30	150

h. **Course Content**

Sr.	**Topics**	**W**	**T**
1	**Introduction and Concepts of Process Modeling**: General aspects of Process Modeling and Simulation, Objectives of Model Development, Principles of Model Formulation, Steps in Model Development,	22	10

	Classification of Models, Introduction to Fundamental Laws, Introduction to Regression Analysis, Basics of various Numerical Methods		
2	**Modeling of Chemical Engineering Systems:** Basics of Mass Balances-Continuity Equations; Energy balances for Non-Reactive & Reactive Systems, Modeling of Various Unit Operations like Mixing, Evaporation, Liquid-Liquid Extraction, Distillation, Reactors, etc., Degree of Freedom Analysis of Various Unit Operations	28	13
3	**Modular and Equation Solving Approaches**: Simulation of the models, Sequential modular approach, Equation oriented approach, Partitioning and Tearing	25	11
4	**Simulation**: Introduction and use of computational tools and process simulation software in process engineering.	25	11
	Total	100	45

i. **Refernece Books**

1. Process Modeling, Simulation, and Control for Chemical Engineers, William L. Luyben | McGraw Hill International Editions, McGraw Hill Publication
2. Process Plant Simulation, B.V. Babu | Oxford University Press
3. Applied Mathematics in Chemical Engineering, Mickley, Sherwood & Reed | McGraw-Hill Inc.
4. Mathematical Methods in Chemical Engineering, Jenson & Jeffereys | Academic Press
5. Computational Methods for Process Simulation Ramirez W.F.| Butterworth- Heinemann

a. **Course Name:** Process Modeling & Simulation
b. **Course Code:** 03022001PC02
c. **Prerequisite:** Fundamentals of Chemical Engineering, Mathematics
d. **Rationale:** To equip students with the knowledge and skills to develop, model, and simulate chemical processes using advanced computational tools and techniques. The course aims to provide students with a strong understanding of the underlying principles of process dynamics, steady-state, and dynamic modeling, as well as the ability to apply simulation software to optimize and analyze industrial processes for design, operation, and control.
e. **Course Learning Objective:**

CLOBJ 1	Develop models for different chemical processes and systems
CLOBJ 2	Differentiate between the structure of modular and equation-oriented mode simulators
CLOBJ 3	Apply various simulation approaches in terms of partitioning and tearing of flow diagrams
CLOBJ 4	Apply various computational tools and simulators for the simulation of chemical processes

f. Course Learning Outcomes:

CLO 1	Develop models for different chemical processes and systems
CLO 2	Differentiate between the structure of modular and equation-oriented mode simulators
CLO 3	Apply various simulation approaches in terms of partitioning and tearing of flow diagrams
CLO 4	Apply various computational tools and simulators for the simulation of chemical processes

g. Teaching & Examination Scheme:

Teaching Scheme				**Evaluation Scheme**					
				Internal Evaluation			**ESE**		**Total Marks**
L	**P**	**T**	**Credit**	**T**	**P**	**CE**	**T**	**P**	
-	2	-	1	-	20	-	-	30	50

h. Course Content

Sr. NO.	Experiment List
1.	To provide an introduction to Matrix Operations, Goal Seek & Excel Solver in Microsoft Excel
2.	To apply Matrix Operations in Microsoft Excel for solving Chemical Engineering Problems
3.	To apply Goal, seek in Microsoft Excel for solving Chemical Engineering Problems
4.	To apply Excel Solver Optimization Tool in Microsoft Excel for solving Chemical Engineering Problems
5.	To provide an introduction to Charts, Linest & Data Regression in Microsoft Excel for Chemical Engineers
6.	To apply Data Regression in Microsoft Excel to solve chemical engineering problems
7.	To apply SCILAB/MATLAB to solve mass transfer and heat transfer problems
8.	To apply SCILAB/MATLAB to solve chemical reaction kinetics-based problems
9.	To provide an introduction to DWSIM Process Simulator
10.	To apply DWSIM simulation software to solve material and energy streams, basic unit operations like mixers, pumps, heaters, heat exchangers, reactors, coolers, compressors, etc.

a. **Course Name:** Advanced Separation Process
b. **Course Code:** 03022001PC03
c. **Prerequisite:** Fundamentals of separation Processes, Mass Transfer Operations
d. **Rationale:** To learn the principle and technical concept of advanced separation processes
e. **Course Learning Objective:**

CLOBJ 1	Explain separation principles, thermodynamics, and mass transport mechanisms.
CLOBJ 2	Analyze design factors and economics of membrane and sorption techniques.
CLOBJ 3	Apply cascade theory for binary and multi-component separations.
CLOBJ 4	Evaluate efficiency of thermal, ionic, and foam separation processes.

f. **Course Learning Outcomes:**

CLO 1	Explain separation principles, thermodynamics, and mass transport mechanisms.
CLO 2	Analyze design factors and economics of membrane and sorption techniques.
CLO 3	Apply cascade theory for binary and multi-component separations.
CLO 4	Evaluate efficiency of thermal, ionic, and foam separation processes.

g. **Teaching & Examination Scheme:**

Teaching Scheme				**Evaluation Scheme**					
				Internal Evaluation			**ESE**		**Total Marks**
L	**P**	**T**	**Credit**	**T**	**P**	**CE**	**T**	**P**	
3	-	-	3	20	-	20	60	-	100

h. **Course Content**

Sr.	**Topics**	**W**	**T**
1	**General Review:** Mechanisms: Separation factors and its dependence on process variables, classification and characterization, thermodynamic analysis and energy utilization, kinetics and mass transport. Theory of cascades and its application in single and multistage operation for binary and multi component separations.	20	9
2	**Membrane Separations:** Types and choice of membranes, their merits, commercial, pilot plant polarization of membrane processes and laboratory membrane permeators, dialysis, reverse osmosis, ultra filtration, Concentration and economics of membrane operations, Design controlling factors.	25	11

3	**Separation by Sorption Techniques:** Types and choice of adsorbents, chromatographic techniques, Types, Retention theory mechanism, Design controlling factors ion exchange chromatography equipment and commercial processes, recent advances and economics.	20	9
4	**Ionic Separations:** Controlling factors, applications, Theory mechanism and equipment for electrophoresis, dielectrophoresis and electro dialysis, commercial applications - Design considerations.	15	7
5	**Thermal & Other Techniques:** Thermal diffusion, zone melting, crystallization, molecular compounds, foam separation, applications, and economics.	20	9
Total		100	45

i. **Refernece Books**

1. New Chemical Engineering Separation Techniques
   H.M. Schoen| Wiley Interscience, New York, 1972.
2. Separation Processes
   C.J. King|Tata McGraw Hill, New Delhi, 1982
3. Industrial Processing with Membranes
   R.E. Lacey and S. Loeb| Wiley–Inter sciences, New York, 1972.
4. Separation process Principles
   J.D. Seader, Ernest J.Henley and D. Keith Roper, 3rd edition, John Wiley & Sons Australia, Limited, 2010.

a. **Course Name:** Advanced Transport Phenomena
b. **Course Code:** 03022001PC05
c. **Prerequisite:** Fundamentals of Chemical Engineering, Mathematics
d. **Rationale** To equip students with the knowledge and skills to develop, model, and simulate chemical processes using advanced computational tools and techniques. The course aims to provide students with a strong understanding of the underlying principles of process dynamics, steady-state, and dynamic modeling, as well as the ability to apply simulation software to optimize and analyze industrial processes for design, operation, and control.
e. **Course Learning Objective:**

CLOBJ 1	Understand the chemical and physical transport processes and their mechanism
CLOBJ 2	Perform heat, mass and momentum transfer analysis
CLOBJ 3	Analyze industrial problems along with appropriate approximations and boundary conditions
CLOBJ 4	Develop steady and time dependent solutions along with their limitations
CLOBJ 5	Analyze various transport processes with understanding of solution approximation methods and their limitations.
CLOBJ 6	Solve mass balance for steady and unsteady-state problems.

f. Course Learning Outcomes:

CLO 1	Understand the chemical and physical transport processes and their mechanism
CLO 2	Perform heat, mass and momentum transfer analysis
CLO 3	Analyze industrial problems along with appropriate approximations and boundary conditions
CLO 4	Develop steady and time dependent solutions along with their limitations
CLO 5	Analyze various transport processes with understanding of solution approximation methods and their limitations.
CLO 6	Solve mass balance for steady and unsteady-state problems.

g. Teaching & Examination Scheme:

Teaching Scheme				**Evaluation Scheme**					
				Internal Evaluation			**ESE**		**Total Marks**
L	**P**	**T**	**Credit**	**T**	**P**	**CE**	**T**	**P**	
3	-	-	3	20	-	20	60	-	100

h. Course Content

Sr.	**Topics**	**W**	**T**
1	**Fundamentals of Transport Phenomena:** Philosophy and fundamentals of three transport phenomena: Importance of transport phenomena; analogous nature of transfer process; basic concepts, conservation laws. Molecular transport of momentum, Heat and mass, laws of molecular transport, Newton's law of viscosity, Fourier's law of heat conduction, and Fick's law of diffusion. Transport coefficients – viscosity, thermal conductivity and mass diffusivity. Estimation of transport coefficients and temperature/pressure dependence.	20	9
2	**One-Dimensional Laminar Flow:** one-dimensional transport in laminar flow (shell balance) : Newtonian and non-Newtonian fluids, General method of shell balance approach to transfer problems; Choosing the shape of the shell; most common boundary conditions; momentum flux and velocity distribution for the flow of Newtonian fluids in pipes, for the flow of Newtonian fluids in planes, slits and annulus, Time derivatives, The equation of continuity, the equation of motion, the equations of change in curvilinear, co-ordinates, use of the equations of change to set up steady flow problems.	22	10
3	**Unsteady and Turbulent Flow:** Unsteady state momentum transport, Flow near a wall suddenly set in motion, Momentum transport phenomena in turbulent flow. Definitions of friction factors, friction factor for flow in tubes, for flow around spheres, for packed bed column	20	9
4	**Heat Conduction and Energy Balance:** shell energy balance, boundary conditions, Heat conduction with an electrical heat source, Heat conduction	20	9

	in cooling fins, heat conduction with exothermic reactions. Temperature distributions with more than one independent variable: Unsteady state heat conduction in solids, Boundary layer theory.		
5	**Mass Diffusion and Balance:** Definitions of concentrations, velocities & mass fluxes, Fick's law of diffusion, Temperature & pressure dependence of mass diffusivity, and Maxwell's law of diffusion. Shell mass balance, boundary conditions, diffusion through a stagnant gas film. Diffusion with heterogeneous chemical reaction, Diffusion with homogeneous chemical reaction, Diffusion into a falling liquid film.	18	8
Total		100	45

i. Refernece Books

1. Transport Phenomena,
   R.B. Bird, W.E. Stewart and E.W. Lighfoot|2nd Edition. John, Wiley, 2002
2. Fundamentals of Momentum Heat and Mass Transfer
   J.R. Wilty, R.W. Wilson, and C.W. Wicks, 4th Edition, John Wiley, New York, 2001
3. Transport Processes and Separation Process Principles
   Christie J. Geankopolis, 4th Edition. Printice-Hall, 2003
4. Transport Phenomena – A Unified Approach
   R.S. Brodkey, and H.C. Hershey, McGraw Hill, 1988

a. **Course Name: -** Industrial Pollution Control

b. **Course Code:** 03022001PE01

c. **Prerequisite:** Fundamentals of Chemical and Environmental Engineering principles

d. **Rationale** To equip students with the knowledge and skills to design, evaluate, and optimize pollution control technologies for minimizing environmental impact in industrial processes

e. **Course Learning Objective:**

CLOBJ 1	Identify the sources, causes, and effects of environmental pollution
CLOBJ 2	Examine the mechanism of pollution in different mediums-air, water, soil
CLOBJ 3	Comprehend various methods for pollution abatement and waste minimization
CLOBJ 4	Devise treatment methods for gas, liquid, and solid wastes

f. **Course Learning Outcomes:**

CLO 1	Identify the sources, causes, and effects of environmental pollution

CLO 2	Examine the mechanism of pollution in different mediums-air, water, soil
CLO 3	Comprehend various methods for pollution abatement and waste minimization
CLO 4	Devise treatment methods for gas, liquid, and solid wastes

g. Teaching & Examination Scheme:

Teaching Scheme				Evaluation Scheme					
				Internal Evaluation			ESE		Total Marks
L	P	T	Credit	T	P	CE	T	P	
3	-	-	3	20	-	20	60	-	100

h. Course Content

Sr.	Topics	W	T
1	**Industries, Pollution & Environment:** Industrial scenario in Indian and Global context, Industrial activities and Environment, Sources, Characteristics and Pollutant Types in different mediums - air, water, soil; environmental concerns and challenges; sustainability principles, Environmental Regulations	10	5
2	**Air Pollution Control:** Introduction, Definition, Sources, Characteristics and Perspective of Air Pollutants, Effects of Air Pollution on Biodiversity, Air Quality and Emission Standards, Air Pollution from Major Industrial Operations, Engineering Systems of Control of Air Pollution by Equipment and by Process Changes	25	11
3	**Water Pollution Control:** Introduction, Definition, Sources, Characteristics, and Perspective of Water and Wastewater Pollutants, Effects of Water Pollution on Biodiversity, Water Quality and Emission Standards, Physical, Chemical, and Biological Parameters, Water Pollution from Major Industrial Operations, Engineering Systems of Control of Water and Wastewater Pollution by Primary, Secondary and Advance Treatment	25	11
4	**Solid Waste Management:** Introduction, Definition, Sources, Characteristics, and Perspective of Solid Waste, Generation, Separation, Handling, Storage, and Transportation of Solid Waste, Waste Minimization of Solid Waste, Physical, Chemical, and Biological Treatment of Solid Waste, Reuse and Recycling of Solid Waste	20	9
5	**Hazardous Waste Management:** Introduction, Definition, Sources, Characteristics and Perspective of Hazardous Waste, Handling, Storage, Transportation of Hazardous Waste, Physical, Chemical and Biological Treatment of Hazardous Wastes	20	9
	Total	100	45

i. Refernece Books

1. Environmental Pollution Control Engineering
   Rao C.S. | New Age International (P) Ltd. Publishers

2. Pollution Control in Process Industries
   Mahajan S. P. | TataMc GrawHill
3. Liquid waste of industry- theories, Practices, and Treatment
   Nemerow N.L. | Addison Wesley, New York
4. Physico-Chemical Processes for water quality control
   Weber W.J.| Wiley Interscience New York
5. Industrial Gas Cleaning
   Strauss W. | Pergamon, London
6. Air pollution
   Stern A.C.|Academic Press Inc.
7. Wastewater Engineering-Treatment and Reuse
   Metcalf and Eddy|Tata McGraw Hill Publishing Company Ltd

a. **Course Name: -** Process Safety & Hazard Management
b. **Course Code:** 03022001PE09
c. **Prerequisite:** Basic knowledge of Chemical Engineering Principles, Thermodynamics and Fluid Mechanics and Awareness of Industrial Processes and Safety Concepts
d. **Rationale** To equip students with the knowledge and skills to identify, assess, and mitigate process safety hazards in industrial operations.
e. **Course Learning Objective:**

CLOBJ 1	Explain fundamental process safety concepts, and hazard identification techniques.
CLOBJ 2	Analyze industrial accidents and identify key lessons for improving process safety.
CLOBJ 3	Apply risk assessment tools such as HAZOP, FMEA, and LOPA to real-world scenarios.
CLOBJ 4	Evaluate fire, explosion, and toxic hazards, proposing appropriate prevention and mitigation strategies.
CLOBJ 5	Design safety measures, pressure relief systems, and emergency response plans for industrial processes.

f. **Course Learning Outcomes:**

CLO 1	Explain fundamental process safety concepts, and hazard identification techniques.
CLO 2	Analyze industrial accidents and identify key lessons for improving process safety.
CLO 3	Apply risk assessment tools such as HAZOP, FMEA, and LOPA to real-world scenarios.
CLO 4	Evaluate fire, explosion, and toxic hazards, proposing appropriate prevention and mitigation strategies.
CLO 5	Design safety measures, pressure relief systems, and emergency response plans for industrial processes.

g. Teaching & Examination Scheme:

Teaching Scheme				Evaluation Scheme					
				Internal Evaluation			ESE		Total Marks
L	P	T	Credit	T	P	CE	T	P	
3	-	-	3	20	-	20	60	-	100

h. Course Content

Sr.	Topics	W	T
1	**Fundamentals of Process Safety:** Importance of Process Safety in Industry Difference Between Process and Occupational Safety Major Industrial Accidents and Lessons Learned (Bhopal, Flixborough, BP Texas) Process Safety Regulations and Standards (OSHA, PSM, NFPA, ISO 45001, EPA)	20	9
2	**Hazard Identification and Risk Assessment:** Hazard Identification Techniques (HAZOP, FMEA, Fault Tree Analysis, Event Tree Analysis), Risk Assessment and Management (QRA, LOPA, Bowtie Analysis), Safety Integrity Levels (SIL) and Layers of Protection, Inherently Safer Design Principles	22	10
3	**Fire, Explosion, and Toxic Hazards:** Fire Triangle and Explosion Pentagon, Flammability Limits and Fire Classification, Explosion Mechanisms (BLEVE, Dust, Vapor Cloud, Detonations), Toxicology and Industrial Hygiene (TLV, PEL, IDLH, Exposure Control), Fire Protection Systems (Extinguishers, Sprinklers, Foam, Water Spray)	20	9
4	**Pressure Relief and Safety Instrumentation:** Design and Sizing of Relief Valves and Rupture Discs, Relief Systems for Fire and Process Contingencies, Safety Instrumented Systems (SIS) and Emergency Shutdown (ESD), Alarm Management and Human Factors in Safety	20	9
5	**Incident Investigation and Emergency Planning:** Incident Investigation Techniques and Root Cause Analysis, Emergency Response and Disaster Management, Learning from Accidents and Near Misses, Case Studies of Process Safety Failures and Improvements	18	8
Total		100	45

i. Refernece Books

1. Chemical Process Safety: Fundamentals with Applications
   Daniel A. Crowl & Joseph F. Louvar| Pearson Education
2. Lees' Loss Prevention in the Process Industries
   Frank P. Lees| Elsevier
3. Process Safety Management
   Chitram Lutchman, Donald Barry, & Brian McVay| CRC Press (Taylor & Francis)
4. Safety Integrity Level Selection: Systematic Methods Including Layer of Protection Analysis" – Edward M. Marszal & Eric W. Scharpf| ISA (International Society of Automation)

Semester 2

a. **Course Name: -** Advanced Process Control
b. **Course Code:** 03022002PC01
c. **Prerequisite:** Knowledge of basic process control concepts, differential equations, linear algebra, and signal processing fundamentals.
d. **Rationale:** Understanding of control system design, modeling, and stability analysis for complex and multivariable chemical processes using both classical and modern techniques, essential for efficient and robust process automation.
e. **Course Learning Objective:**

CLOBJ 1	Explain the concept of advanced control schemes used in process control
CLOBJ 2	Develop control relevant linear perturbation models
CLOBJ 3	Explain the concept of digital control system
CLOBJ 4	Elaborate the use of soft computing techniques in process control
CLOBJ 5	Analyze interaction in multi loop control
CLOBJ 6	Analyze stability of digital control system

f. **Course Learning Outcomes:**

CLO 1	Explain the concept of advanced control schemes used in process control
CLO 2	Develop control relevant linear perturbation models
CLO 3	Explain the concept of digital control system
CLO 4	Elaborate the use of soft computing techniques in process control
CLO 5	Analyze interaction in multi loop control
CLO 6	Analyze stability of digital control system

g. **Teaching & Examination Scheme:**

Teaching Scheme				**Evaluation Scheme**					
				Internal Evaluation			**ESE**		**Total Marks**
L	**P**	**T**	**Credit**	**T**	**P**	**CE**	**T**	**P**	
3	-	-	3	20	-	20	60	-	100

h. Course Content

Sr.	Topics	W	T
1	**Introduction:** Introduction to process dynamics (first and second order process), Block diagram preparation of control system, various modes of control action, Stability, Characteristic equation, Routh-Hurwitz criterion for stability. Root locus Analysis, Frequency response, Bode stability criterion, Bode diagrams, Nyquist stability criterion, Nyquist plots, Frequency response of closed loop systems.	16	7
2	**Controllers & Responses:** Outline of the design problems. Simple Performance criteria, Time-integral performance criteria, Selection of the type of feedback controllers. Designing of Feedback Controllers by Frequency Response Techniques. Gain and Phase margins, Controller tuning, Zeigler – Nichols Tuning technique, Cohen and Coon tuning method, Smith Predictor for dead time compensation.	16	7
3	**Advanced Control Strategies:** Cascade control, Design of Cascade controllers, Various types of selective control- Auctioneering and Override control, Split range control, Feed forward control, Ratio control	15	7
4	**Development of control relevant linear perturbation models:** Development of Control Relevant Linear Perturbation Models, Linearization of Mechanistic Models, Concept of discretization, Introduction to z-transforms and Development of Grey-box models.	15	7
5	**Development of linear black-box dynamic models:** Introduction to Stochastic Processes; Development of ARX models, Statistical Properties of ARX models and Development of ARMAX models, Issues in Model Development, Model Structure Selection and Issues in Model Development, Issues in Model Development and State Realizations of Transfer Function Models.	11	5
6	**Stability analysis, interaction analysis, multi loop and multivariable control:** Stability Analysis of Discrete Time Systems; Lyapunov Functions; Jury's Stability Test, Interaction Analysis and Multi-loop Control; Pairing of controlled and Manipulated Variables; RGA and Singular Value Analysis, Decoupling and Multivariable Control Strategies.	15	7
7	**State estimation and kalman filtering:** Soft Sensing and State Estimation, Development of Luenberger Observer; Introduction to Kalman Filtering.	12	5
	Total	100	45

i. Refernece Books

1. Digital Control Systems
   G. F. Franklin, J. D. Powell, M. L. Workman, Addison Wesley, 3rd Edition, 1997.
2. Process Dynamics and Control
   D. E. Seborg, T. F. Edgar,D. A. Mellichamp, Wiley, 3rd Edition, 2010.
3. Control System Design
   G. C. Goodwin, S.F. Graebe, M. E. Salgado, Prentice Hall, 1st Edition, 2000.
4. Chemical Process Control: An Introduction to Theory and Practice
   G. Stephanopoulos,1st Edition, Prentice Hall India, 2008.

5. Process Systems Analysis and Control
   Coughnower , McGraw Hill, Singapore, Second Edition, 1991.
6. Chemical Process Control, An Introduction to Theory and Practice
   George Stephanopoulose, Prentice Hall of India, New Delhi 1999.
7. Process Modeling, Simulation and Control for Chemical Engineers
   W. L. Luyben, McGraw Hill Singapore, 1990.

a. **Course Name: -** Advanced Reaction Engineering
b. **Course Code:** 03022002PC03
c. **Prerequisite:** Basics of chemical reaction engineering, transport phenomena, and chemical kinetics from undergraduate studies.
d. **Rationale:** Understanding of complex reaction systems, catalyst behavior, and multiphase reactor design, equipping students with advanced tools for analyzing, modeling, and optimizing industrial chemical reactors.

e. **Course Learning Objective:**

CLOBJ 1	Analyse the non-ideal behaviour of reactors by tracer experiments and suitable models.
CLOBJ 2	Understand heterogeneous catalysed reactions.
CLOBJ 3	Design reactors for catalytic reactions.
CLOBJ 4	Discuss about the applications of supported catalysts.
CLOBJ 5	Apply the knowledge gained for the environmental impact.
CLOBJ 6	Distinguish between laboratory and structured reactors.

f. **Course Learning Outcomes:**

CLO 1	Analyse the non-ideal behaviour of reactors by tracer experiments and suitable models.
CLO 2	Understand heterogeneous catalysed reactions.
CLO 3	Design reactors for catalytic reactions.
CLO 4	Discuss about the applications of supported catalysts.
CLO 5	Apply the knowledge gained for the environmental impact.
CLO 6	Distinguish between laboratory and structured reactors.

g. Teaching & Examination Scheme:

Teaching Scheme				Evaluation Scheme					
				Internal Evaluation			ESE		Total Marks
L	P	T	Credit	T	P	CE	T	P	
4	-	-	4	20	-	20	60	-	100

h. Course Content

Sr.	Topics	W	T
1	**Introduction:** Kinetics of heterogeneous catalytic reactions, rate equations, model discrimination and parameter estimation.	18	10
2	**Kinetics of heterogeneous catalysed reactions:** Mass Transfer and Reaction in a Packed bed, Stoichiometric table, Pressure drop in a Reactor, Ergun's equation, Flow through a packed bed.	22	12
3	**Catalyst deactivation and regeneration:** Deactivating catalysts, mechanisms of catalyst deactivation, the rate and performance equations, Typical catalysts used in chemical processes, Catalyst characterizations, Catalyst regeneration.	20	12
4	**Multiphase reactors:** Types of multiphase reactors, mass transfer reactors, mass transfer equations, Interfacial surface area, mass transfer between phases, multiphase reactor equations, equilibrium between phases, membrane reactors, falling film reactors, bubble column reactors.	20	12
5	**Reactor design:** Fixed bed-, Fluid bed-, Trickle bed-, Slurry- reactors, Falling film catalytic wall reactor, catalytic distillation	20	14
Total		100	60

i. Refernece Books

1. Elements of Chemical Reaction Engineering
   H. S. Fogler , 4th Edition, Prentice Hall, NJ, 2006.
2. , "Chemical Reaction Engineering
   Levenspiel ,3rd Edition, John Wiley & Sons, Singapore, 1998.
3. Chemical Engineering Kinetics
   J. M. Smith ,3rd Edition, McGraw-Hill, N Y, 1981.
4. Chemical Reaction Engineering Beyond the Fundamentals
   L. K. Doraiswamy, D. Uner , CRC Press, New York, 2014.
5. Chemical Reactor Analysis and Design
   J. D. Wilde, G. F. Froment., K. B. Bischoff, John Wiley & Sons, Newyork, 1979.
6. The Engineering of Chemical Reactions
7. Lanny D. Schmidt, 2nd edition, Oxford University Press, (2010).

a. **Course Name: -** Advanced Chemical Engineering Thermodynamics
b. **Course Code:** 03022002PC05
c. **Prerequisite:** Basics of chemical engineering thermodynamics, basic physical chemistry, and calculus-based mathematics.

d. Rationale: This course extends classical thermodynamics into advanced topics such as phase and chemical equilibria, statistical and quantum thermodynamics, and interfacial phenomena, essential for understanding and modeling complex chemical engineering systems**.**

e. Course Learning Objective:

CLOBJ 1	Describe intermolecular forces and relate to macroscopic thermodynamic properties.
CLOBJ 2	Differentiate between ideal and non-ideal thermodynamic behaviour in both pure substances and mixtures.
CLOBJ 3	Explain phase equilibria for multicomponent systems.
CLOBJ 4	Estimate the thermodynamics properties of mixtures and solutions.
CLOBJ 5	Evaluate and apply different methods/assumptions for performing phase equilibrium calculations,
CLOBJ 6	Explain multi-reaction equilibria and solve problems.

f. Course Learning Outcomes:

CLO 1	Describe intermolecular forces and relate to macroscopic thermodynamic properties.
CLO 2	Differentiate between ideal and non-ideal thermodynamic behaviour in both pure substances and mixtures.
CLO 3	Explain phase equilibria for multicomponent systems.
CLO 4	Estimate the thermodynamics properties of mixtures and solutions.
CLO 5	Evaluate and apply different methods/assumptions for performing phase equilibrium calculations,
CLO 6	Explain multi-reaction equilibria and solve problems.

g. Teaching & Examination Scheme:

Teaching Scheme				**Evaluation Scheme**					
				Internal Evaluation			**ESE**		**Total Marks**
L	**P**	**T**	**Credit**	**T**	**P**	**CE**	**T**	**P**	
3	-	-	3	20	-	20	60	-	100

h. Course Content

Sr.	**Topics**	**W**	**T**
1	**Introduction** Introduction to Thermodynamics, Internal energy, First law of	10	5

	thermodynamics, Intensive and extensive properties Concept of entropy, Second law of thermodynamics: Extremum principles of Energy and Entropy, Maxwell relations.		
2	**Solution Thermodynamics** Ideal gas: Analytical derivations of the partition functions of ideal gas in various ensembles and thermodynamic properties, Ideal solid: Analytical derivation of partition function, heat capacity, non-ideal gases, second virial coefficient, Liquids: Distribution functions, pair correlation function g(r) and experimental measurement of g(r) by diffraction, Mean-field theory and perturbation theory.	30	13
3	**Phase Equilibria & Chemical equilibria** Multiphase Multicomponent phase equilibrium, VLE/SLE/LLE/VLLE, Solubility of gases in liquids, solubility of solids in liquids, combined phase and Reaction equilibrium.	15	7
4	**Thermodynamic properties of mixtures** Mixtures, partial molar properties, Chemical potential, Gibbs Duhem equations, Property changes on mixing, Fugacity in gas mixtures-Virial and Cubic EOS, corresponding states, fugacities in liquid mixtures, fugacities in liquid mixtures (electrolyte solution) Excess Functions in Liquid Mixtures, Models for Excess Gibbs energy.	30	13
5	**Properties of pure fluids** Thermo properties from Volumetric Data, Equations of State, Generalized correlations. Derivation of Raoults law, Henry's law, Van't Hoff's formula for osmotic pressure.	15	7
Total		100	45

i. Refernece Books

1. Introduction to Chemical Engineering, Thermodynamics
   By J.M. Smith, H.C. Van Ness and M.M. Abbott, | 7th edition, McGraw-Hill International Edition, 2005.
2. Chemical, Biochemical and Engineering Thermodynamics
   By S.Sandler, | 4th edition, Wiley,India
3. A text book of Chemical Engineering Thermodynamics
   By K. V. Narayanan | Prentice-Hall of India Pvt. Ltd.
4. Introduction to Thermodynamics
   By Y.V.C. Rao | Wiley Eastern Limited
5. Molecular Thermodynamics of Fluid-Phase Equilibria
   By John M. Prausnitz; Rudiger N. Lichtenthaler; Edmundo Gomes de Azevedo | Pearson 1998
6. Thermodynamics and an Introduction to thermo statistics
   Herbert B. Callen, John Wiley and Sons, 1985.
7. Molecular Thermodynamics
   D. A. McQuarrie and J. D. Simon Viva Books Pvt. Ltd., 2004.
8. Introduction to modern statistical mechanics
   David Chandler, Oxford University Press, 1987.
9. Molecular Thermodynamics of Fluid-Phase Equilibria
   J.M. Prausnitz, R.M. Lichtenthaler, E.G. Azevedo, 3rd edition, Prentice Hall Inc., 1999.

10. Thermodynamics and Its Applications
    J.W. Tester and M. Modell, 3rd Edition, Prentice Hall, 1997.
11. The Properties of Gases and Liquids
    B. E. Poling, J. M. Prausnitz, J. P. O'Connell, 5th edition, McGraw-Hill, 2001.

a. **Course Name: -** Instrumental Methods of Analysis
b. **Course Code:** 03022002PE03
c. **Prerequisite:** Basic knowledge of analytical chemistry, physical chemistry, and fundamental instrumental techniques such as spectroscopy and chromatography.
d. **Rationale:** This course builds upon core analytical concepts to develop advanced skills in using modern instrumentation for qualitative and quantitative chemical analysis across various applications.
e. **Course Learning Objective:**

CLOBJ 1	Understand the fundamental principles and instrumentation of UV-Vis spectrophotometry, nephelometry, turbidimetry, reflectance, fluorescence, and phosphorescence spectrometry.
CLOBJ 2	Analyze the working principles and applications of flame emission spectroscopy, AAS, electrothermal AAS, hydride generation AAS, flameless mercury analysis, and ICP-AES.
CLOBJ 3	Demonstrate knowledge and application of IR, XRF, NMR, and mass spectrometry for structural and molecular analysis.
CLOBJ 4	Apply electroanalytical and chromatographic techniques (potentiometry, voltammetry, polarography, GC, LC) for analytical problem-solving.
CLOBJ 5	Evaluate HPLC and hyphenated chromatographic methods, and apply statistical methods for error analysis and data interpretation.

f. **Course Learning Outcomes:**

CLO 1	Understand the fundamental principles and instrumentation of UV-Vis spectrophotometry, nephelometry, turbidimetry, reflectance, fluorescence, and phosphorescence spectrometry.
CLO 2	Analyze the working principles and applications of flame emission spectroscopy, AAS, electrothermal AAS, hydride generation AAS, flameless mercury analysis, and ICP-AES.
CLO 3	Demonstrate knowledge and application of IR, XRF, NMR, and mass spectrometry for structural and molecular analysis.
CLO 4	Apply electroanalytical and chromatographic techniques (potentiometry, voltammetry, polarography, GC, LC) for analytical problem-solving.
CLO 5	Evaluate HPLC and hyphenated chromatographic methods, and apply statistical methods for error analysis and data interpretation.

g. Teaching & Examination Scheme:

Teaching Scheme				Evaluation Scheme					
				Internal Evaluation			ESE		Total Marks
L	P	T	Credit	T	P	CE	T	P	
3	-	-	3	20	-	20	60	-	100

h. Course Content

Sr.	Topics	W	T
1	**Introduction to Instrumental Analysis:** Classification of Instrumental Methods, Accuracy, Precision, Sensitivity, and Detection Limits, Calibration and Standardization Techniques.	10	5
2	**Molecular and optical spectroscopic techniques:** UV - Vis Spectrophotometry- Principles, Instrumentation, and Applications, Infrared (IR) Spectroscopy: FTIR, Functional Group Identification, Nephelometry, Turbidimetry, Reflectance Spectrometry, Fluorescence, Phosphorescence Spectrometry.	30	12
3	**Advanced Atomic Spectroscopic Techniques:** Flame Emission and Atomic Absorption Spectrometry, Electro thermal AAS, Hydride generation AAS and Flameless mercury analysis. Inductively Coupled Plasma Atomic Emission Analysis.	15	7
4	**Molecular and Structural Spectroscopic Techniques:** Infrared spectrometry, Introduction to X-Ray techniques, XRF. Introduction to NMR spectroscopy and mass spectrometry.	15	7
5	**Electrochemical Methods:** Potentiometry, Voltametry, Conductometry and Electrochemical Sensors, Coulometry and Electrogravimetric Analysis, pH Measurement	15	7
6	**Chromatographic Techniques:** Chromatographic analysis, HPLC, Polarography Chromatographic analysis: GC, LC, Hyphenated techniques. Errors, statistical methods of data handling	15	7
Total		100	45

i. Refernece Books

1. Instrumental Methods of Analysis
   H.Willard, L.L Meritt, J.A Dean and F.A.Settle, 6th Edition, CBS.
2. Quantitative Inorganic Analysis
   A.I.Vogel, 5th Edition, ELBS.
3. Analytical Instrumentation Hand book
   G.W. Ewing, Marcell Dekker, New York, 1990

a. **Course Name: -** Process Plant Design
b. **Course Code:** 03022002PE09
c. **Prerequisite:** Basic knowledge of core chemical engineering subjects such as thermodynamics, heat and mass transfer, reaction engineering, and process equipment design. Familiarity with engineering economics, flow sheet

preparation, and project management techniques.

d. **Rationale:** This course integrates design, economic analysis, and optimization techniques for developing efficient and practical chemical process plants. Fundamental engineering concepts are crucial to understand complex design hierarchies, flow sheet synthesis, cost estimation, and decision-making strategies involved in process plant design.

e. Course Learning Objective:

CLOBJ 1	Understand the foundational concepts of process plant design including general layout, process development, economic considerations, engineering ethics, network analysis, and project scheduling techniques like PERT/CPM.
CLOBJ 2	Apply hierarchical and systematic approaches to process synthesis, including flow sheet development, energy targeting, and heat integration for various unit operations.
CLOBJ 3	Analyze flow sheet generation using logical and algorithmic methods such as propositional logic, semantic equations, P-graph theory, and optimization algorithms like SSG, MSG, Simplex, and Branch-and-Bound.
CLOBJ 4	Evaluate project economics by estimating investment and production costs, calculating depreciation, and analyzing profitability, taxes, time value of money, and alternative investment options.
CLOBJ 5	Design economically optimized process components and operating strategies using techniques such as break-even analysis, cycle time optimization, and determining optimal values for system parameters like insulation thickness, pipe diameter, and reflux ratio.

f. Course Learning Outcomes:

CLO 1	Understand the foundational concepts of process plant design including general layout, process development, economic considerations, engineering ethics, network analysis, and project scheduling techniques like PERT/CPM.
CLO 2	Apply hierarchical and systematic approaches to process synthesis, including flow sheet development, energy targeting, and heat integration for various unit operations.
CLO 3	Analyze flow sheet generation using logical and algorithmic methods such as propositional logic, semantic equations, P-graph theory, and optimization algorithms like SSG, MSG, Simplex, and Branch-and-Bound.
CLO 4	Evaluate project economics by estimating investment and production costs, calculating depreciation, and analyzing profitability, taxes, time value of money, and alternative investment options.
CLO 5	Design economically optimized process components and operating strategies using techniques such as break-even analysis, cycle time optimization, and determining optimal values for system parameters like insulation thickness, pipe diameter, and reflux ratio.

g. Teaching & Examination Scheme:

Teaching Scheme				**Evaluation Scheme**					
				Internal Evaluation			**ESE**		**Total Marks**
L	**P**	**T**	**Credit**	**T**	**P**	**CE**	**T**	**P**	
3	-	-	3	20	-	20	60	-	100

h. Course Content

Sr.	Topics	W	T
1	**Introduction:** Introduction, Basic concepts, General design considerations, Process design development, Layout of plant items, Flow sheets and PI diagrams, Economic aspects and Optimum design, Practical considerations in design and engineering ethics, Degrees of freedom analysis in interconnected systems, Network analysis, PERT/CPM, Direct and Indirect costs, Optimum scheduling and crashing of activities.	10	5
2	**Hierarchical Approach to Process Design and Integration:** Hierarchy of chemical process design; Nature of process synthesis and analysis; Developing a conceptual design and flow sheet synthesis. Synthesis of reaction-separation systems; Distillation sequencing; Energy targets. Heat integration of reactors, distillation columns, evaporators and driers; Process change for improved heat integration. Heat and mass exchange networks and network design.	15	7
3	**Optimization Techniques in Process Design:** Synthesis of flow sheet, Propositional logic and semantic equations, Deduction theorem, Algorithmic flow sheet generation using P-graph theory, Sequencing of operating units, Feasibility and optimization of flow sheet using various algorithms viz, Solution Structure Generation (SSG), Maximal Structure Generation (MSG), Simplex, Branch-and-bound etc.	15	7
4	**Cost Estimation in Process Design:** Analysis of Cost estimation: Factors affecting Investment and production costs, Estimation of capital investment and total product costs, Interest, Time value of money, Taxes and Fixed charges, Salvage value, Methods of calculating depreciation, Profitability, Alternative investments and replacements.	30	13
5	**Optimum Design and Design Strategy:** Break-even analysis, Optimum production rates in plant operation, Optimum batch cycle time applied to evaporator and filter press, Economic pipe diameter, Optimum insulation thickness, Optimum cooling water flow rate and optimum distillation reflux ratio	30	13
	Total	100	45

i. Refernece Books

1. Plant Design and Economics for Chemical Engineers
   Peters, M.A. and Timmerhaus, K.D., McGraw Hill (2003).
2. Chemical Process Synthesis and Engineering Design
   Anil Kumar, Tata McGraw Hill (1982).
3. A Guide to Chemical Engineering Process Design and Economics
   Ulrich, G.D., John Wiley & Sons (1984).
4. Perry, R.H. and Green, D., Chemical Engineer's Handbook, McGraw-Hill (1997)