Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

# SCHOOL OF CHEMICAL ENGINEERING

## VISION

To improve the quality of life through innovations in Chemical Engineering.

## MISSION

1. To provide quality education in Chemical Engineering in tune with the evolving requirements of society.
2. To impart knowledge and foster technology development through quality research in frontier areas of chemical and interdisciplinary fields.
3. To produce practicing engineers with professional ethics catering to the contemporary needs of society and the environment.

## PROGRAM EDUCATIONAL OBJECTIVES

**The PEO of B. Tech in Chemical Engineering is as follows:**

1. Graduates will be engineering professionals in industry, entrepreneurs in process engineering or in the pursuit of graduate education in chemical engineering and other disciplines.
2. Graduates will assess and relate engineering issues to meet sustainable development goals and contribute to economic growth.
3. Graduates will function in their profession with strong communication skills to work in a diverse multi-faceted team with social awareness and responsibility.

# DETAILED SYLLABI OF ACE CURRICULUM FOR B. TECH CHEMICAL ENGINEERING.

# PROFESSIONAL CORE COURSES

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE101** | **Chemical Engineering Thermodynamics** | **3** | **1** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

The objective of this course is to:

1. Enhance the basic knowledge and intuitive understanding of the thermodynamics of physical and chemical systems.
2. Introduce the concepts of partial molar properties, fugacity, activity, and vapour-liquid equilibrium for ideal and real substances existing in more than one phase under equilibrium.
3. Generalize design thinking skills on property estimation relevant to chemical industries.

**Course Outcomes**

1. Define and illustrate thermodynamic equilibrium state and equations of state.
2. Relate properties such as change in enthalpy, entropy, free energy, heat and work requirements for batch and flow processes occurring in chemical industries.
3. Construct and analyze phase equilibrium data, P-x-y, T-x-y diagrams for ideal, binary, miscible vapour-liquid systems.
4. Device methodologies for qualitative and quantitative analysis of VLE data for non-ideal, binary, miscible systems using van Laar, Margules, and property estimation models.
5. Estimate the feasibility of a chemical reaction and determine the equilibrium rate constant for chemical reactions.

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| **Module:1** | **Fundamental Concepts and Laws of Thermodynamics** | **7 hours** |

Definitions and basic concepts - concept of continuum - equilibrium state process - Volumetric properties of pure fluids - P-V-T relationships - Ideal Gas – Real Gas - First law of thermodynamics - Second law of thermodynamics - change in internal energy - enthalpy - entropy calculations.

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| **Module:2** | **Thermodynamic Properties of Pure Fluids and Solutions** | **9 hours** |

Maxwell's relations and applications - fugacity - determination of fugacity of pure gases, solids, and liquid-fugacity coefficient - partial molar properties - chemical potential - fugacity in solution - Lewis Randall rule - Gibbs - Duhem equation - Gibbs free energy calculations.

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| **Module:3** | **Phase Equilibria** | **9 hours** |

Phase rule - criteria of phase equilibrium - single component - multiple components - Vapour-Liquid Equilibria for ideal solutions - phase diagram for binary systems using Aspen Plus - constant temperature equilibria - constant pressure equilibria - phase equilibrium curves.

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| **Module:4** | **Vapour-Liquid Equilibria – Non-ideal Solutions** | **9 hours** |

Non-ideal solutions – azeotropic systems - minimum boiling – maximum boiling – VLE – P-x-y diagram and T-x-y diagram using Aspen Plus; Bubble point – dew point calculation methods – van Laar equation - Margules equation - Wilson equation - Multicomponent systems – flash vaporization - Consistency test for VLE data.

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| **Module:5** | **Chemical Reaction Equilibria** | **9 hours** |

Chemical reaction equilibria - reaction coordinates - criteria for chemical equilibrium - equilibrium constant - Gibbs free energy of a reaction - effect of temperature on equilibrium constant - equilibrium constant of homogeneous gas and liquid phase reactions.

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| **Module:6** | **Contemporary Topics** | **2 hours** |

Industry Expert Lecture

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| | **Total Lecture hours:** | **45 hours** |

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| **Tutorial** | • **A minimum of 10 problems to be worked out by students Inventory Tutorial Class**<br>• **Another 5 problems per Tutorial Class to be given as homework.** | **15 hours** |

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| **Text Book(s)** | |
| 1. | Narayanan K.V., A Textbook of Chemical Engineering Thermodynamics, 2013, 2nd ed., Prentice Hall India Learning Private Limited, India. |
| 2. | R Ravi, Chemical Engineering Thermodynamics: Theory and Applications, 2020, Taylor and Francis, India |
| **Reference Books** | |
| 1. | Matsoukas T., Fundamentals of Chemical Engineering Thermodynamics, 2012, 1st ed., Pearson Prentice Hall, USA. |
| 2 | Smith J.M., Van Ness H.C., Abbott, M.M., Swihart M.T., Bhatt, B.I., Introduction to Chemical Engineering Thermodynamics, 2019, 8th ed., McGraw Hill India, India. |
| 3. | Dahm K.D., Visco D.P., Fundamentals of Chemical Engineering Thermodynamics, 2012, 1st ed., Cengage Learning India Private Limited, India. |

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

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| Recommended by Board of Studies | 22-9-2025 | | |
| Approved by Academic Council | No. 78 | Date | 12-6-25 |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE102 | Chemical Process Calculations | 3 | 1 | 0 | 4 |
| Pre-requisite | NIL | Syllabus version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. Formulate material balances for compositions and flow rates of process streams.
2. Solve single and multiple reactions involved in chemical processes.
3. Perform material and energy balance calculations for various unit operations.

**Course Outcomes**

1. Explain the basic chemical calculations, including units, dimensions, and composition expressions relevant to chemical engineering.
2. Apply gas laws and vapour pressure relations to solve problems involving single and mixed component systems.
3. Perform material balance calculations for non-reactive processes under steady-state conditions.
4. Analyse chemical processes involving reactions to determine limiting/excess reactants, conversion, yield, and perform recycle, purge, and bypass calculations.
5. Evaluate energy balances in processes with and without chemical reactions.

| Module:1 | Basic Chemical Calculations | 6 hours |
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Units and dimensions – conversion factors - mole concept – normality, molarity, and molality – density and specific gravity – methods of expressing composition of mixtures and solutions – weight fraction – mole fraction – volumetric composition – Ideal gas law – Dalton’s law – Amagat’s law.

| Module:2 | Vapor Pressure and Humidity Calculations | 7 hours |
|---|---|---|

Vapor pressure of liquids – Clausius-Clapeyron equation - Antoine equation - Vapor pressure of immiscible liquids and ideal solutions – Raoult’s law – Henry’s law – Saturation and Humidity – Principles – Wet bulb and dry bulb temperature – Relative and percentage saturation – Psychometric chart and its use

| Module:3 | Material Balances without Chemical Reaction | 8 hours |
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General material balance equation for steady and unsteady state – Balances on single and multiple unit processes without reaction – Typical steady state material balances in distillation, absorption, extraction, crystallization, drying, and evaporation – Material balances on non-reactive processes with or without recycle and bypass.

| Module:4 | Material Balances involving Chemical Reactions | 11 hours |
|---|---|---|

Stoichiometric equation – stoichiometric ratio – limiting reactant – excess reactant – % excess reactants – conversion – yield – selectivity – material balance with single and multiple chemical reactions; Recycle, purge, and bypass calculations in unit operations, single and multiple effect evaporators, distillation, and drying.

| Module:5 | Combustion Calculations & Energy Balances | 11 hours |
|---|---|---|

Calorific value of fuels, flue gas analysis, Orsat analysis, air/ fuel ratio calculations - theoretical and excess air requirement for solid, liquid, and gaseous fuels; General steady state energy balance equation - heat capacity - standard heat of reaction - enthalpy changes for pure substances and their mixtures in ideal states - enthalpy changes accompanying chemical reactions

| Module:6 | Contemporary Topics | 2 hours |
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Industry Expert Lecture

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| | **Total Lecture hours:** | **45 hours** |
| **Tutorial** | | **15 hours** |

| Text Book(s) | | | |
|---|---|---|---|
| 1. | Felder, R. M. and Rousseau, R. W., 2005, Elementary principles of chemical processes, 3rd ed., John Wiley & Sons Inc. | | |
| 2. | G V Reklaitis, Introduction to Material & Energy Balances, John Wiley & Sons Inc; 1st edition (14 December 1983) | | |
| **Reference Books** | | | |
| 1. | Himmelblau D.M., Basic Principles and Calculations in Chemical Engineering, 2015, 8th ed., Pearson India Educational Services, India. | | |
| Mode of Evaluation: Continuous Assessment Test / Written assignment / Quiz / Final Assessment Test | | | |
| Recommended by the Board of Studies | 22-09-2025 | | |
| Approved by the Academic Council | No. | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE103 | Momentum Transfer | 3 | 0 | 2 | 4 |
| Pre-requisite | NIL | Syllabus Version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. Understand and apply the fundamental principles of fluid statics and dynamics
2. Formulate and solve fluid flow problems using conservation laws
3. Evaluate pressure drops, velocity profiles, and energy losses in pipeline systems
4. Apply dimensional analysis and similitude principles
5. Analyze turbulent flows and flow past immersed bodies

**Course Outcomes**

1. Describe fluid properties, classify fluids, and apply fluid statics principles.
2. Apply fluid kinematics and dynamics principles to analyze ideal and real flows.
3. Evaluate pressure losses, energy balance, and flow in pipelines using pumps, compressors, and flow meters.
4. Use dimensional analysis and similitude concepts to formulate and scale fluid flow experiments
5. Analyze turbulent flow, boundary layers, and immersed body flow using theoretical models and empirical correlations

| Module:1 | Fundamentals of Momentum Transfer | 8 hours |
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Introduction to fluids and classification (ideal, real, Newtonian, non-Newtonian), Properties of fluids: density, viscosity, surface tension, compressibility. Fluid statics: Pressure variation in static fluid. Hydrostatic forces on planes and curved surfaces, Manometers and pressure measurement Buoyancy and stability of floating bodies, Surface tension and capillarity

| Module:2 | Fluid Kinematics and Dynamics | 9 hours |
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Fluid flow types: steady/unsteady, laminar/turbulent, compressible/incompressible, Description of flow: Streamlines, Path lines, streak lines. Equation of continuity (mass conservation). Derivation and application of Bernoulli’s Equation. Linear and angular momentum principles, Shell balance approach, and differential analysis. Equation of motion (Navier-Stokes equations) – introduction and simplification

| Module:3 | Energy Analysis and Flow in Pipelines | 9 hours |
|---|---|---|

Equation of mechanical energy and energy balance, Head loss due to friction – Darcy-Weisbach equation, Major and minor losses in pipelines, Flow through series and parallel pipe systems, Macroscopic friction factor (Moody diagram, Reynolds number effects). Flow meters: Venturi, orifice, rotameter. Pumps and compressors: types, performance curves, selection, NPSH, cavitation

| Module:4 | Dimensional Analysis and Boundary Layers | 8 hours |
|---|---|---|

Dimensional homogeneity and Buckingham Pi theorem, Common dimensionless numbers: Reynolds, Prandtl, Schmidt, Froude, etc., Similitude and model testing, Boundary layer theory: Laminar and turbulent boundary layers, Boundary layer thickness, displacement thickness, Flow separation

| Module:5 | Turbulent Flow and Complex Flow Systems | 9 hours |
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Characteristics of turbulent flow: fluctuating velocity components, Reynolds decomposition, Reynolds-averaged Navier-Stokes (RANS), Universal velocity profile (log-law, viscous sublayer), Pressure drop in turbulent flow. Flow past immersed bodies: drag and lift, drag coefficients. Packed bed flow: Ergun

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| equation. Fluidized beds: minimum fluidization velocity, applications | | |
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Industry Expert Lecture | |
| | **Total Lecture hours:** | **45 hours** |

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| **Text Books** | |
| 1 | Cengel Y.A., Cimbala J.M., Fluid Mechanics (SIE): Fundamentals and Applications, 2019, 4th ed., McGraw Hill, New York. |
| 2 | McCabe W.L., Smith J.C., Harriott P., Unit Operations of Chemical Engineering, 2017, 7th ed., McGraw Hill, New York. |
| **Reference Books** | |
| 1. | Fox R.W., McDonald A.T., Pritchard P.J., Mitchell J. W., Introduction to Fluid Mechanics, 2015, 9th ed., Wiley Publications, Delhi. |
| 2. | Munson, B. R., Young, D.F., Okiishi, T.H., Fundamentals of Fluid Mechanics, 2015, 8th ed., Wiley Publications, Delhi. |
| 3. | R.K. Bansal, A Textbook of Fluid Mechanics and Hydraulic Machines, 2015, 10th ed., Laxmi Publications, New Delhi. |

**Mode of Evaluation:** Quiz, Case studies, Continuous Assessment Test, and Final Assessment Test

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| **List of Experiments** | | |
| 1. | Flow through Venturi meter | CO3 |
| 2. | Flow through Orifice meter | CO3 |
| 3. | Flow through a circular pipe | CO3 |
| 4. | Flow through non-circular pipe | CO3 |
| 5. | Determination of Minor losses | CO3 |
| 6. | Reynolds Experiment | CO3 |
| 7. | Verification of Bernoulli’s theorem | CO3 |
| 8. | Characteristics of Centrifugal pump | CO3 |
| 9. | Flow through Packed bed | CO5 |
| 10 | Flow through Fluidized bed | CO5 |
| | **Total hours:** | **30 hours** |

**Mode of Evaluation:** Individual Experiment Assessment, Final Assessment Test

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| **Recommended by Board of Studies** | 22-9-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|

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|---|---|---|---|---|---|
| **BACHE201** | **Mass Transfer I** | **3** | **1** | **0** | **4** |
| **Pre-requisite** | **BACHE103** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives:**

1. To understand the fundamentals of diffusion and the theories of mass transfer
2. To impart the knowledge of humidification, drying and crystallization
3. To solve application-oriented problems using separation techniques

**Course Outcomes:**

1. Determine the diffusivity and flux of fluids and solids
2. Apply the theories of mass transfer and determine the mass transfer coefficients
3. Design the cooling tower using principles of humidification
4. Calculate the drying rate of various dryers in process industries
5. Select suitable crystallizers used for industrial applications

| **Module:1** | **Diffusion in fluids and solids** | **12 hours** |
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Introduction to Mass transfer operation, Fick's law of diffusion, Steady state molecular diffusion in gases and liquids under stagnant and laminar flow conditions, Multicomponent diffusion, Diffusion through variable cross-sectional area, Diffusivity in solids and its applications, Diffusion coefficient measurement and prediction

| **Module:2** | **Mass transfer coefficients and interphase mass transfer** | **12 hours** |
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Mass transfer coefficients–Individual and overall, Correlation for convective mass transfer coefficient, Analogies between momentum, heat and mass transfer to predict mass transfer coefficients- Theories of Mass Transfer- Overall mass transfer coefficients

| **Module:3** | **Single Equilibrium Stages and Flash Calculations** | **7 hours** |
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Binary Vapour-Liquid Systems – Binary Azeotropic Systems – Multicomponent Flash, Bubble and Dew Point calculations – Ternary Liquid-Liquid Systems – Multicomponent Liquid-Liquid Systems – Solid-liquid systems – Gas-liquid systems – Gas-Solid systems –Multi phase systems.

| **Module:4** | **Humidification and Drying** | **7 hours** |
|---|---|---|

Introduction to humidification and dehumidification concepts - Cooling Towers–Mechanical Draft Towers: forced draft towers and induced draft towers, Design calculations of cooling tower.

Principles of Drying – Definitions of moisture and other terms on Drying –Classification of Drying operations - Rate of Drying – moisture movement in solids - Through Circulation Drying - Rate of drying for Continuous Direct heat Driers. Types of Dryers used in practice and their operation – Batch and Continuous Dryers

| **Module:5** | **Crystallization** | **5 hours** |
|---|---|---|

Crystal Geometry - Invariant Crystals - Principles of Crystallization- Super saturation Nucleation - Crystal growth -Material & Energy Balance applied to Crystallizers – Types of Crystallizers used in practice

| **Module:6** | **Contemporary issues** | **2 hours** |
|---|---|---|

Guest lecture from industry and R&D organizations

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|---|---|---|
| | **Total Lecture hours:** | **45 hours** |
| **Tutorial** | | **15 hours** |

| **Text Books:** | | | | |
|---|---|---|---|---|
| 1. | J.D. Seader, Ernest J. Henley, D. Keith Roper, Separation Process Principles, Chemical and Biochemical Operations, 3rd edition, John Wiley & Sons, USA. | | | |
| 2. | R.E. Treybal, Mass-Transfer Operations, 2017, 3rd ed., McGraw-Hill Inc., USA. | | | |
| **Reference Books:** | | | | |
| 1. | B.K. Dutta, Principles of Mass transfer and Separation Processes, 2010, 1st ed., PHI, India. | | | |
| 2. | Christie J, Geankoplis, Transport processes and Unit Operations, 2003, 4th ed., Prentice Hall India Pvt. Ltd., India. | | | |
| 3. | N. Anantharaman, K. M. Meera Sheriffa Begum, Mass transfer-Theory and practice, 2011, Prentice-Hall of India, New Delhi, India. | | | |
| 4. | E.L.Cussler, Diffusion: Mass Transfer in Fluid Systems, 2017, 3rd ed., Cambridge University Press, United Kingdom. | | | |
| Mode of evaluation: Continuous Assessment Test, Quiz, Assignment, Final Assessment Test | | | | |
| Recommended by Board of Studies | | 22-9-2025 | | |
| Approved by Academic Council | | | | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE202 | Heat Transfer | 3 | 0 | 2 | 4 |
| Pre-requisite | NIL | Syllabus Version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. To develop a comprehensive understanding of the basic modes of heat transfer
2. To solve various heat transfer problems using the principles of different modes of heat transfer
3. To design and estimate heat loads for several heat transfer equipment such as heat exchangers and evaporators

**Course Outcomes**

1. Classify the different modes of heat transfer with their significance
2. Model and solve steady/unsteady state heat transfer problems
3. Analyze the heat transfer phenomena in fluids involving phase and no phase changes
4. Examine the radiative heat transfer using radiation shields through shape factor concept
5. Design the performance of various types of heat exchangers and evaporators

| Module:1 | Conduction: steady and unsteady state | 9 hours |
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Conduction – Fourier's Law of Heat conduction –Thermal Conductivity – Generalized conduction equation - Steady State Conduction – conduction through composite systems – Critical thickness of insulation – Extended surfaces – Fin efficiency and effectiveness – Unsteady state heat conduction – Lumped parameter system – Conduction through semi-infinite solids

| Module:2 | Convection with and without phase change | 10 hours |
|---|---|---|

Natural and Forced Convection – Thermal boundary layer & Convective heat transfer coefficients – Convection correlations through Dimensional analysis; Laminar flow over a flat plate – Turbulent flow over a flat plate – Flow over cylinders – Internal flow through pipes – annular spaces – Natural convection in vertical, inclined and horizontal surfaces. Condensation – Drop wise and Film wise condensation – Film condensation on a vertical plate; Boiling – Nucleate boiling and film boiling correlations – Critical heat flux

| Module:3 | Radiation | 7 hours |
|---|---|---|

Radiation heat transfer – Thermal radiation – Laws of radiation – Blackbody concepts –
Emissive power – Real surfaces: Emissivity, absorptivity, reflectivity, transmissivity - Radiation shape factor – Radiation exchange between diffuse, gray surfaces in an enclosure – Radiation shields - Gas Radiation

| Module:4 | Heat Exchangers | 8 hours |
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Heat exchangers – Types and practical application – Concept of LMTD & Overall heat transfer coefficient; Effectiveness – NTU method for heat exchanger design - Fouling factor and estimation of Overall heat transfer coefficient - Special type of heat exchangers

| Module:5 | Evaporators | 9 hours |
|---|---|---|

Introduction – Types of Evaporators – Capacity – Steam economy – Boiling point elevation(Duhring rule); Material and energy balance of single effect evaporator - multiple effect evaporators - Design of single and multiple effect evaporators

| Module:6 | Contemporary Issues | 2 hours |
|---|---|---|
| | Guest lecture from industry and R&D organizations | |
| | **Total Lecture hours:** | **45 hours** |

| **Text Books** | | |
|---|---|---|
| 1. | Ghajar A.J., Cengel Y.A., Heat and Mass Transfer: A Practical Approach, 2015, 5th ed., McGraw-Hill, USA. | |
| 2. | J Holman, S Bhattacharyya., Heat Transfer, 2017, 10th ed., McGraw Hill Education, India. | |
| **Reference Books** | | |
| 1. | Frank Kreith, Raj M Manglik, Principles of Heat Transfer, 2016, 8th ed., Cengage Learning, USA. | |
| 2. | S P Venkatesan, Heat Transfer, 2021, 3rd ed., Springer Nature, Switzerland. | |
| 3. | B K Dutta, Heat Transfer: Principles and Applications, 2023, 2nd ed., PHI Learning Pvt. Ltd., India | |
| **Mode of Evaluation: Quiz, Assignment, CAT and FAT** | | |
| **List of Experiments** | | |
| 1. | Measurement of thermal conductivity of metal rod and liquids | CO1 |
| 2. | Analysis of Transient Heat Conduction | CO2 |
| 3. | Analysis of Fin efficiency & effectiveness | CO2 |
| 4. | Performance of Natural Convection heat transfer | CO3 |
| 5. | Performance of Forced Convection heat transfer | CO3 |
| 6. | Emissivity measurement | CO4 |
| 7. | Performance of Double Pipe Heat Exchanger | CO5 |
| 8. | Performance of Plate type Heat Exchanger | CO5 |
| 9. | Performance of shell and tube Heat Exchanger | CO5 |
| 10 | Analysis of Heat Exchanger using Aspen Plus and PROSIM software | CO5 |
| | **Total hours:** | **30 hours** |
| **Mode of Evaluation: Internal Assessments and FAT** | | |

| **Recommended by Board of Studies** | 22-09-2025 | | |
|---|---|---|---|
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| ACHE205 | **Process Instrumentation, Dynamics and Control** | 3 | 0 | 2 | 4 |
| **Pre-requisite** | **BAMAT101** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To introduce the fundamental concepts of instruments and control system to understand the dynamic behavior of the process
2. To impart knowledge on modes of controllers, their characteristics and analyze the stability of control systems
3. To develop basic understanding on advanced control strategies and implementation of computer control in process industries

**Course Outcomes**

1. Explain various measuring instruments used in process industries and understand their operating principles
2. Develop transfer functions of first and higher order systems and study the responses using different forcing functions
3. Identify the modes of control action required for closed loop control system and analyze its characteristics
4. Analyze the stability of control system in transient and frequency domain and optimize control parameters using tuning methods.
5. Compare advanced control strategies for chemical processes and explore the implementation of computer-based control systems.

| Module:1 | Process Instrumentation | 6 hours |
|---|---|---|

Measuring instruments - Principles and Performance characteristics - Static and Dynamic characteristics - Measuring instruments for- Temperature, Pressure, Flow Rate, Liquid Level, pH and Concentration

| Module:2 | Open Loop Systems | 9 hours |
|---|---|---|

Laplace transformation - Transform of standard functions - Transfer functions - Forcing functions - step, impulse and sinusoidal - Dynamic behavior of First order and Higher order system - First order systems in series – Linearization of nonlinear systems – Transportation lag

| Module:3 | Closed Loop Systems | 9 hours |
|---|---|---|

Development of Block diagram – Block diagram reduction technique – Components of closed loop control system – Servo and Regulator Problem – Pneumatic and Electronic controllers – Modes of control action – ON/OFF, P, PI, PD, PID and their characteristics – offset calculation – Final control elements: sizing and characteristics

| Module:4 | Stability Analysis | 10 hours |
|---|---|---|

Transient response of closed loop control systems – Characteristic equation – Concept of poles and zeros of a transfer function – Routh stability criterion – Root locus analysis,Frequency response analysis – Bode diagrams – Bode stability criteria – Gain margin – Phase margin – Nyquist plot – Controller tuning using Ziegler – Nichols and Cohen – Coon method (Using MATLAB)

| Module:5 | Advanced and Computer Process Control | 9 hours |
|---|---|---|

Introduction to advanced control systems – Cascade control – Feed forward control – Ratio control – Control of chemical processes (Distillation column, Chemical reactors, Heat exchanger)
Introduction to computer control of chemical processes – Programmable Logic Controller – Distributed Control System – Decentralized control based on IoT – Hardware for computer-based control – Interfacing computer system with process

| Module:6 | Contemporary Issues | | 2 hours |
|---|---|---|---|
| Expert lectures from industry or R&D institutions / Industrial Visits | | | |
| | | Total Lecture hours: | 45 hours |
| **Text Books** | | | |
| 1 | Coughanowr C. R., Koppel L. M., Process System Analysis and Control, 3rd ed., McGraw Hill, New Delhi, 2013 | | |
| 2 | Stephanopoulos G., Chemical Process Control, 1st ed., Pearson Education India, New Delhi, 2015 | | |
| **Reference Books** | | | |
| 1. | Seborg D.E., Edgar, T. F., Mellichamp D.A., Process Dynamics and Control, 4th ed., Wiley, India, New Delhi, 2021 | | |
| 2. | Wayne Bequette B., Process Dynamics: Modeling, Analysis, and Simulation, Pearson Education, Inc., India, New Delhi, 2003 | | |
| 3. | Rajkamal, Internet of Things: Architecture, Design Principles and Applications, McGraw Hill Higher Education. | | |
| **Mode of Evaluation: Quiz, Assignment, CAT and FAT** | | | |
| **List of Experiments** | | | |
| 1. | Automatic level control loop in a cylindrical tank | | CO3 |
| 2. | Automatic flow control loop in a pipe line | | CO3 |
| 3. | Automatic temperature control loop in a heating tank | | CO3 |
| 4. | Automatic pressure control loop in a cylindrical tank | | CO3 |
| 5. | Dynamics of non-interacting tanks/interacting tanks | | CO2 |
| 6. | Control Valve Characteristics | | CO2 |
| 7. | Controller tuning using an open loop method (Cohen-Coon method) in MATLAB | | CO4 |
| 8. | Controller tuning using a closed loop method (Ziegler–Nichols method) in MATLAB | | CO4 |
| 9. | Dynamics of Ratio control using PROSIM | | CO5 |
| 10 | Automatic cascade control loop | | CO5 |
| | | **Total hours:** | **30 hours** |
| **Mode of Evaluation: Quiz, Assignment, CAT, and FAT** | | | |
| **Recommended by Board of Studies** | 22-09-2025 | | |
| **Approved by Academic Council** | **No.** | **Date:** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE301** | **AI and ML for Chemical Engineers** | **3** | **0** | **2** | **4** |
| **Pre-requisite** | **BAMAT201** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Understand supervised and unsupervised learning techniques with applications.
2. Explore neural network architectures and optimization techniques used in AI models
3. Apply AI/ML concepts in solving real-world chemical engineering problems.

**Course Outcomes**

1. Apply data processing/feature selection methods in process engineering.
2. Apply suitable machine learning method(s) in chemical engineering processes.
3. Design and analyze neural networks for prediction and classification.
4. Apply optimization techniques in AI model development.
5. Implement AI/ML in process control and fault detection in chemical engineering.

| Module:1 | Introduction to Artificial Intelligence and Machine Learning | 9 hours |
|---|---|---|

Introduction to Artificial Intelligence (AI) – Scope of AI in Chemical Engineering – Phases of AI – Machine Learning – Deep Learning - Definitions and differences; Machine Learning Types – Supervised – Unsupervised – Semi-supervised – Reinforcement learning; Data-driven modeling versus first-principles models – Applications of ML in chemical engineering – predictive modeling – Fault detection – Process optimization; Data pre-processing – Data visualization – Outlier detection – Smoothing techniques; Data scaling – Need for Scaling – Scale invariance – Standardization – Normalization; Dimensionality reduction – Feature extraction and selection – Importance of feature selection and dimensionality reduction in chemical datasets.
Overview of MATLAB® Machine Learning Toolbox/Opensource coding using python notebook – introducing platforms such as Google Colab, Jupyter Notebook etc.

| Module:2 | Supervised and Unsupervised Learning | 9 hours |
|---|---|---|

Supervised Learning – Linear regression and polynomial regression for property prediction and trend analysis – Logistic regression for binary classification of failures or phase transitions – Support Vector Machine (SVM), Concept of hyperplane and margin – Kernel functions: linear, polynomial, Gaussian; Decision trees and random forest – Tree structure – splitting criteria (Gini, Entropy); Ensemble learning - Bagging-boosting.
Unsupervised Learning and Feature Reduction – k-means clustering – Fuzzy C-means (FCM) clustering; Hierarchical Clustering – Agglomerative and divisive clustering –dendrogram; Principal Component Analysis (PCA) – Dimensionality reduction – Variance and principal components; Overview of t-SNE nonlinear dimensionality reduction.

Model Evaluation and Selection for classification and regression – Accuracy – Precision–Recall – F1-score – Confusion matrix – ROC curve and AUC – RMSE (Root Mean Squared Error) – MAE (Mean Absolute Error) – MSE (Mean Squared Error) – Supervised learning and unsupervised algorithms in MATLAB.Overview of MATLAB® app for classification and regression/Open source coding/toolbox.

| Module:3 | Neural Networks and Deep Learning | 9 hours |
|---|---|---|
| Fundamentals of artificial neural networks (ANN) – Structure of neurons – Layers (input, hidden, output) – Weights – Biases; Activation functions – Sigmoid – tanh – ReLU – Forward propagation and backpropagation concepts – Optimization techniques used in neural networks; Gradient Descent and Variants – Hyperparameter Optimization – Deep learning concepts; Overview of Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNN) – Modeling time-series behavior in batch reactors and continuous processes.<br>Implementation of neural networks in MATLAB® using Deep Learning Toolbox/Open source coding/toolbox | | |
| **Module:4** | **Optimization using AI** | **9 hours** |
| Classical optimization – Gradient-based optimization – Global optimization techniques – genetic algorithm – particle swarm optimization – Simulated Annealing – Fuzzy logic – Fuzzy sets and concepts – Operation on fuzzy sets – Fuzzy relations – Fuzzification – defuzzification – Fuzzy membership functions – Multi-objective optimization – Visualization of Pareto fronts and decision boundaries.<br>Overview of various optimization tools in MATLAB®/Open source optimization coding/toolbox. | | |
| **Module:5** | **AI/ML Applications in Chemical Engineering** | **7 hours** |
| Fault detection and diagnosis in process plants – Methods of fault diagnosis – Neural network method – Fuzzy logic method; Conventional versus AI based process control – ANN – Fuzzy logic – Artificial Neuro Fuzzy Inference System (ANFIS) – Mamdani Fuzzy Inference System (MAMFIS) – Sugeno Fuzzy Inference System (SUGFIS).<br>Implementation of MATLAB® coding/toolbox for FIS/Open source coding/toolbox. | | |
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Expert lectures from industry or R&D institutions / Industrial Visits | |
| | **Total Lecture hours** | **45 hours** |

**Text Books**

| | |
|---|---|
| 1 | Romagnoli, J.C, Briceño-Mena, L., Manee, V., AI in Chemical Engineering: Unlocking the Power Within Data, 1st ed., CRC Press, USA, 2025. |
| 2 | López-Flores, F.J, Ochoa-Barragán, R., Raya-Tapia, A.Y, Ramírez-Márquez, C., Ponce-Ortega, J.M., Machine Learning Tools for Chemical Engineering: Methodologies and Applications, 1st ed., Elsevier Science, USA 2025. |

**Reference Books**

| | |
|---|---|
| 1. | Sher F. Artificial intelligence in chemical engineering, 1st ed., Elsevier, USA, 2025. |
| 2. | Ren, J., Shen, W., Man, Y., Dong, L. (Eds.), Applications of Artificial Intelligence in Process Systems Engineering, 1st ed., Elsevier, USA, 2021. |

**Mode of Evaluation: Continuous Assessment Test, Quizzes, Case studies, Final Assessment Test**

**List of Experiments**

| | | |
|---|---|---|
| 1. | Classification with imbalanced data | CO1 |
| 2. | Fitting data with generalized linear models / unsupervised anomaly detection | CO1 |
| 3. | Classification using decision trees | CO1 |

| | | |
|---|---|---|
| 4. | Signal classification using Support Vector Machines | CO2 |
| 5. | k-means and hierarchical clustering | CO2 |
| 6. | Evaluate optimal number of clusters | CO2 |
| 7. | Chemical process fault detection using deep learning | CO3 |
| 8. | Predict chaotic time-series using ANFIS | CO3 |
| 9. | Temperature control in a shower using FIS | CO3 |
| 10. | Automated classifier selection with Bayesian and ASHA optimization | CO4 |
| 11. | Fuzzy PID control with Type-2 FIS | CO4 |
| 12. | Weighted nonlinear regression on water pollution data | CO4 |
| 13. | Dimensionality reduction and feature extraction | CO5 |
| 14. | Cluster analysis and anomaly detection | CO5 |
| 15. | Label data using semi-supervised learning techniques | CO5 |
| | | |
| | **Total Lab hours:** | **30 hours** |

| | | | |
|---|---|---|---|
| **Mode of Evaluation: Case studies, Final Assessment Test** | | | |
| **Recommended by Board of Studies** | 22-9-2025 | | |
| **Approved by Academic Council** | | **Date** | |

# CONCENTRATIONS

# CONCENTRATION 1 – COMPUTATIONAL CHEMICAL ENGINEERING

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE302 | **Computational Methods in Chemical Engineering** | 3 | 0 | 2 | 4 |
| **Pre-requisite** | **BAMAT101** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Develop models for single and simultaneous equations, interpolation, regression, optimization, integration, ordinary differential equations (ODE) and partial differential equations (PDE).
2. Solve single and simultaneous equations, optimization, integration, ODE and PDE
3. Develop MATLAB® code/use commercial tools to solve single and simultaneous equations, interpolation and regression analysis, optimization problems, integration, ODE and PDE

**Course Outcomes**

1. Estimate the roots/solution of single/simultaneous equations.
2. Apply suitable interpolation, regression method for analyzing data.
3. Select suitable optimization method for optimizing a chemical processes.
4. Solve integration and ordinary differential equations using suitable computational method.
5. Compute partial differential equations using suitable computational method.

| Module:1 | Solution for Single and Simultaneous Equations | 9 hours |
|---|---|---|

Mathematical models for solving engineering problems, programming and software; Finding roots of a single equation- Direct methods (bisection, Regula falsi) - Indirect methods (Newton-Raphson, Secant method). Types of matrices and matrix operation rules; Solution for linear system of simultaneous equations Direct methods (Gauss Elimination, Gauss Jordan), Iterative methods (Gauss-Jacobi and Gauss-Seidel); Overview of non-linear system of equations; Solving single and simultaneous equations using commercial software such as MATLAB®, MS-Excel®, Aspen Plus®.

| Module:2 | Interpolation and Regression Analysis | 6 hours |
|---|---|---|

Newton's divided-difference interpolating polynomial Linear - polynomial - quadratic rules; Lagrange interpolating polynomial - Linear - polynomial Regression. Usage of curve fitting and regression tools in MATLAB®, MS-Excel®.

| Module:3 | Unconstrained and Constrained Optimization | 8 hours |
|---|---|---|

One-Dimensional unconstrained optimization-Golden section search and Newton's method; Overview on multidimensional unconstrained optimization gradient and non-gradient methods; Constrained optimization Simplex method; Optimization of Chemical Processes using commercial software such as MATLAB®, MS-Excel®, Aspen Plus®.

| Module:4 | Integration and Ordinary Differential Equations | 10 hours |
|---|---|---|

Newton cotes Integration- Trapezoid method – Simpson's 1/3rd rule and 3/8th rule; Initial Value Problems Euler - Predictor-corrector - Runge-Kutta methods; Boundary Value Problems Shooting method - Central difference method. Solving ordinary differential equations using commercial software such as MATLAB®, MS-Excel®.

| Module:5 | Partial Differential Equations | 10 hours |
|---|---|---|

Finite difference solutions of elliptic equations method – Liebmann's method - finite difference solutions of parabolic equations Crank-Nicolson and implicit methods - Overview of hyperbolic equations; Case study on solving PDE using MATLAB®, MS-Excel®.

| | | |
|---|---|---|
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Expert lectures from industry or R&D institutions / Industrial Visits | |
| | **Total Lecture hours** | **45 hours** |

**Text Books**

| | |
|---|---|
| 1 | Chapra S.C, Canale R.P, Numerical Methods for Engineers, 8th ed., McGraw Hill Publications, USA, 2021. |
| 2 | Al-Malah, K.I.M., MATLAB-based computations of chemical engineering principles, 1st ed., John Wiley & Sons Inc., USA, 2025. |

**Reference Books**

| | |
|---|---|
| 1. | Dorfman K.D., Daoutidis P, Numerical Methods with Chemical Engineering Applications, 1st ed., Cambridge University Press, USA, 2017. |
| 2. | Jana A.K., Chemical Process Modelling and Computer Simulation, 3rd ed., Prentice Hall of India, India, 2018. |

**Mode of Evaluation: Continuous Assessment Test, Quizzes, Case studies, Final Assessment Test**

**List of Experiments**

| | | |
|---|---|---|
| 1. | Develop the code/apply commercial tools for single equations – closed Methods | CO1 |
| 2. | Develop the code/apply commercial tools for single equations – Open Methods | CO1 |
| 3. | Develop the code/apply commercial tools for simultaneous equations-Direct Methods | CO1 |
| 4. | Develop the code/apply commercial tools for simultaneous equations-Indirect Methods | CO1 |
| 5. | Develop the code/apply commercial tools for Lagrange interpolation | CO2 |
| 6. | Develop the code/apply commercial tools for Newton’s interpolation | CO2 |
| 7. | Develop the code/apply commercial tools for regression analysis | CO2 |
| 8. | Develop the code/apply commercial tools for unconstraint optimization | CO3 |
| 9. | Develop the code/apply commercial tools for constraint optimization | CO3 |
| 10. | Develop the code/apply commercial tools for Integration | CO4 |
| 11. | Develop the code/apply commercial tools for ODE initial value problems – Euler Method | CO4 |
| 12. | Develop the code/apply commercial tools for ODE initial value problems – Runge-Kutta Method | CO4 |
| 13. | Develop the code/apply commercial tools for ODE boundary value problems | CO4 |
| 14. | Develop the code/apply commercial tools for PDE - elliptic equations | CO5 |
| 15. | Develop the code/apply commercial tools for PDE – parabolic equations | CO5 |
| | **Total Lab hours:** | **30 hours** |

| | | | |
|---|---|---|---|
| **Mode of Evaluation: Case studies, Final Assessment Test** | | | |
| **Recommended by Board of Studies** | 22 – 9- 2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE303** | **Process Equipment Design and Visualization** | **3** | **0** | **2** | **4** |
| **Pre-requisite** | **BCHE302L, BCHE302P** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Describe and distinguish the foundational concepts of unit operations and unit processes in chemical engineering.
2. Apply design principles to major chemical process equipment through informed decision-making.
3. Analyze energy requirement and construct efficient energy network designs for chemical processes.

**Course Outcomes**

1. Apply design principles and standards to analyze process flow diagrams and evaluate fluid and pressure vessel systems.
2. Design and assess heat transfer equipment and energy integration systems
3. Design and assess heat and mass transfer equipment based on thermal and separation principles.
4. Design and evaluate ideal homogeneous and heterogeneous reactors by applying reaction engineering principles.
5. Design and assess solid-fluid process equipment by applying fluid-solid interaction principle.

| **Module:1** | **Process Flow Diagram and Pressure Vessel Design** | **7 hours** |
|---|---|---|

Introduction to process design: Types of flowcharts and interpretation techniques - Design of fluid handling equipment: pumps, pipes, pipe standards. Pressure Vessel Basics: Classification of pressure vessels, Key design codes and selection criteria, Supports and storage design for liquids and gases.

| **Module:2** | **Heat Transfer and Energy Integration** | **9 hours** |
|---|---|---|

**Heat Transfer Equipment:** Basic design equations for heat exchange, Design of double-pipe and shell-and-tube heat exchangers, TEMA classifications and Kern's design method, Design considerations for condensers. **Heat Exchanger Network Design:** Introduction to Pinch Technology and pinch point analysis, Composite and Grand Composite curves.

| **Module:3** | **Mass Transfer Equipment Design** | **10 hours** |
|---|---|---|

Separation Equipment Design: Principles of distillation and separation, Design of distillation and absorber columns, Trays and packing, Design of packed and tray towers, Evaporators: Single-effect and multiple-effect evaporator configurations and Rotary dryer design.

| **Module:4** | **Reactor Design** | **8 hours** |
|---|---|---|
| **Module:5** | **Solid-Fluid Processing Equipment Design** | **8 hours** |

Agitator Design: Impeller selection, flow regimes, mixing parameters, and scale-up principles. Centrifuge Design: Sedimentation and filtration fundamentals, centrifuge types and design. Settling and Clarifier Systems: Design of horizontal, vertical clarifiers; settling behaviors and sludge tank design.

| **Module:6** | **Contemporary Issues** | **2 hours** |
|---|---|---|
| | Expert lecture from industry and R & D organizations | |
| | **Total Lecture hours:** | **45 hours** |

**Text Books**

| | |
|---|---|
| 1 | V.V. Mahajani and S.B. Umarji, Joshi's Process Equipment Design. Laxmi Publications, 2016, 5th ed.,India. |
| 2 | Coulson J.M., Richardson J.F., Chemical Engineering, Volume 6, 2005, 4th ed., Butterworth – Heinemann Publishing Ltd., USA. |
| 3 | H. Scott Fogler, Elements of Chemical Reaction Engineering, 2015, 4$^{th}$ ed., Pearson, India. |

| **Reference Books** | |
|---|---|
| 1. | Joshi. M.V., Mahajani. V.V., Process Equipment Design, 2000, 3rd ed., Mc-Millan India Ltd., India. |
| 2. | Richard A. Turton, Richard C. Bailie, Wallace B.Whiting, Joseph A. Shaeiwitz, Debangsu Bhattacharyya - Analysis, Synthesis and Design of Chemical Processes, 4th ed., Prentice Hall, USA, 2014 |
| 3. | Christie J Geankoplis, Transport processes and Unit Operations, 2003, 4th ed. Prentice Hall India Pvt. Ltd, India. |

**Mode of Evaluation: Quiz, Case studies, Design Project, Case Study, Seminar, CAT and FAT**

| **List of Experiments** | | |
|---|---|---|
| 1. | Preparation of basic Process Equipment symbols | CO1 |
| 2. | Preparation of Process Flow Diagrams | CO1 |
| 3. | Design and drawing of Pressure vessel | CO1 |
| 4. | Design and drawing of Shell and Tube heat Exchanger | CO2 |
| 5. | Analysis of the performance of Heat Exchanger using Aspen plus | CO2 |
| 6. | Design and drawing of Bubble cap tray | CO3 |
| 7. | Design and drawing of Rotary Louvre dryer | CO3 |
| 8. | Design and analysis of Distillation Column using Aspen plus | CO3 |
| 9. | Design of Reactor and Solid-Fluid Equipment using Aspen Plus/Prosimulator | CO4 |
| 10. | Design of Solid Fluid Equipment's Agitator, Centrifuge and Sludge Tanks. | CO5 |
| | **Total hours:** | **30 hours** |

**Mode of Evaluation:**

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22-09-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course code | Course title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE304** | **Process Modelling and Simulation** | **3** | **0** | **2** | **4** |
| **Pre-requisite** | **BAMAT101** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives:**

1. To study the modelling & simulation techniques of chemical processes
2. To discuss the importance of modelling to science, engineering and the economics
3. To identify different types of models and simulations and explain the use of models and simulations for hypothesis testing

**Course Outcomes:**

1. Explain the different modelling approaches
2. Develop mathematical models for various chemical processes
3. Analyze physical and chemical phenomena involved in various processes
4. Interpret the models in the simulators and perform the sensitivity analysis
5. Usage of model solving/developing tools: Matlab, DWSIM, Aspen

| **Module:1** | **Modelling Conservative Principles and Models** | **7 hours** |
|---|---|---|

Introduction to modelling and simulation - classification of mathematical models - systematic approach to model building - conservation principles - constitutive relations.

| **Module:2** | **Steady & Unsteady State Lumped Systems & Distributed** | **10 hours** |
|---|---|---|

Degree of freedom analysis - single and network of process units - systems yielding linear and non-linear algebraic equations - Analysis of liquid level tank - gravity flow tank - jacketed stirred tank heater - Isothermal and Non-isothermal reactors - flash and distillation column - closed loop systems - heat conduction - heat transfer in packed bed - mass diffusion

| **Module:3** | **Flow Sheeting and Solution** | **9 hours** |
|---|---|---|

Flow sheeting - sequential modular and equation oriented approach - partitioning and precedence ordering - simulation of lumped systems including simultaneous solution - modular solution and simulation of distributed parameter systems with examples.

| **Module:4** | **Artificial Neural Network** | **9 hours** |
|---|---|---|

Artificial neural networks, development of ANN based models-Architecture-identification of inputs-choice of the architecture-training the ANNs-Performance of ANN Models-Learning methods- over fitting and under fitting Networks.

| **Module:5** | **Simulations of Engineering systems** | **8 hours** |
|---|---|---|

Monte-Carlo simulation - simulation of continuous and discrete processes with on mass, heat & chemical reaction engineering systems – develop the models/solving using tools

| **Module:6** | **Contemporary issues** | **2 hours** |
|---|---|---|

Guest lecture from industry/ R&D organizations

| | |
|---|---|
| **Total Lecture hours:** | **45 hours** |

**Text books:**

| | |
|---|---|
| 1. | Ashok K., Process Modelling and Simulation in Chemical, Biochemical and Environmental Engineering, 2015,1st ed., CRC press, Boc Raton, FL. |
| 2 | Simant R.U., Process Modelling And Simulation for Chemical Engineers Theory and Practice, 2017, 1st ed., John Wiley & sons Ltd, Chichester, UK. |

**Reference Books**

| | |
|---|---|
| 1. | Jana A.K., Chemical Process Modelling and Computer Simulation, 2018, 3rd ed., PHI Learning, Delhi |
| 2. | Nayef G., Modeling and Simulation of Chemical Process Systems, 2019,1st ed., CRC press, FL |

Mode of evaluation: Continuous Assessment Test, Quiz, Case studies, Final Assessment Test

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22-09-2025 | | |
| Approved by Academic Council | | Date | |

| Experiments | | Course Outcome |
|---|---|---|
| 1. | To develop a model by applying the conservation laws and solve the model | CO1 |
| 2. | To verify the response of interacting tank system by developing the model with the help of Simulink | CO1 |
| 3. | To develop the model for Jacketed stirred tank Heater and solve | CO2 |
| 4. | To develop the model for Van de Vusse Reaction Mechanism and solve | CO2 |
| 5. | To develop model for Non-isothermal CSTRs in series | CO2 |
| 6. | To develop CSTB (continuous stirrer tank bio-reactor) model and solve | CO3 |
| 7. | To develop the Simulink model for Mixing Tank | CO4 |
| 8. | To develop model for heat conduction in solid rod and obtain the temperature profile for various boundary conditions | CO4 |
| 9. | To develop model for steady state heat conduction in rectangular plate using PDE toolbox/PDE modeler | CO5 |
| 10. | To develop model for Un-steady state mass diffusion using PDE toolbox/PDE modeler | CO5 |
| | **Total Laboratory Hours** | **30 hours** |
| **Mode of assessment: Individual Experiment Assessment, Final Assessment Test** | | |

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22-9-2025 | | |
| Approved by Academic Council | No. xx | Date | DD-MM-YYYY |

| Course code | Course title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE401** | **Process Plant Design and Simulation** | **3** | **0** | **2** | **4** |
| **Pre-requisite** | **BAMAT101** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives:**

1. To emphasize on the basic concepts of steady state process plant simulation
2. To impart knowledge and awareness to understand the validity and physicochemical interpretation of thermodynamic models and their limitations
3. To develop skills for plant simulation and optimization, solve chemical engineering problems encountered in chemical industries using professional software's

**Course Outcomes:**

1. Explain the principles for developing a Process flow sheet and its execution
2. Illustrates the approaches to follow in plant simulation
3. Utilize commercial software's for complete simulation of refineries
4. Interpret steady state process plant simulation
5. Overcome the debottleneck existing in process plant and have maximum productivity

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Introduction & Approaches to process simulation** | **8 hours** |
| Introduction to Process Synthesis, Flow sheeting & simulation, Degrees of freedom, Process flow sheet - Process plant simulation Approaches: Sequential modular approach - Simultaneous modular approaches - Equation solving approach | | |
| **Module:2** | **Equation solving Approach** | **9 hours** |
| Partitioning, Decomposition, Probabilistic Transformation *Method (*PTM), slow-wave structure(SWS), Steward, and Rudd-Algorithms, Direct Methods, Iterative methods, Block triangular form (BTF), Bordered block transformation ( BBTF), Block Back Substitution, Beecham-Titchener-Simpson ( BTS). | | |
| **Module:3** | **Decomposition of Networks** | **8 hours** |
| Tearing Algorithms in decomposition of networks, digraph, signal flow graph, Boyer Moore (BM) Algorithm, Binary Tree Algorithm (BTA), Kennard-Stone (K&S) Algorithm, Metropolis-Hastings (M&H) Algorithms, and related problems. | | |
| **Module:4** | **Convergence promotion** | **9 hours** |
| Linear equation – nonlinear equation, Convergence Promotion scheme Newton's method, Direct substitution, Wegstein's method, Dominant eigen value method, Quasi-Newton methods, Acceleration criterion. | | |
| **Module:5** | **Application of flow sheeting software** | **9 hours** |
| Flow sheeting software: Aspen Plus-Steady state simulation, Aspen Hysys-dynamic simulation<br>Complete plant (un)steady state simulation: Any process such as Ammonia plant, Biodiesel plant, NG liquefaction, etc | | |
| **Module:6** | **Contemporary issues** | **2 hours** |
| Guest lecture from industry/ R&D organizations | | |
| | **Total Lecture hours:** | **45 hours** |

**Textbook(s)**

| | |
|---|---|
| 1. | Robin S., Chemical Process Design and Integration, 2016, 2nd ed., Wiley, USA |
| 2 | Jana A.K., Process Simulation and Control using Aspen, 2012, 1st ed., PrenticeHall, New Delhi |

**Reference Books**

| | |
|---|---|
| 1. | Nishanth G.C, Chien H.C, Denny N.K.S, Rafil E, Cheng L.C, Lung C.I, Hao Y.L, Rene E.D., Chemical Engineering Process Simulation, 2017, 1st ed., Elsevier Science, USA |
| 2 | Babu B.V., Process Plant Simulation, 2004, Oxford, India. |

Mode of evaluation: Continuous Assessment Test, Quiz, Case studies, Final Assessment Test

| List of Experiments | | Course Outcome | |
|---|---|---|---|
| 1. | Simulation of Binary Distillation using Aspen plus/ Hysys | CO1 | |
| 2. | Simulation of Heat Exchanger using Aspen plus/ Hysys | CO1 | |
| 3. | Simulation of CSTR using Aspen plus/ Hysys | CO2 | |
| 4. | Simulation of PFR using Aspen plus/ Hysys | CO2 | |
| 5. | Simulation of Adsorption process using Aspen plus/ Hysys | CO2 | |
| 6. | Simulation of Absorption process using Aspen plus/ Hysys | CO2 | |
| 7. | Simulation of Ammonia refrigeration cycle using Aspen plus/ Hysys | CO3 | |
| 8. | Simulation of Ammonia production process using Aspen plus/ Hysys | CO3 | |
| 9. | Simulation of NG liquefaction process using Aspen plus/ Hysys | CO4 | |
| 10. | Simulation of HEN analysis using Aspen Energy Analyser | CO5 | |
| | **Total Laboratory Hours** | | **30 hours** |
| **Mode of assessment: Individual Experiment Assessment, Final Assessment Test** | | | |
| Recommended by Board of Studies | 22-9-2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE402** | **Molecular Dynamics and Simulation** | **3** | **0** | **2** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

The objective of this course is to:

1. Enhance the basic knowledge and intuitive understanding of the molecular dynamics simulations.
2. Developing skills in implementing basic molecular dynamics codes and analyzing their output.
3. Ability to calculate equilibrium and transport properties using both molecular dynamics simulations and Monte Carlo sampling techniques and understand underlying approximations and associated advantages and limitations.

**Course Outcomes**

1. Describe the thermodynamic averaging and statistical ensembles.
2. Explain the finite difference methods used in molecular dynamics simulations to integrate Newton's equations of motion and update particle positions and velocities.
3. Apply the basics of Monte Carlo integration.
4. Analyse the molecular dynamics simulations at constant temperature and pressure.
5. Analyse the simple Brownian dynamics and hydrodynamics.

| | | |
|---|---|---|
| **Module:1** | **Statistical Mechanics** | **7 hours** |
| Common statistical ensembles - Transforming between ensembles - Thermodynamic averages - Fluctuations - Structural quantities - Time correlation functions – Transport coefficients - Long-range corrections - Quantum corrections - Constraints. | | |
| **Module:2** | **Molecular Dynamics** | **9 hours** |
| Equations of motion for atomic systems - Finite difference methods - Molecular dynamics of rigid non-spherical bodies - Constraint dynamics - Checks on accuracy - Molecular dynamics of hard systems. | | |
| **Module:3** | **Monte Carlo Methods** | **9 hours** |
| Monte Carlo integration - Importance sampling - The Metropolis method - Isothermal-isobaric Monte Carlo - Grand canonical Monte Carlo - Molecular liquids. | | |
| **Module:4** | **Advanced Simulation Techniques** | **9 hours** |
| Free energy estimation - Smarter Monte Carlo - Constant temperature molecular dynamics - Constant pressure molecular dynamics - Practical points - The Gibbs Monte Carlo method. | | |
| **Module:5** | **Brownian Dynamics and Non-Equilibrium Molecular Dynamics** | **9 hours** |
| Projection operators - Brownian dynamics - Hydrodynamic and memory effects - Shear flow - Expansion and contraction - Heat flow - Diffusion - Other perturbations - Practical points | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Industry Expert Lecture | | |
| | **Total Lecture hours:** | **45 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | M. P. Allen and D. J. Tildesley, Computer simulation of Liquids, Oxford University Press, New York, 1987. |
| 2. | D. Frenkel and B. Smit, Understanding Molecular Simulation: From Algorithms to Applications, 2nd Ed., Academic Press, San Diego, 2002. |

**Reference Books**

| | |
|---|---|
| 1. | D. C. Rapaport, The art of molecular dynamics simulation, Cambridge university press, 2004. |
| 2 | D. Landau, K. Binder, A guide to Monte Carlo simulations in statistical physics, Cambridge university press, 2021. |
| 3. | B. M. McCoy, Advanced statistical mechanics, OUP Oxford, 2009. |

| | | |
|---|---|---|
| Mode of Evaluation: Quiz/ Case studies / Design Project / Seminar / CAT / FAT | | |
| **List of Experiments** | | |
| 1. | Setting up and running conventional MD simulation with different ensembles and barostats. | CO1 |
| 2. | Familiarity with basic LINUX commands for Molecular Dynamics (MD) simulations | CO2 |
| 3. | Development of force field parameters for MD simulations | CO2 |
| 4. | Analysis of trajectories. | CO2 |
| 5. | MD Softwares: NAMD, CPMD, AMBER, CHARMM, MMTSB. | CO2 |
| 6. | Visualization Softwares: VMD, Pymol. | CO2 |
| 7. | Hybrid molecular dynamics/Monte Carlo methods. | CO3 |
| 8. | Determination of Phase equilibria. | CO4 |
| 9. | Evaluation of transport coefficients. | CO4 |
| 10. | Advanced molecular dynamics methods, including constraints and non-equilibrium molecular dynamics. | CO5 |
| | **Total hours:** | **30 hours** |
| **Mode of Evaluation:** Case studies/ FAT | | |

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22-9-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

# CONCENTRATION 2 – SEPARATION AND PURIFICATION TECHNOLOGY

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE305** | **Mechanical Operations** | **3** | **0** | **2** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Introduce the fundamental principles of particle technology, including characterization, size reduction, and separation techniques.
2. Understand and analyze various mechanical operations such as settling, sedimentation, centrifugation, filtration, agitation, and mixing.
3. Apply theoretical concepts to practical problems in the design and operation of mechanical processing equipment.

**Course Outcomes**

1. Characterize particulate solids based on properties such as particle shape, size, and mixture types, and understand the principles of various screening and conveying methods.
2. Explain and apply the principles of size reduction for different materials, including the operation and selection of various comminution equipment.
3. Analyze and differentiate between various solid-liquid separation techniques such as settling, sedimentation, and centrifugation, and select appropriate methods for specific applications.
4. Understand the theory and practical applications of different filtration methods, including the design and operation of various filter types.
5. Describe the principles of agitation and mixing, and explain the design considerations and performance characteristics of agitators and mixers in various industrial processes.

| **Module:1** | **Introduction to particulate solids** | **8 hours** |
|---|---|---|

Characterization of solid particles: Particle shape, size, mixed particle sizes and size analysis, average particle size, screen analysis, and standard screens; Types of industrial screens: Stationary screens, grizzlies, gyrating screens, vibrating screens, and centrifugal sifter; Comparison of ideal and actual screens, material balances over screen, screen effectiveness and capacity.

| **Module:2** | **Size reduction of solids** | **8 hours** |
|---|---|---|

Principles of comminution, criteria for comminution, energy and power requirements in comminution, crushing efficiency; Laws of crushing; Size-reduction equipment: Crushers, grinders, ultrafine grinders, and cutting machines; Operation of size-reduction equipment: open-circuit and closed-circuit operation, feed control, mill discharge, energy consumption, and removal of heat.

| **Module: 3** | **Settling, Sedimentation, and Centrifugation** | **8 hours** |
|---|---|---|

Theory of particle movement through a fluid, hindered settling, differential settling and separation of solids in classification, sedimentation and thickening, equipment for settling and sedimentation. Centrifugal separation processes: Forces developed in centrifugal separation, equations for rates of settling in centrifuges, centrifuge equipment for sedimentation, centrifugal filtration, and gas–solid cyclone separators.

| **Module: 4** | **Filtration** | **9 hours** |
|---|---|---|

Principles of cake filtration, pressure drop through filter cake, compressible and incompressible filter cakes, filter-medium resistance, cake resistance, constant-pressure filtration, constant-rate filtration, and continuous filtration; Filtration equipment – plate and frame filter press, leaf filter, and rotary drum filter; Filter media, filter aids, and washing filter cakes.

| **Module: 5** | **Agitation and Mixing** | **10 hours** |
|---|---|---|

Purposes of agitation, agitation equipment, impellers, flow patterns in agitated vessels, power consumption, power correlation, and scale-up of agitator design; Blending of miscible liquids, blending in process vessels, jet mixers, and motionless mixers.

| | | |
|---|---|---|
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Expert lecture from industry and R & D organizations | |
| | **Total Lecture hours** | **45 hours** |

**Text Books**

| | |
|---|---|
| 1. | McCabe, W.L., Smith, J.C., and Harriott, P. Unit Operations of Chemical Engineering, Seventh Edition, McGraw Hill Education, 2017. ISBN: 978-8184959635. |
| 2. | Geankoplis, C.J., Hersel, A.A., and Lepek, D.H. Transport Processes and Separation Process Principles, Fifth Edition, Pearson Education, Inc., 2018. ISBN: 978-0134181028. |

**Reference Books**

| | |
|---|---|
| 1. | Swain, A.K., Patra, H. and Roy, G.K. Mechanical Operations, Tata McGraw Hill Education Private Limited, 2011. ISBN: 978-0070700222. |
| 2. | Coulson and Richardson’s Chemical Engineering, Volume 2A: Particulate Systems and Particle Technology, Sixth Edition, Butterworth-Heinemann, 2019. ISBN: 978-0081010983. |
| 3. | Rhodes, M. Introduction to Particle Technology, Second Edition, John Wiley & Sons Limited, 2008. ISBN: 978-0470014288. |
| 4. | Seville, J. and Wu, C.-Y. Particle Technology and Engineering - An Engineer’s Guide to Particles and Powders: Fundamentals and Computational Approaches, Butterworth-Heinemann, 2016. ISBN: 978-0080983370. |

**List of Experiments**

| | | |
|---|---|---|
| 1. | Determination of screen effectiveness | CO5 |
| 2. | Size reduction studies in jaw crusher | CO5 |
| 3. | Determination of the critical speed of ball mill | CO5 |
| 4. | Size reduction studies in roll crusher | CO5 |
| 5. | Determination of terminal settling velocity of a sphere | CO5 |
| 6. | Filtration studies in plate and frame filter press | CO2 |
| 7. | Filtration studies in leaf filter | CO2 |
| 8. | Determination of area of thickener | CO2 |
| 9. | Solids separation using cyclone separator | CO5 |
| 10. | Effectiveness of mixing | CO2 |
| | **Total Lab hours:** | **30 hours** |

**Mode of Evaluation: Assignments, Final Assessment Test**

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22-09-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE306** | **Membrane Separation Processes** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **BACHE201** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To explain the basic membrane separation mechanisms, transport models, membrane materials and modules
2. To characterize and evaluate the membrane performance using membrane permeability parameters
3. To select a suitable membrane for various industrial applications.

**Course Outcomes**

1. Identify suitable membrane modules and membrane separation processes
2. Recognize suitable methods for membrane fabrication and characterization
3. Compute flux, concentration polarization, fouling and operating parameters for various membrane processes
4. Design membrane processes using various transport models
5. Select suitable advanced membrane processes for a given industrial waste.

| **Module:1** | **Membrane Fabrication and Characterization** | **12 hours** |
|---|---|---|

Basic principles of membrane separation processes, membrane processes classifications, membrane materials – polymer, inorganic, and metal materials used in membrane fabrication, advantages and disadvantages of various membrane materials, membrane modules, and typical flow patterns. Membrane fabrication methods - phase inversion process, track-etching, sol-gel peptization, template leaching, interfacial polymerization, wet, dry, and melt spinning, sintering, dip and spin coating methods, membrane modification; membrane characterization - visual methods (SEM and TEM), XRD, FTIR, Hydraulic permeability, bubble point, liquid displacement, mercury porosimetry, permporometry, thermporometry, gas adsorption-desorption, molecular weight cut-off (MWCO), microbial challenge test.

| **Module:2** | **Membrane Transport Theory and models** | **10 hours** |
|---|---|---|

Description of transport process – Mechanism of facilitated transport, Coupled transport, Passive and active transport, Transport through porous membrane and nonporous membrane, Membrane transport models – Kedem-Katchalsky, Spiegler-Kedem, solution- diffusion (SD) model, fouling model, concentration and gel polarization models, and Artificial Intelligence models.

| **Module:3** | **Pressure driven membrane processes** | **12 hours** |
|---|---|---|

Principles of osmosis and reverse osmosis (RO), nanofiltration (NF), microfiltration (MF) and ultrafiltration (UF) membrane processes, Transport mechanism and parameters affecting the performance of pressure-driven membranes, pressure-driven membrane modules and configurations, Calculation of permeate flux and rejection, Industrial applications and design of membrane modules for various industrial applications.

| **Module:4** | **Concentration driven membrane processes** | **12 hours** |
|---|---|---|

Principles of Dialysis – Dialysis Systems, Mass transfer in Dialysis, Hemodialysis, Diffusion dialysis, Application of dialysis in industries. Electro dialysis – Basic principles, Ion exchange membranes, energy requirement, Current utilization, Efficiency, Electro dialysis reversal (EDR), Electro deionization, Applications of electro dialysis.

| **Module:5** | **Other membrane Processes** | **12 hours** |
|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Liquid membranes, Membrane contactor, Membrane distillation, PEM for fuel cell application, membrane bioreactors, and membranes for bio-separation applications. | | | | | |
| **Module:6** | | **Contemporary Issues** | | | **2 hours** |
| **Text Books** | | | | | |
| 1 | Kaushik Nath, Membrane Separation Processes, 2nd ed., PHI Learning Private Limited, New Delhi, India, 2017. | | | | |
| **Reference Books** | | | | | |
| 1. | Ismail A.F., Matsuura T., Membrane Separation Processes Theories, Problems, and Solutions, 1st ed., Elsevier, USA, 2021. | | | | |
| 2. | Pabby A.K., Wickramasinghe S.R., Sastre A.M., Handbook of Membrane Separations Chemical, Pharmaceutical, Food, and Biotechnological Applications, 3rd ed., CRC Press, USA, 2023. | | | | |
| **Mode of Evaluation: Continuous Assessment Test, Quizzes, Case studies, Final Assessment Test** | | | | | |
| **Mode of Evaluation: Case studies, Final Assessment Test** | | | | | |
| **Recommended by Board of Studies** | | | 22-9-2025 | | |
| **Approved by Academic Council** | | | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE307** | **Decarbonization and Energy Transition** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Understand the principles of decarbonization and energy transition
2. Analyze the technical and economic aspects of renewable energy sources
3. Design and evaluate sustainable energy systems

**Course Outcomes**

1. Explain the fundamentals of sustainability in energy systems
2. Assess the benefits of implementing de-carbonisation in energy market
3. Apply carbon management strategies to chemical industry
4. Evaluate decarbonisation pathways in cement, steel and chemicals industry
5. Analyze crosscutting, economics, and policy issues in energy market

| | | |
|---|---|---|
| **Module:1** | **Fundamentals of Energy Systems and Sustainability** | **10hours** |
| Thermodynamic laws, principles of sustainability, sustainability metrics, energy balance in chemical industry, problems in energy efficiency, Greenhouse gases, Power to gas technologies, and energy conversion losses, and demonstrating sustainability metrics in Cement process using Block and PFD diagram | | |
| **Module: 2** | **Energy Conversion in industries** | **12hours** |
| Environment impact of coal, oil and gas resources, grid integration of renewable energy resources, and use of life cycle analysis in industries, Energy conversion in Steel process, demonstrating energy conversion metrics in Coal plants using Aspen Hysys | | |
| **Module:3** | **Electricity and gas generation and distribution** | **12 hours** |
| Fundamentals of electricity and Gas grids, types of hydrogen, green hydrogen production, Industrial heat demand, problems related to role of renewable energy integration, and demonstrating the simulation of electricity and gas generation distribution using Aspen Hysys | | |
| **Module:4** | **Carbon Management and Energy efficiency** | **12 hours** |
| Types of Carbon capturing, Oxy-fuel combustion, storage methods, Carbon capture, utilization, and storage (CCUS), Recycling and closed-loop systems, Problems related to Amine based carbon di oxide capturing systems, and Simulation of $CO_2$ capturing using Hysys | | |
| **Module:5** | **Pathways to Zero-Carbon Industry** | **12 hours** |
| Issue related to Economics in energy transitions, carbon pricing, applying subsidies to green start up, Finance regulation towards net zero emission, Equity, justice, and global cooperation, and Roadmaps for sustainable prosperity | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Industry Expert Lecture | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**


1. Boyle, G., Everett, B., & Ramage, J. (2012). Energy systems and sustainability: Power for a sustainable future (2nd ed.). Oxford University Press, UK.
2. Rissman, J. (2024). Zero-carbon industry: Transformative technologies and policies to achieve sustainable prosperity. Columbia University Press.

| **Reference Books** | | | |
|---|---|---|---|
| 1. | MacKay, D. J. C. (2009). Sustainable energy – Without the hot air. UIT Cambridge. | | |
| 2 | McKinnon, A. (2018). Decarbonizing logistics: Distributing goods in a low-carbon world. Kogan Page. | | |
| Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test | | | |
| Recommended by the Board of Studies | 22-9-2025 | | |
| Approved by the Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE403** | **Nano Science and Separations** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To understand the fundamental principles of nanoscience and the unique properties of materials at the nanoscale
2. To gain knowledge of various synthesis methods for different types of nanomaterials relevant to separation applications
3. To analyze and critically evaluate the application of nanomaterials in diverse separation techniques, including their advantages and limitations

**Course Outcomes**

1. Describe the basic concepts of nanoscience and distinguish the physical and chemical properties of nanomaterials from bulk materials
2. Evaluate and select appropriate synthesis techniques for specific nanomaterials tailored for separation processes
3. Apply the principles of nanotechnology to design and optimize separation strategies using nano adsorbents, nanomembranes, and catalytic nanomaterials
4. Analyze and interpret data from characterization techniques used to assess the properties and performance of nanomaterials in separation systems
5. Propose innovative solutions for challenging separation problems, leveraging the unique capabilities of nanomaterials

| **Module:1** | **Fundamentals of Nanoscience** | **10 hours** |
|---|---|---|

Introduction to Nanoscience and Nanotechnology - Size-Dependent Properties: Quantum Confinement, Surface Area to Volume Ratio, Surface Energy - Electronic Properties - Optical Properties - Mechanical Properties - Magnetic Properties - Self-Assembly and Bottom-Up Approaches - Top-Down Approaches: Lithography, Milling - Different Types of Nanomaterials

| **Module:2** | **Nanomaterial Synthesis and Characterization for Separations** | **12 hours** |
|---|---|---|

Overview of Chemical Synthesis Methods: Wet Chemical Routes - Gas Phase Synthesis: Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD) - Biological and Green Synthesis Routes - Template-Assisted Synthesis Methods - Introduction to Characterization Techniques - Structural Characterization - Spectroscopic Characterization - Surface Characterization - Thermal Analysis - Particle Size and Zeta Potential Measurement - Advanced Characterization for Porous Materials: Mercury Intrusion Porosimetry, Gas Adsorption Isotherms

| **Module:3** | **Nanoadsorbents for Separation Processes** | **12 hours** |
|---|---|---|

Introduction to Adsorption: Principles, Isotherms - Advantages of Nanoadsorbents - Carbon Nanoadsorbents: Activated Carbon, Carbon Nanotubes, Graphene-based materials for Adsorption - Metal-Organic Frameworks (MOFs) as Adsorbents - Magnetic Nanoadsorbents for Easy Separation and Recovery - Polymeric Nanoadsorbents and Dendrimer-based Adsorbents - Nanoadsorbents for Gas Separation: CO2 Capture, Hydrogen Storage - Regeneration and Reusability of Nanoadsorbents

| **Module:4** | **Nanomembranes for Separation Processes** | **12 hours** |
|---|---|---|

Introduction to Membrane Separations - Advantages of Nanomembranes - Polymeric Nanocomposite Membranes - Carbon Nanotube (CNT) Membranes - Graphene and Graphene Oxide (GO) Membranes - Zeolite Membranes and Metal-Organic Framework (MOF) Membranes - Gas Separation using Nanomembranes - Fouling in Nanomembranes and Strategies for Mitigation

| Module:5 | Advanced Nanoscience Applications in Separations & Future Directions | 12 hours |
|---|---|---|
| Nano Catalysis for Selective Separations - Nanomaterials in Chromatographic Separations: Nano-HPLC, Nano-GC - Microfluidics and Nano fluidics for Lab-on-a-Chip Separations - Nanomaterial-based Sensors for Real-time Monitoring of Separations - Environmental Impact of Nanomaterials in Separations: Toxicity and Safety - Challenges and Limitations of Nanoscience in Separations - Research Frontiers and Future Directions in Nanoscience and Separations | | |
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Expert lecture from industry and R & D organizations | |
| | **Total Lecture hours:** | **60 hours** |

**Text Books**

| | |
|---|---|
| 1. | Charles P. Poole, Jr., Frank J. Owens., Introduction to Nanotechnology, 2023, 1st ed., John Wiley & Sons, Inc., USA. |
| 2. | Sulabha K. Kulkarni., Nanotechnology: Principles and Practices, 2014, 3rd ed., Springer Nature. |

**Reference Books**

| | |
|---|---|
| 1. | Chaudhery Mustansar Hussain., Handbook of Functionalized Nanomaterials for Industrial Applications., 2020, 1st ed., Elsevier. |
| 2. | Chris Binns, Introduction to Nanoscience and Nanotechnology, 2010, 1st edition, John Wiley & Sons Inc, USA. |

**Mode of Evaluation: Quiz, Case studies, CAT and FAT**

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22-9-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE404 | Downstream Processing | 4 | 0 | 0 | 4 |
| Pre-requisite | NIL | Syllabus version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. To impart basic knowledge in the area of separation technologies for biomolecules.
2. To understand the workflow for the separation of DNA, RNA, proteins and secondary metabolites.
3. To assimilate recent research findings, advancements and developments in the subject

**Course Outcomes**

1. Outline the importance of separation technologies for biomolecules.
2. Explain the underlying principles of filtration and centrifugation.
3. Choose the appropriate techniques to isolate and concentrate the bioproducts.
4. Select the specific chromatography based on the nature of the product and the required purity level.
5. Outline the principle behind the crystallization and filtration process.

| Module:1 | INTRODUCTION TO DOWNSTREAM PROCESSING | 12 hours |
|---|---|---|

Introduction to the separation of biomolecules and its importance in biotechnology, Characteristics of fermentation broth and biomolecules. Cell Disruption for Product Release: Physical, Chemical, and Enzymatic Methods. Pretreatment and stabilization of bioproducts

| Module:2 | PHYSICAL METHODS OF SEPARATION | 12 hours |
|---|---|---|

Unit operations for solid-liquid separation - Filtration, Centrifugation-based methods for separation of the cell organelles and biomolecules (DNA, RNA, Proteins, and secondary metabolites).

| Module:3 | RECOVERY AND ISOLATION OF PRODUCTS | 10 hours |
|---|---|---|

Liquid-liquid extraction - aqueous two-phase extraction; Membrane separation - microfiltration, ultrafiltration, nanofiltration and reverse osmosis, dialysis; Precipitation of proteins by different methods.

| Module:4 | PRODUCT PURIFICATION | 12 hours |
|---|---|---|

Basics of chromatography and its use in separation of biomolecules; Types of chromatography - adsorption, size exclusion, ion-exchange, chiral column, hydrophobic interaction, HPLC, bioaffinity, pseudo-affinity, hydroxyapatite chromatographic techniques.

| Module:5 | FINAL PRODUCT POLISHING AND FINISHINGOPERATIONS | 12 hours |
|---|---|---|

Crystallization - Basic Concepts, Crystal size distributions, Batch crystallization, Recrystallization, Drying - Basic Concepts, Equipment.

| Module:6 | Contemporary Topics | 2 hours |
|---|---|---|

Industry Expert Lecture.

| | Total Lecture hours: | 60 hours |
|---|---|---|

**Text Book(s)**

| | |
|---|---|
| 1. | Belter P.A., Cussler E.L., and Wei-Houhu, (1988), Bio separations- Downstream Processing for Biotechnology, Wiley Interscience. |
| 2. | Roger G.H., Paul W.T., Scott R.R, and Demetri P.P. (2015), Bio separations Science and Engineering, 2nd Edition, OxfordUniversity Press. |

**Reference Books**

| | |
|---|---|
| 1. | Jenkins R.O., 1992, Product Recovery in Bioprocess Technology - Biotechnology, Open Learning Series, Butterworth-Heinemann. |
| 2. | Janson J.C., and Ryden L. (1989), Protein Purification - Principles, High Resolution Applications, VCH publications. |

| | |
|---|---|
| 3. | Bailey, J.E., and Ollis, D.F. (1986). Biochemical Engineering Fundamentals, Chemical Engineering Education, 2nd Edition. |

Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test

| | | | |
|---|---|---|---|
| Recommended by the Board of Studies | 22-9-2025 | | |
| Approved by the Academic Council | No. xx | Date | DD-MM-YYYY |

# CONCENTRATION 3 – ENERGY AND ENVIRONMENTAL TECHNOLOGY

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE308** | **Hydrogen Production, Storage and Utilization** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **x.x** | | | |

**Course Objectives**

The objectives of this course are to:

1. Understand how hydrogen is produced, stored, and safety issues
2. Evaluate how hydrogen as an energy vector can help solve energy problems
3. Assess the use of hydrogen in industries

**Course Outcomes**

1. Describe the basic thermodynamic and electrochemical principles of hydrogen production, storage, and utilization.
2. Demonstrate the role of hydrogen in future energy systems
3. Assess green hydrogen production methods and analyze techno-economic feasibility
4. Evaluate the performance and efficiency of hydrogen storage systems
5. Analyse fuel cell utilization and hydrogen policy frameworks

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Introduction** | **10 hours** |

Types of hydrogen, properties, decarbonization, global policies, power to gas technologies, hydrogen from fossil energy sources, and problems in thermodynamics of hydrogen production

| | | |
|---|---|---|
| **Module:2** | **Role of Hydrogen Production** | **12 hours** |

Process flow chart of steam and ethanol reforming, partial oxidation, autothermal reforming, biomass gasification, ethanol reforming, and material and energy balance of steam reforming using Aspen

| | | |
|---|---|---|
| **Module:3** | **Green hydrogen from electrolysis** | **12 hours** |

Hydrogen color spectrum, PEM water electrolysis, sea water elecctrolysis, alkaline electrolysis, solid oxide electrolysis, Scale up. Problems in green electrolysis, cost analysis, and process optimization of PEM electrolysis using Aspen Hysys

| | | |
|---|---|---|
| **Module:4** | **Performance of hydrogen storage systems** | **12 hours** |

Compressed gas, liquefied storage methods, chemical carriers (ammonia, LOHCs)
Storage Materials selection, carbon based & advanced sorbents, problems in chemical storage systems, cryogenic liquid hydrogen, hydrogen transport simulation, and storage vessel and cylinder design

| | | |
|---|---|---|
| **Module:5** | **Fuel cell utilization and hydrogen policies** | **12 hours** |

Fuel cells types, thermodynamics and kinetics of fuel cell. Analysis of Fuel Cell performance, hydrogen transport and utilization, integration in gas grids, hydrogen Safety, hydrogen economy and national green hydrogen mission, demand creation, hydrogen eco system, supply chain, simulation of hydrogen purification and compression, Aspen Plus simulation of steam methane reforming for hydrogen

| | | |
|---|---|---|
| **Module:6** | **Contemporary Topics** | **2 hours** |

Industry Expert Lecture

| | | |
|---|---|---|
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | Abbas T., Hamid R V, Albert L, and Sedigheh, F., Hydrogen Production, Storage, and Utilization: Technologies and Applications, CRC Press, 2024. |
| 2. | Rifkin J. (2002) The hydrogen economy: the creation of the worldwide energy web and the redistribution of power on earth, New York: J.P. Tarcher/Putnam. |

**Reference Books**

| | |
|---|---|
| 1. | Larminie, J. and Dicks A. (2003). Fuel cell systems explained. 2nd Ed, Chichester, West Sussex: J. Wiley. |
| 2 | Cherryman S J, Maddy J, Hawkes F R, Hawkes D L, Dinsdale R M, Guwy A J, Premier G C, (2004) |

| | |
|---|---|
| | Hydrogen and Wales - A Vision of the Hydrogen Economy in Wales: Placing Wales in a position to take full advantage of the hydrogen economy, University of Glamorgan, 1-84054-116-4. |
| 3 | Boudellal., M. (2018). Power-to-Gas: Renewable hydrogen economy for the energy transition. De Gruyter. |
| 4 | *Hydrogen and Fuel Cells: Emerging Technologies and Applications* by Bent Sørensen |

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE309** | **Electrochemical Engineering** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |

**Course Objectives:**

1. Outline the concepts of electrochemical potential and electrode & electrochemical cells
2. Develop a fundamental understanding of the electrical double layers and the electrokinetic model
3. Solve problems related to electrochemical processes and devices.

**Course Outcome:**

Upon successful completion of the course, the students will be able to

1. Study the concepts of electrostatics, electrodynamics, electrical circuit theory, and Faraday's Law
2. Evaluate the potential of electrochemical systems based on thermodynamic data
3. Formulate an electrochemical theory to characterize the half-cells
4. Apply knowledge of electrokinetic phenomena to design a fuel cell and an electrolyzer
5. Perform data analytics to measure the properties of different components of electrochemical cells

| | | |
|---|---|---|
| **Module:1** | **Introduction to electrochemical engineering** | **12 hours** |
| Fundamentals of potential, voltage, current, Faraday's law, redox reaction, limiting current density, supporting electrolyte, transport processes within electrolytes, and potential -pH diagram, Problems in electrochemical cells and electrode potentials | | |
| **Module:2** | **Electrochemical double layer** | **12 hours** |
| Electrolytic polarization, Dissolution and decomposition potential, overvoltage, diffusion layer, charge density, double layer capacitance by electrocapillary, Helmholtz, Gouy-Chapman, and Stern models of the double layer, and Problems in the double layer | | |
| **Module:3** | **Electrode kinetics** | **12 hours** |
| Equilibrium potential, Nernst equation, Butler Volmer Equation, Problems in exchange current density, charge transfer measurement, concepts of rate-determining step, Polarization curve and Tafel method | | |
| **Module:4** | **Electrocatalysis and electrochemical properties** | **12 hours** |
| Volcano plot, comparison of electrocatalysts, mechanism of hydrogen evolution, and oxygen reduction reaction, determination of leak current using linear sweep voltammetry, measuring electrochemical area using cyclic voltammetry, derivation of Randles-Sevcik's equation, effect of sweep rate-analysis of cyclic voltammograms, Chronopotentiometry, Impedance spectroscopy | | |
| **Module:5** | **Electrochemical cells** | **10 hours** |
| Design of the electrolytic cells, fuel cells, lead acid batteries, lithium ion batteries, and half-cells for electrode characterizations | | |
| **Module:6** | **Contemporary issues and** | **2 hours** |
| Guest lectures of the experts from Industry and R &D organizations | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | J.O.M Bockris & A.K.N. Reddy, “Modern Electrochemistry”, Vol 2, Plenum Press (Chapter 7 for unit I: Chapters 8 & 9 for unit II ; Chapter 10 for unit III), 1996. |
| 2 | A.J.Bard & L.R. Faulkner, ”Electrochemical Methods Fundamentals and Applications”, John Wiley & Sons. 3nd Edition, 2001. |

**Reference Books**

| | |
|---|---|
| 1. | James A. Plam Beck, “Electroanalytical Chemistry – Basic Principles and Applications”, John Wiley & Sons, Wiley Publication, 1982 |

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE310** | **Green and Sustainable Engineering** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Familiarize with the fundamentals of green chemistry and engineering and apply these principles for sustainably designing the chemical processes.
2. Emphasize on the basic concepts of environmentally friendly, hazard-free, and safer chemical products.
3. Impart the necessary knowledge required for evaluating the environmental fate, exposure, and life cycle concepts with reference to chemical processes.

**Course Outcomes**

1. Explain the principles of green chemistry and engineering
2. Apply the green chemistry principles in synthesizing the green chemicals and designing the processes and products
3. Identify the appropriate pollution prevention techniques for different unit operations and flow sheets.
4. Evaluate the fate and exposure of different chemicals using physical and chemical properties.
5. Explain different concepts in environmental cost accounting and life cycle concepts in product and process design

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Introduction to Green and Sustainable Engineering** | **10 hours** |
| The twelve principles of green chemistry and green engineering with examples. Green chemistry metrics- atom economy, E factor, reaction mass efficiency, and other green chemistry metrics, application of green metrics analysis to synthetic plans. | | |
| **Module:2** | **Environmentally benign processes** | **12 hours** |
| Introduction to environmentally friendly processes -alternate solvents- supercritical solvents, ionic liquids - water as a reaction medium - energy efficient design of processes- photo, electro, and sonochemical methods - microwave assisted reactions.Introduction to Process Energy and Mass Integration: A Case Study of a Process Flowsheet. | | |
| **Module:3** | **Unit Operations and Pollution Prevention** | **12 hours** |
| Pollution prevention in material selection for unit operations – Pollution prevention for chemical reactors - separation devices- Pollution prevention applications for separative reactors. Pollution prevention in storage tanks and fugitive sources. Pollution prevention assessment integrated with HAZOP analysis. Integrating risk assessment with process design—A Case Study. | | |
| **Module:4** | **Evaluating Environmental Fate and Exposure** | **14 hours** |
| Introduction - Chemical and physical property estimation - Estimating environmental persistence - Estimating ecosystem risks - Using property estimates to estimate environmental fate and exposure - Classifying environmental risks based on chemical structure. Occupational exposures - Recognition, evaluation, and control - Exposure assessment for chemicals in the ambient environment- Designing safer chemicals | | |
| **Module:5** | **Environmental Cost Accounting and Life Cycle concepts** | **10 hours** |
| Environmental cost accounting – Life cycle concepts and product stewardship – Industrial Ecology | | |
| **Module:6** | **Contemporary Issues** | **2 hours** |
| Expert lectures from Industry / R&D Labs | | |
| | **Total Lecture hours:** | **45 hours** |

| Text Book(s) | | | |
|---|---|---|---|
| 1. | Allen and Shonnard, Green Engineering, 1st edition, Prentice Hall, 2001. | | |
| 2. | Lancaster, Green Chemistry: An introductory text, RSC Publishing, 2016, | | |
| **Reference Books** | | | |
| 1. | Alexi Lapkin and David Constable (Eds), Green chemistry metrics, Wiley publications, 2008 | | |
| 2 | Stanley E Manahan, Environmental Chemistry, 1st edition, Lewis Publishers,1993 | | |
| 3. | V.K.Ahluwalia, Green Chemistry, 1st Edition, Narosa Publishing House Pvt. Ltd., 2012 | | |
| Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test | | | |
| Recommended by the Board of Studies | 22.9.2025 | | |
| Approved by the Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE405** | **Environmental Pollution Control** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To understand the pollution types, their impact and different environmental standards related to air and water
2. To identify and design the equipment's for air and water pollution control
3. To illustrate the effective methods of solid and hazardous waste management and pollution control strategies in process industries

**Course Outcomes**

1. Explain types of pollution, their impacts, relevant prevention strategies, environmental standards, and their linkage to Sustainable Development Goals (SDGs).
2. Analyze meteorological impacts on air pollutant dispersion and assess air pollution control equipment for particulate and gaseous emissions.
3. Examine the characteristics of effluent streams and evaluate the performance of wastewater treatment processes across preliminary, primary, secondary, and tertiary stages.
4. Demonstrate appropriate methods for the classification, collection, storage, and disposal of solid, hazardous, biomedical, and e-wastes, using sustainable waste management practices.
5. Apply pollution control strategies to selected industries and interpret basic concepts of circular economy and life cycle assessment.

| Module:1 | Introduction | 12 hours |
|---|---|---|

Introduction to Environmental pollution: pollution types - types of emissions from chemical industries and effects on environment and human health - Pollution Prevention strategies and processes - characterization of emission and effluents - Environmental standards (water and air) -Environmental Legislations and regulations - EIA – MINAS - Sustainable Development Goals (SDGs)

| Module:2 | Air pollution control | 12 hours |
|---|---|---|

Metrological aspects of air pollution dispersion - Temperature lapse rates - atmospheric stability and inversions - Dispersion of air pollutants - The Gaussian plume model - Principles and design of air pollution control equipments (particulate and gaseous pollutants) - gravity settling chamber – cyclone separator – electrostatic precipitators – fabric filters – absorbers – adsorbers.

| Module:3 | Water pollution control | 12 hours |
|---|---|---|

Characterization of effluent streams - Oxygen sag curve - Selection, design and performance analysis of waste water treatment processes: preliminary, primary (screening, grit removal, sedimentation, coagulation and flocculation) and secondary treatment processes (suspended and attached growth process) – sludge separation and drying - tertiary treatment processes (qualitative treatment)

| Module:4 | Solid waste management | 12 hours |
|---|---|---|

Classification of solid waste - collection, storage and transport of solid waste - 4R concept - waste disposal methods: composting, landfilling and incineration - Hazardous wastes; definition and classification - Hazardous waste management techniques - biomedical and e-waste management

| Module:5 | Pollution control in chemical process industries | 10 hours |
|---|---|---|

Sources – characteristics – pollution control strategies for selected industries: Textiles - Tanneries - Pharmaceuticals - Electroplating - Refineries - Thermal power plants – Circular economy - Life cycle assessment (basic concepts)

| Module:6 | Contemporary Issues | 2 hours |
|---|---|---|

Expert lectures from industry or R&D institutions / Industrial Visits

| | | |
|---|---|---|
| | **Total Lecture hours:** | **60 hours** |

| **Text Books** | | |
|---|---|---|
| 1. | Rao C.S., Environmental Pollution Control Engineering, 2018, $3^{rd}$ ed., New Age International Publishers, India. | |
| 2. | Metcalf & Eddy, Inc., Wastewater Engineering: Treatment and Resource Recovery, 2014, $5^{th}$ ed., McGraw-Hill, New York. | |
| **Reference Books** | | |
| 1. | Tchobanoglous G., Theisen H., Vigil S.A., Integrated Solid Waste Management, 2014, $1^{st}$ ed., McGraw Hill Education, India. | |
| 2. | Bhatia S.C., Environmental Pollution and Control in Chemical Process Industries, 2013, $2^{nd}$ ed., Khanna publishers, India. | |
| 3. | Keshav Kant, Rajni Kant, Air Pollution and Control, 2023, $1^{st}$ ed., Khanna publishers, India. | |
| 4. | Karia, G. L., Christian, R.A., Juriwala, N.D, Wastewater Treatment: Concepts and Design Approach, $3^{rd}$ ed., PHI learning, India. | |
| 5. | Pollution Control Law Series: PCLS/02/2010, Central Pollution Control Board, 2010, $6^{th}$ ed., India. | |
| **Mode of Evaluation: Quiz, Assignment, CAT and FAT** | | |
| **Recommended by Board of Studies** | 22.9.2025 | |
| **Approved by Academic Council** | | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE406** | **Renewable Energy Policies and Economics** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **Nil** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Explain the basics of renewable energy sources, integrating with the role in sustainability, and energy transition economics
2. Explore the components of an electricity market, its regulation, and its pricing systems.
3. Assess and evaluate the project finance along with the cash flows, analyzing them, especially in terms of risk management.
4. Familiarize students with finance metrics and key policy instruments
5. Critical thinking on global renewable energy transitions, on sustainable futures, and policy innovations.

**Course Outcomes**

1. Explain the economic principles and policy frameworks that guide the global and national shift from fossil fuels to renewable energy sources.
2. Examine the structure, regulation, and pricing methods of electricity markets. Consider the integration challenges of renewable energy.
3. Apply financial models and tools to assess the feasibility and risks of renewable energy projects in various business and market situations.
4. Evaluate the impact and effectiveness of different policy tools, such as feed-in tariffs, tax credits, and carbon pricing, in encouraging clean energy investments.
5. Explain strategies for energy transition, climate policies, and innovations in sustainable energy technologies.

| **Module 1:** | **Renewable energy sources and economic policies** | **11 hours** |
|---|---|---|

Fundamentals of renewable energy sources - Renewable vs. non-renewable sources - Developments in renewable energy towards sustainability - From fossil fuels to renewable energy - Energy economics and policy - Basic economic principles of energy demand and supply - Frameworks of global and national renewable energy policies - Basics of renewable energy project financing.

| **Module 2:** | **Electricity Markets, Regulation, and Grid Economics** | **11 hours** |
|---|---|---|

Electricity generation, utilities, and economics- Deregulation, pricing models, and smart grid evolution - Types of various market models - Transmission cost management and grid access issues - Renewable energy in power markets - Managing transmission costs and risks for renewable projects.

| **Module 3:** | **Renewable Energy Project Finance and Risk Management** | **12 hours** |
|---|---|---|

Basics of project finance - Modelling of cash flow, debt sizing, and financial ratios - Stakeholder roles and risk allocation strategies - Business models for rooftop solar and distributed energy - Project development and valuation- Energy storage financing- Renewable energy finance in the international context.

| **Module 4:** | **Renewable Project Valuation & Policy Tools** | **12 hours** |
|---|---|---|

Economic metrics tools: LCOE, NVP, IRR, payback analysis - Offtake strategies: PPAs, merchant pricing, hedging mechanisms - Policy tools: FIT, RPS, tax equity, subsidies - Tax structures for financing renewable energy projects - Emerging market trends and incentive evaluation.

| **Module 5:** | **Global Energy Transitions and Future Frontiers** | **12 hours** |
|---|---|---|

Based on India, the U.S., and Europe - Innovation of clean energy, storage financing, and hydrogen economy - Geothermal, Ocean Power, and climate change - Cap-and-Trade Emissions trading - Montreal and Kyoto protocol - Climate finance - Taxing carbon and carbon pricing, and sustainability indicators - Policies for the sustainable future of energy.

| **Module 6:** | **Contemporary Topics** | **2 hours** |
|---|---|---|

Industry Expert Lecture

| | **Total Lecture hours:** | **60 hours** |
|---|---|---|

| Textbooks: | |
|---|---|
| 1. | R. L. Nersesian, Energy Economics: Markets, History and Policy, 2016, 2nd ed., Routledge, United Kingdom. |
| 2. | S. Raikar, S. Adamson, Renewable Energy Finance: Theory and Practice, 2020, 1st ed., Academic Press (Elsevier), United States. |
| **Reference Books:** | |
| 1. | B. K. Sovacool, M. A. Brown, S. V. Valentine, Fact and Fiction in Global Energy Policy, 2016, 1st ed., Johns Hopkins University Press, United States. |
| 2 | D. Thomas, J. M. Harris, B. Roach, The Economics of Renewable Energy, 2014, 1st ed., Global Development and Environment Institute, Tufts University, United States. |
| 3. | J. Twidell, T. Weir, Renewable Energy Resources, 2015, 3rd ed., Routledge, United Kingdom. |

Mode of Evaluation: CAT / Written Case studies / Quiz / FAT / Seminar / Group Discussion.

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|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

# CONCENTRATION 4: INDUSTRIAL CHEMICAL ENGINEERING

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE311** | **Chemical Process Technology and Economics** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To provide students with a comprehensive understanding of core chemical process industries, including chloro-alkali, cement, inorganic, industrial gases, and clean energy technologies, alongside an introduction to their economic considerations.
2. To equip students with knowledge of the manufacturing processes, economic aspects, and key products within the fertilizers, agrochemical, and related industries, as well as the fundamentals of petroleum technology from crude oil refining to secondary processes.
3. To develop students' ability to analyze and apply principles of process plant economics, including cash flow management, cost estimation, financial statements, and depreciation methods, in the context of industrial operations.

**Course Outcomes**

1. Describe the fundamental principles and processes involved in major inorganic chemical industries such as chloro-alkali, cement, and glass manufacturing, and discuss their environmental and techno-economic considerations.
2. Analyze the production methods and applications of industrial gases ($CO_2$, hydrogen, oxygen, nitrogen) and articulate the significance of clean and renewable energy processes in modern industrial settings.
3. Explain the manufacturing of various fertilizers (ammonia, urea, phosphoric acid, potash) and agro-products, and identify key economic aspects related to their production.
4. Illustrate the different stages of petroleum refining, from crude oil processing to advanced secondary refining techniques, and comprehend the impact of crude oil composition on refining processes.
5. Evaluate the financial viability of industrial projects by applying concepts of cash flow, capital expenditure estimation, operational costs, and various depreciation calculation methods.

| **Module:1** | Chloro-Alkali, Cement & Inorganic Process Industries | **12hours** |
|---|---|---|

Chloro-Alkali Industry; Sulphur and Sulphuric Acid; Cement Industry; Glass Manufacturing; Techno-Economic Considerations

| **Module:2** | **Industrial Gases & Clean Energy Technologies** | **12 hours** |
|---|---|---|

Industrial Gases $CO_2$, Hydrogen, Oxygen and Nitrogen; Producer Gas & Syn-Gas; Natural Gas Processing; Clean and Renewable Energy Processes; Economic Evaluation

| **Module:3** | Fertilizers, Agrochemical and Agro-products Industries | **12 hours** |
|---|---|---|

**Nitrogenous Fertilizers-** Ammonia, Urea, Nitric Acid; **Phosphatic Fertilizers-** Phosphoric acid, Mono- and Di-ammonium phosphate, Single and Triple super phosphate; **Potassium Fertilizers** Potash mining and refining; **Economic Aspects; Pulp and Paper; Sugar; Fats, Oils, Soap and Detergent**

| **Module:4** | **Petroleum Technology** | **12 hours** |
|---|---|---|

**Overview of Refining Industry;** Crude oil composition, classification, assays, Desalting, atmospheric and vacuum distillation; Petroleum refining processes - cracking - reforming - secondary refining processes

| **Module:5** | **Process plant Economics** | **10 hours** |
|---|---|---|

Cash flow for industrial operations, financial sources, Equipment costs, material transfer and handling costs, Estimation of capital requirements and operating expenses. Cost and asset accounting, financial statements, Interest and Investment costs, Taxes and Insurance, Depreciation- Calculation methods

| | | |
|---|---|---|
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Guest lectures of the experts from Industry and R &D organizations | |
| | **Total Lecture hours** | **60 hours** |

**Text Books**

| | |
|---|---|
| 1 | M. Gopala Rao and Marshall sittig, Dryden's Outline of Chemical Technology, 2010, 3rd ed., East West press, India. |
| 2 | James R Couper: Process Engineering Economics, 2003, Marcel Dekker Inc., USA. |

**Reference Books**

| | |
|---|---|
| 1. | Austin G.T., Shreve's Chemical Process Industries, 201 7, 5th ed., McGraw Hill, USA. |

**Mode of Evaluation: Continuous Assessment Test, Quizzes, Case studies, Final Assessment Test**

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|---|---|---|---|
| **Recommended by Board of Studies** | 22-9-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE313 | Bioprocess Technology | 4 | 0 | 0 | 4 |
| Pre-requisite | NIL | Syllabus version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. To introduce the fundamental principles of bioprocess.
2. To develop an understanding of bioreactors' basic design and various bioprocessing cultivation strategies.
3. To understand various media components, sterilization kinetics and strategies involved in growth and product formation.

**Course Outcomes**

1. Describe the significance of microbiology, biochemistry and industrial bioreactors.
2. Explain the basic principles of enzyme and their kinetics.
3. Explain the formulation of medium, which supports maximization of product.
4. Choose an appropriate sterilization design for sterilizing different media.
5. Apply appropriate cultivation strategies for maximum product formation.

| Module:1 | Basic Microbiology, Biochemistry and introduction to bioreactors | 12 hours |
|---|---|---|

Basics of Biology - overview of biotechnology - Diversity in microbial cells - Cell constituents - Chemicals for life - Examples of microbial synthesis - Major metabolic pathways - Bioenergetics - Glucose metabolism - Biosynthesis.

Classification of bioreactors - Batch and continuous types - Fed-batch reactors - Free and immobilized whole-cell and enzyme reactors - Reactors in series with and without recycle

| Module:2 | Enzymes and Enzyme kinetics | 12 hours |
|---|---|---|

Enzymes - Classification of enzymes - Mechanism of enzymatic reactions - Michaelis Menten kinetics - Enzyme inhibition - Inhibition kinetics - Enzyme denaturation and inactivation- Factors affecting the reaction rates - Enzyme immobilization - kinetics of immobilized enzymes - Mass transfer effects on immobilization.

| Module:3 | Media design and optimization | 12 hours |
|---|---|---|

Criteria for good medium, medium requirements for fermentation processes, carbon, nitrogen, minerals, vitamins and other complex nutrients, oxygen requirements, medium formulation for optimal growth and product formation, examples of simple and complex media, medium optimization methods – Plackett-Burman design, Response Surface Methodology.

| Module:4 | Sterilization kinetics | 10 hours |
|---|---|---|

Concept of media sterilization; Thermal Death Kinetics; Design of batch and continuous sterilization processes; Filter sterilization of liquid media and air; filter sterilization based numerical problems.

| Module:5 | Kinetics of microbial growth, product formation and transport in microbial systems | 12 hours |
|---|---|---|

Biomass estimation - Direct and Indirect methods, Kinetics of cell growth & substrate utilization; Unstructured kinetic models for microbial growth (Monod & modified Monod models - logistic equation); Kinetics of product formation - Luedeking-Piret equation and analysis; Substrate and product inhibition of cell growth and product formation; Batch and continuous cultivation.

Rheological behaviour of broth - Agitation and mixing - Power consumption -gas/liquid transport in cells - Mass transfer coefficients and its measurement - Oxygen transfer -Factors affecting oxygen transfer rate.

| Module:6 | Contemporary Topics | 2 hours |
|---|---|---|

Guest lectures of the experts from Industry and R &D organizations

| | Total Lecture hours: | 60 hours |
|---|---|---|

| Text Book(s) | |
|---|---|
| 1. | Michael L. Shuler and Fikret Kargi, (2017) Bioprocess Engineering: Basic Concepts, 2nd Edition, Prentice Hall. |
| 2. | Doran, P.M., (2012) Bioprocess Engineering Principles, Academic Press. |
| **Reference Books** | |
| 1. | Clark, D.S., and Blanch, H.W., (1997) Biochemical Engineering, 2nd Edition, CRC press. |
| 2. | Bailey, J.E., and Ollis, D.F., (1986) Biochemical Engineering Fundamentals, Chemical Engineering Education, 2nd Edition. |
| 3. | Stanbury, P.F., Whitaker, A., and Hall, S.J., (2016) Principles of Fermentation Technology, 3rd Edition, Elsevier. |
| Mode of Evaluation: Continuous Assessment Test / Written assignment / Quiz / Final Assessment Test | |

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|---|---|---|---|
| Recommended by the Board of Studies | 22-9-2025 | | |
| Approved by the Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE407** | Food Process Engineering | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To provide a comprehensive understanding of the principles and techniques used in food processing and preservation.
2. To develop skills in designing and optimizing food processing systems for quality, safety, and efficiency.
3. To familiarize students with modern technologies and sustainable practices in food process engineering.

**Course Outcomes**

1. CO1: Explain the physical, thermal, rheological and microbial properties of food materials relevant to process design.
2. CO2: Perform mass and energy balances and apply heat transfer principles in food processing and equipment design.
3. CO3: Apply mass transfer principles to unit operations such as drying and evaporation.
4. CO4: Evaluate thermal and non-thermal preservation methods and select packaging based on functionality, safety, and sustainability.
5. CO5: Integrate unit operations, HACCP, and quality control in food plant design and equipment selection.

| Module:1 | Introduction to Food Process Engineering | 12 hours |
|---|---|---|

Overview of the food industry and the role of chemical engineers - Introduction to food processing - Food composition: water, carbohydrates, proteins, lipids, vitamins, minerals - Physical properties of foods: density, viscosity, thermal properties (specific heat, thermal conductivity, thermal diffusivity), rheological properties of fluid and semi-solid foods - Chemical and biochemical properties: water activity, pH, enzymatic reactions, browning reactions (enzymatic and non-enzymatic) - Introduction to food microbiology: microbial growth, spoilage, and foodborne pathogens.

| Module:2 | Unit Operations in Food Processing - Part I | 14 hours |
|---|---|---|

Material and energy balances in food processing plants.

**Fluid Flow in Food Processing -** Fluid mechanics principles - Rheology of food materials (Newtonian and non-Newtonian fluids) - Flow measurement and transportation of food fluids (pumps, pipes, valves) - Mixing and agitation in food processing.

**Heat Transfer in Food Processing -** Heat transfer modes (conduction, convection, radiation) - Thermal properties of foods. Design and analysis of heat exchangers for food applications (plate, tubular, scraped surface) - Unsteady-state heat transfer in food processing - Principles of pasteurization and sterilization (D, z, F values).

| Module:3 | Unit Operations in Food Processing - Part II | 12 hours |
|---|---|---|

**Mass Transfer in Food Processing** - Mass transfer principles - Diffusion and Fick's law applied to food systems - Drying and dehydration of foods: principles, drying kinetics, types of dryers (tray, spray, freeze dryers) - Evaporation: principles, single and multiple effect evaporators, applications in food concentration.

**Separation Processes** - Mechanical separations: filtration, centrifugation, sedimentation - Membrane separation processes: microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and their applications in the food industry - Extraction: solid-liquid extraction (leaching), liquid-liquid extraction.

| Module:4 | Food Preservation and Packaging | 10 hours |
|---|---|---|
| **Food Preservation Techniques** - Dehydration and concentration - Thermal processing (blanching, pasteurization, sterilization, UHT) - Low-temperature preservation (chilling, freezing, freeze concentration) - Chemical preservation (use of preservatives, pH control).<br>**Non-thermal processing methods** - high-pressure processing, pulsed electric fields, irradiation overview - Fermentation as a preservation method.<br>**Food Packaging** - Functions of food packaging - Packaging materials: glass, metals, plastics, paper, composites. Properties and selection criteria - Package-product interactions, migration - Modified Atmosphere Packaging (MAP) and Active Packaging - Aseptic packaging - Packaging machinery overview - Sustainability in food packaging (biodegradable materials, recycling) - Labeling and regulatory aspects. | | |
| **Module:5** | **Food Plant Design, Safety, and Quality Control** | **10 hours** |
| Principles of food plant layout and design - Cleaning and sanitation in food plants (CIP, SIP) - Food safety principles: Hazard Analysis and Critical Control Points (HACCP) - Introduction to food quality control and assurance (FSSAI, ISO etc.) - of food processing plants/processes. | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Industry Expert Lecture | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | Singh, R.P., and Heldman, D.R. "Introduction to Food Engineering", 5th ed., Academic Press, 2013. |

**Reference Books**

| | |
|---|---|
| 1. | Fellows, P.J., Food Processing Technology: Principles and Practice, 2022, 5th ed., Woodhead Publishing, UK. |
| 2 | Zeki Berk. "Food Process Engineering and Technology", 3rd ed., Academic Press, 2018, UK. |

Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test

| | | | |
|---|---|---|---|
| Recommended by the Board of Studies | 22-9-2025 | | |
| Approved by the Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE408** | **Agrochemical Synthesis and Applications** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To introduce the fundamental principles and classifications of agrochemicals used in modern agriculture.
2. To provide knowledge of synthetic routes, reaction mechanisms, and formulation of pesticides, herbicides, and fertilizers.
3. To analyze the environmental and regulatory considerations related to agrochemical use and their sustainable applications.

**Course Outcomes**

1. Classify various types of agrochemicals and describe their roles in crop protection and yield enhancement.
2. Explain the synthetic methods, mechanisms, and industrial production of key agrochemicals.
3. Analyze the mode of action, application techniques, and resistance mechanisms of agrochemicals.
4. Evaluate environmental impacts, safety protocols, and regulatory frameworks governing agrochemical usage.
5. Recommend appropriate agrochemical formulations with safety and sustainability.

| **Module:1** | **Introduction to Agrochemicals** | **12 hours** |
|---|---|---|

Historical development and evolution of agrochemicals - importance of agrochemicals in modern agriculture and food security. Classification: Insecticides, herbicides, fungicides, rodenticides, plant growth regulators, and fertilizers - role in agriculture, global consumption trends - toxicology basics and formulation science - challenges and future trends in agrochemical research and development.

| **Module:2** | **Synthesis of Insecticides and Herbicides** | **12 hours** |
|---|---|---|

Synthetic strategies: Chlorination, esterification, sulfonation, nitration - organochlorines (DDT), Organophosphates (Malathion), Carbamates (Carbaryl). Herbicides: Triazines, Glyphosate, Phenoxy compounds. Application methods, selectivity, and resistance mechanisms.

| **Module:3** | **Fungicides and Plant Growth Regulators** | **12 hours** |
|---|---|---|

**Classification of Fungicides:** Mechanism of action-based classification (e.g., sterol biosynthesis inhibitors, quinone outside inhibitors, multi-site contact fungicides) –

Chemical families: Azoles, dithiocarbamates, benzimidazoles –

**Plant growth regulators:** Synthesis and application mechanisms - Plant hormones and synthetic analogs – auxins, gibberellins, cytokinins.

Application methods, systemic, m contact fungicides, and resistance development.

| **Module:4** | **Fertilizers and Soil Conditioners** | **12 hours** |
|---|---|---|

Nitrogenous (urea, ammonium nitrate), phosphatic (superphosphate), and potassic fertilizers - controlled-release and nano-fertilizers. Impact on soil chemistry and microbial ecology. Genetically Modified Organisms (GMO) in fertilizer.

| **Module:5** | **Safety, Environmental Concerns, and Regulatory Frameworks** | **10 hours** |
|---|---|---|

**Agrochemical Formulations**: Types of formulations (EC, WP, SC, GR), adjuvants, and their role - biopesticides and integrated pest management (IPM)

**Agrochemical Regulations and Safety:** Registration processes (e.g., EPA, FSSAI in India), - Guidelines by FAO, WHO, and Indian agencies (CIBRC, FCO)- Maximum Residue Limits (MRLs) - safe handling, storage, and disposal of agrochemicals - Good Agricultural Practices (GAPs) and responsible use.

| | | |
|---|---|---|
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Industry Expert Lecture. | | |
| | **Total Lecture hours:** | **60 hours** |

| | |
|---|---|
| **Text Book(s)** | |
| 1. | Bhushan, K. (2018). Introduction to Agrochemicals. CRC Press. |
| 2. | S. K. Ghosal, S. R. Sinha, and V. S. R. Rao, (2023). Fundamentals of Insecticides and Fungicides, Scientific Publishers, 3rd Edition,. |
| **Reference Books** | |
| 1. | Nonga, H. (2014). Agrochemicals: Their Application and Effects on Pests. Nova Science Publishers. |
| 2. | Worthing, C. R., & Hance, R. J. (Eds.). (2008). The Pesticide Manual: A World Compendium (15th ed.). British Crop Protection Council. |
| 3. | Matsumura, F. (2012). Toxicology of Pesticides. Springer. |

Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test

| | | | |
|---|---|---|---|
| Recommended by the Board of Studies | 22-09-2025 | | |
| Approved by the Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE312** | **Polymer Technology** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Understand the fundamental principles of polymer chemistry, polymerization methods, and classifications of polymers.
2. Analyze various polymer processing techniques and select appropriate methods for different polymeric materials.
3. Characterize polymers using mechanical, thermal, and spectroscopic techniques to determine structure–property relationships.
4. Evaluate the effects of molecular structure, morphology, and environmental factors on the physical and chemical properties of polymers.
5. Explore modern applications and emerging technologies in polymer science, including sustainable and smart polymer systems.

**Course Outcomes**

1. Explain the types of polymers and polymerization techniques with clarity on molecular structure and its effect on properties.
2. Apply suitable processing methods to fabricate polymeric products based on their thermal and rheological behavior.
3. Select and interpret data from thermal, mechanical, and spectroscopic analyses to characterize polymer materials.
4. Correlate polymer microstructure with its macroscopic properties and performance in real-world applications.
5. Identify and critically assess the use of polymers in advanced applications including sustainability and smart materials.

| **Module:1** | **Fundamentals of Polymer Science** | **12 hours** |
|---|---|---|

Introduction to polymers: Definitions, classification (thermoplastics, thermosets, elastomers, fibers), Types of polymerization: Addition and condensation, Polymerization mechanisms: Free radical, cationic, anionic, coordination, Molecular weight of polymers: Number average, weight average, polydispersity index, Chain configuration and conformation, Crystallinity and glass transition temperature (Tg)

| **Module:2** | **Polymer Processing Techniques** | **12 hours** |
|---|---|---|

Overview of processing methods, Molding techniques: Injection molding, compression molding, transfer molding, Extrusion and blow molding, Calendering, thermoforming, and rotational molding, Fiber spinning techniques: Melt, dry, and wet spinning, Processing of thermosets and composite

| **Module:3** | **Polymer Characterization and Testing** | **12 hours** |
|---|---|---|

Mechanical testing: Tensile, impact, hardness, creep, fatigue, Thermal analysis: DSC, TGA, DMA, Spectroscopic techniques: FTIR, NMR, UV-Vis, Morphological analysis: SEM, TEM, AFM, Rheological behavior and viscoelasticity, Molecular weight determination: GPC, viscometry, osmometry

| **Module:4** | **Structure–Property Relationships** | **12 hours** |
|---|---|---|

Influence of molecular weight, branching, and crosslinking on properties, Thermoplastic vs. thermoset behavior, Barrier properties, optical properties, and electrical properties, Degradation and stability of polymers (thermal, oxidative, photo, hydrolytic), Polymer blends and alloys, Biodegradable and bio-based polymers

| **Module:5** | **Applications and Emerging Trends** | **10 hours** |
|---|---|---|

Polymers in packaging, automotive, aerospace, biomedical, and electronics, Smart polymers and stimuli-responsive materials, Conductive polymers and polymer nanocomposites, Polymers in energy storage and conversion (fuel cells, solar cells), 3D printing with polymers Sustainable polymers and recycling technologies

| | | |
|---|---|---|
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Guest lecture from industry and R&D organizations | |
| | **Total Lecture hours:** | **60 hours** |

| | |
|---|---|
| **Text Books** | |
| 1 | Gowariker V.R., Viswanathan N.V., and Sreedhar J: Polymer Science, New Age International, 1986, 1st edition, New Delhi |
| 2 | Billmeyer, F, Textbook of Polymer Science, Independently Published, 1995, 2nd Edition. |
| 3 | Michael Niaounakis, Biopolymers: Applications and Trends, 2015, 1st Edition, William Andrew Publishing,USA |
| **Reference Books** | |
| 1. | McCrum, N.G., Buckley, C.P., and Bucknall, C.B. Principles of Polymer Engineering, 1988, Oxford University Press, New York. |
| 2. | Athalye, A.S., Handbook of Plastic Technology, 1995, 3rd Edition, Multi-Tech Publishing, India |
| 3. | Stuart, B.H., Polymer Analysis, 2002, 1st Edition, John Wiley & Sons, USA |

**Mode of Evaluation:** Quiz, Assignment, Continuous Assessment Test, and Final Assessment Test

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|---|---|---|---|
| **Recommended by Board of Studies** | 22-09-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

# CONCENTRATION 5: OIL AND GAS ENGINEERING

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE314** | Natural Gas Engineering | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

The objective of this course is to:

1. Develop a comprehensive understanding of the fundamental principles and engineering practices involved in the production, handling, processing, and transportation of natural gas.
2. Enable students to analyze the properties of natural gas and apply this knowledge to the design and operation of relevant processes.
3. Familiarize students with the economic considerations and technological aspects related to the natural gas industry, including onshore and offshore operations, gas processing technologies, and market dynamics.

**Course Outcomes**

1. Recall the fundamental principles and terminology associated with offshore and onshore natural gas production and handling operations.
2. Explain the operational mechanisms of natural gas water systems, gas lift techniques, and the processes involved in the separation, storage, and transportation of natural gas.
3. Apply knowledge of dehydration and desulfurization processes to select appropriate methods for treating sour natural gas streams.
4. Analyze the composition and properties of natural gas to determine its suitability for various processing and utilization applications.
5. Evaluate the economic factors influencing the selection of port locations and the feasibility of different natural gas processing technologies in the Indian context.

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Natural Gas Offshore Production and Handling** | **10 hours** |
| Drilling Deepwater Reservoir – Directional Drilling and Horizontal Drilling - Deepwater production systems – Mooring Systems – Gas Terminals. | | |
| **Module:2** | **Natural Gas Onshore Production and Handling** | **12 hours** |
| Gas water system: water content, Gas Hydrates, Hydrate Inhibition – Testing of Gas Wells – Gas Lift: Sucker Rod pumping – Separation, Storage, Transportation of Natural Gas | | |
| **Module:3** | **Natural Gas Processing** | **12 hours** |
| Dehydration – Desulphurization processes (Sour gases, Toxicity of $H_2S$, Physical and Chemical Absorption process, Carbonate process, sulphur recovery) – Low temperature processes (Joule Thompson effect, Turbo expander, Refrigeration, Low temperature Heat Exchanger), NGL, LPG, Kerosene, C3, C2 Fraction Recovery from Natural Gas, Equipment, Process Variables, Design Considerations | | |
| **Module:4** | **Properties and Composition of Natural Gas** | **12 hours** |
| Natural gas origin – Composition of Natural Gas – Source of Natural Gas – Thermodynamics properties – Compressibility factor for Natural Gas – Heating value and flammability limit of Natural Gas | | |
| **Module:5** | **Economics of Natural Gas** | **12 hours** |
| Status in India, Trade, Selection of port location, Economics of Gas Processing | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Industry Expert Lecture | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | Mokhatab, S., Poe, W. A., & Economides, M. J., *Handbook of Natural Gas Transmission and Processing*, 2019, 4th ed., Gulf Professional Publishing, USA. |
| 2. | Lyons, W. C., Plisga, G. J., & Lohrenz, J., *Petroleum Engineering: Principles and Practice*, 2021, 3rd ed., Gulf Professional Publishing, USA. |

| **Reference Books** | |
|---|---|
| 1. | Guo, B., Song, S., & Chalaturnyk, R. J., *Natural Gas Engineering Handbook*, 2020, Wiley-Blackwell, USA. |
| 2 | Ahmed, T., *Reservoir Engineering Handbook*, 2024, 6th ed., Gulf Professional Publishing, USA. (While the core concepts remain, newer editions often include updated , technologies and regulations relevant to natural gas). |
| 3. | Fanchi, J. R., *Energy in the 21st Century: Opportunities and Challenges*, 2020, Wiley-IEEE Press, USA. |
| Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion. | |

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| Recommended by Board of Studies | 22-9-2025 | | |
| Approved by Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE315** | **Petroleum Technology** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

The objective of this course is to:

1. Impart a comprehensive understanding of the fundamental aspects of crude oil, including its origin, composition, classification, transportation, and initial processing steps like dehydration and distillation.
2. Develop the ability to analyze and evaluate various refining processes such as cracking and reforming, along with their associated technologies and reactor configurations, for the conversion of crude oil fractions into valuable products.
3. Enable students to apply principles of purification, property analysis, and handling procedures to ensure the quality and safe management of diverse petroleum products and fuels.

**Course Outcomes**

1. Understand the origin, composition, classification, and transportation of crude oil, as well as the fundamental principles of petroleum dehydration.
2. Analyze the components of crude oil and various crude oil distillation systems to determine the appropriate separation techniques and predict the uses of different petroleum product fractions.
3. Evaluate the necessity, types, advantages, and disadvantages of thermal and catalytic cracking and reforming processes, including fixed bed, moving bed, and fluid bed reactor configurations.
4. Apply knowledge of sweetening processes, purification techniques, and lube oil treatment methods to assess the properties and composition of various petroleum products.
5. Explain the reasons for knocking in fuels and the role of additives in petroleum, aviation gasoline, and aviation turbine fuel (ATF), as well as the procedures for the storage and handling of liquid fuels.

| Module:1 | Petroleum | 10 hours |
|---|---|---|
| Origin, Composition, Classification, and constituents of petroleum-dehydration of crude, Transportation of crude, Classification of petroleum | | |
| **Module:2** | **Distillation** | **12 hours** |
| Components of crude oil distillation-various crude oil distillation systems, and uses of petroleum products. | | |
| **Module:3** | **Cracking, Reforming & Secondary Refining Process** | **12 hours** |
| Necessity of cracking-types of cracking-advantages and disadvantages of catalytic cracking over thermal cracking- Houdry's fixed bed processes-moving bed processes-fluid bed catalytic cracking processes. Thermal and catalytic Reforming, polymerization-alkylation-and Isomerization. | | |
| **Module:4** | **Purification and Properties and Composition of Petroleum Products** | **12 hours** |
| Sweetening processes types-Merox, HDS,dewaxing,Deasphalt and lube oil treatment. Specific gravity- vapor pressure-viscosity-red wood viscometer - Flash point-fire point-pour point-smoke point-aniline point-diesel index-octane number-performance number-cetane number-properties of greases-drop point of grease. | | |
| **Module:5** | **Knocking** | **12 hours** |
| Reasons for knocking- additives in petrol-aviation gasoline-aviation turbine fuel(ATF)-storage and handling of liquid fuels. | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Guest lectures of the experts from Industry and R &D organizations | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | **Kaiser, M. J., de Klerk, A., Gary, J. H., & Handwerk, G. E.**, *Petroleum Refining: Technology, Economics, and Markets*, 2020, 6th ed., CRC Press, USA. |

| | |
|---|---|
| 2. | **Ray Chaudhuri, U.**, *Fundamentals of Petroleum and Petrochemical Engineering*, 2020, 1st ed., Notion Press, India. |
| **Reference Books** | |
| 1. | **Speight, J. G.**, *Handbook of Petroleum Refining*, 2020, 1st ed., CRC Press, USA. |
| 2 | **Ali, H. M. & Yaqoob, H. (Eds.)**, *Innovations in Production and Applications of Alternative Fuels (Emerging Technologies and Materials in Thermal Engineering)*, [1] 2025 (Expected), Elsevier, Netherlands. |
| Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion. | |

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| Recommended by Board of Studies | 22-09-2025 | | |
| Approved by Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE316 | Utilities and Piping Design | 4 | 0 | 0 | 4 |
| Pre-requisite | NIL | Syllabus version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. To equip the students with a basic understanding of different types of utilities.
2. To impart insights into the selection of different utilities and their optimum utilization.
3. To provide exposure to piping design, materials, and insulation in process plants.

**Course Outcomes**

1. Analyze the selection and operational requirements of compressed air and inert gas systems in process industries.
2. Apply the operation and treatment methods of water and steam generation systems in process industries.
3. Analyze the principles, components, and industrial applications of humidification and refrigeration systems.
4. Apply fundamental principles of chemical engineering to piping system design.
5. Identify appropriate piping and insulation materials for process industries.

| Module:1 | Compressed air and inert gases | 12 hours |
|---|---|---|

Importance of utilities - Compressed Air Systems: Types of compressed air in process plants - Air compressor types and selection - Reciprocating, Rotary, and Centrifugal compressors - Air treatment and conditioning - Instrument air quality standards - Inert Gas Systems: Role of inert gases in process industries - Purging, blanketing, and pressurization - Common inert gases used - Nitrogen generation methods - Hazards and safety considerations

| Module:2 | Process water and steam | 12 hours |
|---|---|---|

Process water systems: Classification of process water - Water quality parameters for industrial use - Water treatment techniques - Preliminary treatment – Membrane treatment - Deaeration – Disinfection - Boiler feed water conditioning - Industrial applications of treated water

Steam generation: Types of steam - Applications of steam in process industries - Steam generation equipment - Fire-tube and water tube boilers – Boiler mountings and accessories - Boiler feed water requirements and treatment standards - Steam distribution systems - Steam traps - Condensate recovery systems

| Module:3 | Humidification and refrigeration systems | 10 hours |
|---|---|---|

Humidification systems: Purpose and industrial applications - Basic psychrometrics - Types of humidification methods – Heating with humidification – Cooling with dehumidification.
Refrigeration systems: Principles of refrigeration - Coefficient of Performance - Types of refrigeration systems - Vapor compression and vapor absorption systems – Refrigerant Types - Properties and environmental considerations - Applications in industry

| Module:4 | Piping design | 12 hours |
|---|---|---|

Basic considerations and flow diagrams in chemical engineering - Pipe Sizing and Hydraulic Design – Pipe fitting and joints - Piping Drawing and Documentation - Design Codes and Standards - Pipe thickness calculation and pressure rating

| Module:5 | Piping materials and insulation | 12 hours |
|---|---|---|

Piping Materials - Classification of piping materials - Material selection criteria - pressure, temperature, corrosion resistance, and cost - Material standards: ASTM, ASME, API, IS codes - Common applications. Piping Insulation: Purpose and benefits - Types of insulation materials - Insulation for different services - Insulation design considerations - Standards and codes for insulation

| Module:6 | Contemporary Topics | 2 hours |
|---|---|---|

Industry Expert Lecture

| | Total Lecture hours: | 60 hours |
|---|---|---|

| **Text Books** | |
|---|---|
| 1. | J. Broughton, Process Utility Systems: Introduction to Design, Operation and Maintenance, 2004, The Institution of Chemical Engineers. UK |
| 2. | R. Smith, Process Plant Design, 2023, 1st Edition, John Wiley & Sons Inc, US |
| 3. | Max S. Peters, Klaus D. Timmerhaus, Ronald E., Plant Design and Economics for Chemical Engineers, 2017, McGraw-Hill, USA |
| **Reference Books** | |
| 1. | R. Keith Mobley, Plant Engineer's Handbook. 2001, 1st Edition, Butterworth-Heinemann Ltd., UK |
| 2. | G. Towler, R. Sinnott., Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, 2021, 3rd Edition, Butterworth-Heinemann Ltd., UK |
| 3. | M. Nayyar., Piping Handbook, 1999, 7th Edition, McGraw-Hill, USA |

Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test

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| Recommended by the Board of Studies | 22-9-2025 | | |
| Approved by the Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE410** | **Petroleum Economics and Risk Management** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **Nil** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Understand the fundamental knowledge of economics, petroleum exploration, production, and development.
2. Evaluate petroleum projects using risk analysis techniques.
3. Analyze and assess fiscal regimes and types of contracts in upstream operations.
4. Explain the optimization of investment decisions through portfolio management and sensitivity analysis.

**Course Outcomes**

1. Apply economic indicators such as NPV, IRR, and payback period for the evaluation of oil and gas projects.
2. Analyze upstream petroleum investment in terms of commercial, geological, and technical risks.
3. Apply appropriate decision analysis tools in making investment and operational decisions in petroleum projects.
4. Examine various fiscal regimes and contract types on their impact on the economic viability of petroleum projects.
5. Explain portfolio management principles and strategic decision-making methods in the context of petroleum economics.

| Module:1 | Fundamentals of Petroleum Engineering | 12 hours |
|---|---|---|
| World oil and gas supply, demand, and historical trends- Structure of the oil and gas industry- Characteristics of crude oils and properties of petroleum- Forecasts of global energy supply and demand- Basics of financing the project | | |
| **Module:2** | **Economic Analysis of Petroleum Projects** | **12 hours** |
| Time value of money (TVM)- Depreciation and depletion in oil projects- Financial measures and profitability analysis- Risk, uncertainty, and decision analysis- Break-even and sensitivity analysis- Optimization techniques | | |
| **Module:3** | **Exploration and Development Decision Economics** | **10 hours** |
| Exploration and drilling- Production operations- Reserves and reserve estimates- Financing the project- Risk and uncertainty in exploration- Risk management of the development concept | | |
| **Module:4** | **Risk Analysis, Fiscal Systems, and Economic Evaluation** | **12 hours** |
| Cash flow components- Production profile and sales price- Capex and opex- Fiscal systems- Constructing the project cash flow- Discounting- Incremental projects and economics- Incorporation of inflation into the project cash flow- Economic Indicators and types of efficiency- Risk management of the development concept | | |
| **Module:5** | **Portfolio Management and Strategic Decision-Making** | **12 hours** |
| Identifying incremental projects and economics- Decommissioning- Managing value and risk- Portfolio effect on volumes, value, and risk- The efficient frontier- The Gambler’s ruin and exploration portfolios | | |
| | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Industry Expert Lecture | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | H. K. Abdel-Aal and M. A. Alsahlawi, Petroleum Economics and Engineering, 2014, 3rd ed., CRC Press, Taylor & Francis Group, USA. |
| 2. | M. Cook, Petroleum Economics and Risk Analysis: A Practical Guide to E&P Investment Decision-Making, 2021, 1st ed., Elsevier, Netherlands. |

| Reference Books | |
| --- | --- |
| 1. | D. Johnston, International Petroleum Fiscal Systems and Production Sharing Contracts, 1994, 1st ed., PennWell Books, USA. |
| 2 | D. Wood, Project Economics and Decision Analysis: Volume 1- Deterministic Models, 2011, 2nd ed., OGEL Press, USA. |
| 3. | E. E. Okonkwo, Applied Petroleum Economics and Risk Management, 2020, 1st ed., Springer, Switzerland. |

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

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| Recommended by Board of Studies | 22-9-2025 | | |
| Approved by Academic Council | No. xx | Date | DD-MM-YYYY |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE409** | **Digital Oil Field and Smart Technology** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Study the fundamentals of digital transformation of oil fields through automation, AI, and sensor-based monitoring.
2. Explain integrated digital oil field architectures and smart technologies.
3. Include machine learning, data analytics, and optimization techniques in the oil recovery process and operations.
4. Impart knowledge on real-time monitoring and control and predictive maintenance practices in oil and gas fields.

**Course Outcomes**

1. Explain the evolution, structure, and main parts of Digital Oil Fields (DOF), including SCADA systems and cyber-security aspects.
2. Apply data filtering, validation, and conditioning techniques in DOF operations.
3. Explore the role of AI, data analytics, and IIoT in upstream oil and gas operations. Evaluate how they fit into digital oil field systems.
4. Apply workflow automation strategies and smart control methods to improve exploration and production (E&P) operations in DOFs.
5. Explain smart well technologies and explain how to monitor reservoirs in real time for digital oil field management

| **Module:1** | **Fundamentals of Digital Oil Fields** | **12 hours** |
|---|---|---|

Digital oil field (DOF) evolution- Traditional vs. Digital operations- Smart technologies in upstream oil and gas fields- Key drivers: Efficiency, productivity, and safety- SCADA- Sensors and remote sensing- Control technology by field types- Data gathering and SCADA architecture- Special note on cybersecurity- Architecture of DOF.

| **Module:2** | **Data filtering and conditioning** | **12 hours** |
|---|---|---|

DOF system data validation and management- Basic system for cleansing, filtering, altering, and conditioning- Data filtering from signals- Concept of automation- Difference between AI and Automation- Components of AI in automation and applications- Integration of control systems with remote operations- Layers of digital oil field and management.

| **Module:3** | **Components of AI, Data Analytics, and IIoT** | **12 hours** |
|---|---|---|

Intelligent Data Analytics and Visualization- Applications to Digital Oil and Gas Fields- Background and Evolution of IIoT- Main Architecture of IIoT- Social IoT- Standards and Frameworks of IoT- Applications in the Industry- IIoT for the Oil and Gas Industry- Introduction of trusted AI and its philosophy- Testing methodology and key technologies of AI- Factsheet for AI systems and Component Analysis

| **Module:4** | **Workflow automation and Intelligent control** | **12 hours** |
|---|---|---|

Introduction to process control- Preparation of automated workflows for E&P- Virtual Multiphase flow metering-based model- Smart production surveillance for regular operations- Well test validation and production performance in right time- Diagnostics and proactive well optimization with a well analysis model- Advisory and tracking actions- Introduction to IAM and optimization approaches- Advanced model calibration with assisted history matching- Optimization of modern DOF assets-Distributed digital control systems for oil and gas operations

| **Module:5** | **Smart Wells and Techniques for Reservoir Monitoring** | **10 hours** |
|---|---|---|

Introduction to smart wells- Types of Down-Hole valves- Surface data acquisition and control- Smart well application, performance, modelling and control- Smart improved oil recovery/enhanced oil recovery management- Reservoir management and iCloud storage- The future digital oil field.

| Module:6 | Contemporary Issues | 2 hours |
|---|---|---|
| | Guest lecture from industry and R&D organizations | |
| | **Total Lecture hours:** | **60 hours** |

**Text Books**

| | |
|---|---|
| 1 | G. Carvajal, M. Maucec and S. Cullick, Intelligent Digital Oil and Gas Fields: Concepts, Collaboration and Right-Time Decisions, 2017, 1st ed., Gulf Professional Publishing (Elsevier), United Kingdom. |
| 2 | N. K. Mitra, AI and Digital Technology for Oil and Gas Fields, 2024, 1st ed., CRC Press (Taylor& Francis Ltd.), United Kingdom. |
| 3 | Michael Niaounakis, Biopolymers: Applications and Trends, 2015, 1st Edition, William Andrew Publishing,USA |

**Reference Books**

| | |
|---|---|
| 1. | S. D. Mohaghegh, Data-Driven Reservoir Modeling, 2017, 1st ed., Springer, USA. |
| 2. | S. A. Cullick, Integrated Digital Oil Fields: Real-Time Field Optimization, 2021, 1st ed., Elsevier, Netherlands. |

**Mode of Evaluation:** Quiz, Assignment, Continuous Assessment Test, and Final Assessment Test

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22-09-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

# OPEN ELECTIVES

| Course code | Industrial Safety and Hazard Analysis | L | T | P | C |
|---|---|---|---|---|---|
| BACHE318 | | 4 | 0 | 0 | 4 |
| Pre-requisite | NIL | Syllabus version | | | |

**Course Objectives:**

1. Assess the significance of the Safety Analysis
2. Identify the occupational hazards in the work environment
3. Determine the root cause of the failure events in the workplace

**Course Outcome:**

Upon successful completion of the course, the students will be able to

1. Apply Hazard and Operability Study (HAZOP) for Hard and Soft Industries
2. Analyse the root cause of the work-related accidents using safety analysis
3. Demonstrate behaviour-based analysis for various human and technical errors in the workplace
4. Implement safety framework at the workplace
5. Identify the hazard and conduct a safety audit

| Module:1 | Introduction to Safety in process Industries | 10 hours |
|---|---|---|

Development of safety consciousness in process industries - Hazard – Risk - Danger and Accident - Hazan - Safety symbols - Dangerous and Toxic Chemicals - Routes of entry - Effects of toxicants and its elimination - Extreme operating conditions - Safe operating practices – Psychological attitude towards safety- Behaviour-Based Safety

| Module 2 | Safety Programs in Industries | 12 hours |
|---|---|---|

Importance of Safety Programs in industries - Elements of Safety Program - Economic and Social Benefits from safety program - Involvement of Human factors and Errors - Developing safety checklist - Safety training at various levels - Bowtie diagram in process safety management - Safety committee - plant layout - Accidents identification and prevention - on site & off-site emergency planning

| Module:3 | Process safety in design and operations | 12 hours |
|---|---|---|

Safe Handling and Operation of materials and Machinery - Periodic inspection and Replacement - Elements of the safety in plant design – Safety factors for designing process equipment - Process safety design strategies - Failure modes in Unit operations - Design for Worst case scenario - Dominos' effect - Personal Protective Equipment - Fire Extinguisher

| Module:4 | Hazard identification and risk assessment | 12 hours |
|---|---|---|

Hazard identification –Types of hazards - Safety audits - Job Safety Analysis – Checklists and Databases Types of risks - Qualitative and quantitative Risk assessment techniques - Risk matrix - What-if analysis - Vulnerability models - Fault tree analysis- Event tree analysis - Reliability analysis - Failure Modes and Effects Analysis (FMEA) – HAZOP Studies - ISO certifications

| Module:5 | Process Safety Models and analysis | 12hours |
|---|---|---|

Toxic release and dispersion models - venting and flare systems - Layer of Protection Analysis (LOPA) - Radio Active decay models – Resilience engineering models - FRAM models, Bayesian safety regression models – Industrial Accident

| Module:6 | Contemporary issues | 2 hours |
|---|---|---|

Guest lectures of the experts from Industry and R &D organizations

| | Total Lecture hours: | 60 hours |
|---|---|---|

**Text Book(s)**

| | |
|---|---|
| 1. | Ericson C.A., Hazard Analysis Techniques for System Safety, 2nd ed., Wiley, USA, 2015.<br>Crowl, D A, and Louvar, J F., Chemical Process Safety, 2nd Ed, Prentice-Hall, New Jersey, 2002 |

| | | | |
|---|---|---|---|
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| **Reference Books** | | | |
| 1. | Gupta A., Industrial Safety and Environment, 2nd ed., Laxmi Publications, India, 2015 | | |
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE319** | **Chemical Process Optimization** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Understand the mathematical foundations and formulation strategies for optimization problems relevant to chemical engineering.
2. Explore single and multivariable optimization techniques, with and without constraints.
3. Apply linear and nonlinear programming methods to solve real-world chemical process problems.
4. Analyze chemical engineering systems to identify optimization opportunities in design, operation, and resource utilization.
5. Implement optimization models using numerical and algorithmic methods for process performance improvement.

**Course Outcomes**

1. Formulate mathematical models for optimization problems in chemical processes, considering constraints, degrees of freedom, and system objectives.
2. Solve unconstrained single-variable and multivariable optimization problems using analytical and numerical techniques.
3. Apply linear and nonlinear programming methods to constrained optimization problems.
4. Analyze and optimize typical chemical processes including compressors, distillation columns, heat exchangers, and reactors for cost or efficiency improvements.
5. Use modern computational tools to simulate, solve, and interpret optimization results for industrial.

| **Module:1** | **Fundamentals of Optimization and Problem Formulation** | **12 hours** |
|---|---|---|

Nature and classification of optimization problems, Structure and organization of optimization models, Degrees of freedom analysis, Gradient and Hessian matrix, convex functions and sets, Formulation of optimization models in chemical processes, Data-based model fitting: Least squares method, Factorial experimental design for process optimization

| **Module:2** | **Single and Multivariable Unconstrained Optimization** | **12 hours** |
|---|---|---|

Single-variable optimization: Search methods with and without derivatives, Newton, Quasi-Newton, Secant methods, Region elimination methods: Interval halving, Fibonacci search, Golden section, Multivariable optimization: Graphical visualization: Contour plots, 3D surfaces Gradient-based methods: Steepest descent, Conjugate gradient, Newton’s method

| **Module:3** | **Constrained Optimization Techniques** | **12 hours** |
|---|---|---|

Linear Programming (LP): Problem formulation and graphical solution, Simplex method, Duality and sensitivity analysis, Introduction to interior-point methods, Nonlinear Programming (NLP): Equality and inequality constraints, Lagrange multipliers and KKT conditions, Quadratic programming, Successive linear and quadratic programming, Branch and bound methods, Separable nonlinear programming

| **Module:4** | **Optimization Techniques for Process Utilities and Equipment Design** | **12 hours** |
|---|---|---|

Applications in process equipment and utilities: Optimal pipe diameter, Minimum work of gas compression, Optimal operation of fixed-bed filters, Design of gas transmission networks, Optimal recovery of waste heat, Minimum-cost routing problems

| **Module:5** | **Optimization Techniques for Process Intensification and AI/ML** | **10 hours** |
|---|---|---|

Optimization of integrated process systems: Optimal design and operation of staged distillation columns, Optimization in chemical reactor design (CSTR, PFR), Optimum design of shell and tube heat exchangers, Optimization of heat exchanger networks (HEN), Multistage evaporator optimization, Optimization in ML and DL, Particle Swarm Optimization, Response Surface Methodology

| | | |
|---|---|---|
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Industry Expert Lecture from R & D organizations | |
| | **Total Lecture hours:** | **60 hours** |

| | |
|---|---|
| **Text Books** | |
| 1 | Edger T.F., Himmelblau D.M., Lasdon L.S., Optimization of Chemical Processes, 2nd ed., McGraw-Hill, USA,2015. |
| 2 | Hillier F.S., Lieberman G.J., Introduction to Operations Research, 7th ed., McGraw-Hill, USA, 2001. |
| 3 | Rao S. S., Engineering Optimization: Theory and Practice, 4th ed., John Wiley & Sons Ltd., USA,2009. |
| **Reference Books** | |
| 1. | Smith, R., Chemical Process Design and Integration, 2nd Edition, John Wiley & Sons Ltd., USA,2016 |
| 2. | Dutta, S., Introduction to Optimization in Chemical Engineering, 1st Edition, Cambridge University Press, India, 2016. |
| 3. | Nocedal J., and Wright, S. J. Numerical Optimization, 2nd Edition, Springer, USA 2006 |

**Mode of Evaluation:** Quiz, Case studies, Continuous Assessment Test, and Final Assessment Test

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22.9.2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE320** | **Chemical Product Design** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To train the students in identifying the needs and converting needs to product specifications
2. To facilitate generation of innovative ideas for chemical products and select among the ideas
3. To familiarize the student with intellectual property issues and manufacture and design of speciality products

**Course Outcomes**

1. Analyze the needs of the customer
2. Apply engineering knowledge to convert needs to product specifications
3. Create and generate innovative ideas for products
4. Evaluate and select among ideas
5. Analyze the manufacture of products

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Introduction and Needs of Chemical Product** | **12 hours** |
| Introduction to chemical product design – Classification of Products - Customer needs - lead users - interviews and alternatives to interviews - consumer products – examples of needs | | |
| **Module:2** | **Needs to specifications** | **12 hours** |
| Consumer assessments - simple comparison test - relative grading test - test for assessing ratios -Converting needs to specifications - revising product specifications – examples | | |
| **Module:3** | **Ideas and Selection of Ideas** | **12 hours** |
| Human sources of ideas - brainstorming - problem solving styles - chemical sources of ideas - natural product screening - random molecular assembly - combinatorial chemistry - sorting the ideas - screening the ideas – examples - Selection using thermodynamics - ingredient substitutions - substitutions in consumer products - ingredient improvements - selection using kinetics - less objective criteria - risk in product selection – examples | | |
| **Module:4** | **Product manufacture** | **12 hours** |
| Intellectual property - patents and trade secrets - requirements for patents - supplying missing information - final specifications - micro structured products - device manufacture – examples | | |
| **Module:5** | **Specialty chemical manufacture and Economic Concerns** | **10 hours** |
| First steps towards production - extending laboratory results - reaction engineering - separations - heuristics for separations - specialty scale up - Product versus process economics - Gantt chart - cash flow - time value of money – examples | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Industry Expert Lecture | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

1. Cussler E.L., Moggridge G. D., Chemical Product Design, Cambridge University Press, 2nd ed., UK, 2011.

**Reference Books**

1. Seider W.D., Seader J D., Lewin D.R., Product and Process Design Principles, Wiley, 4th ed., USA, 2016.
2. Wei J., Product Engineering: Molecular Structure and Properties, Oxford University Press, 1st ed., UK, 2007.

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE321 | Colloids and Interfacial Science | 4 | 0 | 0 | 4 |
| Pre-requisite | NIL | Syllabus Version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. To describe the theories of colloids and interfacial phenomena
2. To explain solution thermodynamics, stability of colloids, light scattering, capillary effects
3. To expose the importance of colloidal phenomena through real life examples

**Course Outcomes**

1. Describe the concept of the origin of long-range, non-covalent colloidal forces
2. Explain the link between liquid surface tension and contact angle
3. Apply the knowledge of thermodynamics for micellization in surfactant solutions
4. Describe the thermodynamics of emulsion formation for kinetic and thermodynamic stability of emulsions
5. Design of colloidal systems or engineered surfaces

| Module:1 | Introduction and properties of colloids at interfaces | 12 hours |
|---|---|---|

Fundamentals of Colloidal Science - Colloids definition - Van der Waals interactions - The Hamakerconstant - Electrostatic Interactions in Colloids - The electrical double layer (EDL) theory - Zeta potential-Gibbs energy of electrostatic interactions - Surface tension of liquids – definition - Lewis Acid-Base interactions - Surface tension & contact angle - Measuring contact angles

| Module:2 | Interactions at Interfaces: Surfactants and Emulsions | 12 hours |
|---|---|---|

Surfactants Types – Cationic surfactant – Anionic surfactant – Definitions - applications - thermodynamics - Surface excess - Definitions and applications of emulsions - Types of emulsions - Thermodynamics of emulsification - Emulsion stability

| Module:3 | Design of Interfaces | 12 hours |
|---|---|---|

Adsorption-Models of adsorption-Adsorption at the solid-liquid interface-Adsorption at the liquid-air interface-Adsorption at the solid-air interface Machine Learning for Interface Design Interfaces for Energy and Sustainability – applications

| Module:4 | Principles of Light Scattering | 12 hours |
|---|---|---|

Fundamentals of light scattering – Types of scattering - Static light scattering-Dynamic light scattering - Advanced Light Scattering Techniques - Electrophoretic Light Scattering (ELS) - Small-Angle X-ray Scattering (SAXS) and Small-Angle Neutron Scattering (SANS) - Multi-Angle Light Scattering (MALS) – applications

| Module:5 | Applications of colloidal and interfacial systems | 10 hours |
|---|---|---|

Colloidal and interfacial phenomena in biology - food technology – Photovoltaic – Water treatment – Medicine – Tribology – colloids in Micro/Nanomachines – Engineering

| Module:6 | Contemporary Issues | 2 hours |
|---|---|---|
| | Guest lectures of the experts from Industry and R &D organizations | |
| | **Total Lecture hours:** | 60 hours |

**Text Books**

| | |
|---|---|
| 1. | Pallab Ghosh, Colloid and Interface Science, 2009, 1st edition, PHI, India |
| 2. | Robert J. Hunter., Foundations of Colloid Science, 2001, 2nd Edition, Oxford University Press, UK. |

**Reference Books**

| | |
|---|---|
| 1. | Hiemenz P.C., Rajagopalan R., Principles of Colloid and Surface Chemistry, 1997, 3rd ed., CRC Press, USA. |
| 2. | Wang C., Leblanc R.M., Recent Progress in Colloid and Surface Chemistry, 2016, 1st ed., Oxford University Press Inc., UK. |

**Mode of Evaluation: Quiz, Case studies, CAT and FAT**

| Recommended by Board of Studies | 22.9.2025 | | |
|---|---|---|---|
| Approved by Academic Council | No. | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE322** | **Pharmaceutical Technology** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Introduce engineering students to pharmaceutical unit operations and formulation processes.
2. Provide a foundation in design, operation, and control of pharmaceutical manufacturing processes.
3. Integrate chemical engineering principles with regulatory and quality aspects of pharmaceutical production.
4. Explore process scale-up strategies and evaluate process design for pharmaceutical applications.
5. Examine the regulatory, safety, and quality requirements specific to pharmaceutical engineering.

**Course Outcomes**

1. Explain the structure, scope, and regulatory framework of the pharmaceutical industry, including GMP, GLP, and regulatory agencies.
2. Apply principles of chemical engineering unit operations to pharmaceutical formulation and production.
3. Design and analyze chemical reactors for active pharmaceutical ingredient synthesis, considering reaction kinetics and process parameters.
4. Select and evaluate appropriate separation and purification methods used in pharmaceutical manufacturing.
5. Assess the role of quality systems, safety practices, and emerging technologies in modern pharmaceutical engineering.

| **Module:1** | **Introduction to Pharmaceutical Industry & Regulatory Landscape** | **12 hours** |
|---|---|---|

Overview of the pharmaceutical industry: types of products, market structure, and trends, Role of chemical engineers in pharmaceutical manufacturing, Drug development pipeline: discovery to commercialization, Good Manufacturing Practices (GMP), cGMP, GLP, and ICH guidelines, Regulatory authorities: USFDA, EMA, CDSCO – an overview

| **Module:2** | **Pharmaceutical Process Engineering** | **12 hours** |
|---|---|---|

Unit operations in pharmaceutical manufacturing: Mixing, drying, filtration, crystallization, and granulation, Scale-up and process design considerations for: Tablet and capsule manufacturing, Liquid and semi-solid formulations, Batch vs continuous processing in pharma, Material and energy balance applications in pharmaceutical processes

| **Module:3** | **Reactor Design and Kinetics in Pharma Production** | **12 hours** |
|---|---|---|

Reaction kinetics relevant to active pharmaceutical ingredients (API) synthesis, Selection and design of reactors for pharmaceutical synthesis (CSTR, PFR, batch), Thermal and catalytic reactions in organic synthesis, : synthesis of key intermediates and APIs, Green chemistry approaches in pharmaceutical production

| **Module:4** | **Separation and Purification Techniques** | **12 hours** |
|---|---|---|

Extraction (liquid-liquid and solid-liquid), Distillation and fractional distillation, Membrane separation: ultrafiltration, reverse osmosis, nanofiltration, Chromatographic techniques: basics of HPLC, GC, Drying and lyophilization: process design and equipment

| **Module:5** | **Quality, Safety, and Emerging Technologies** | **10 hours** |
|---|---|---|

Quality by Design (QbD) and Process Analytical Technology (PAT), Containment, cleanroom design, and HVAC in pharma plants, Safety considerations in handling active pharmaceutical ingredients (APIs), Introduction to continuous manufacturing and automation, Emerging areas: biopharmaceuticals, personalized medicine, nanotechnology in drug delivery

| **Module:6** | **Contemporary Issues** | **2 hours** |
|---|---|---|
| | Industry Expert Lecture | |
| | **Total Lecture hours:** | **60 hours** |

**Textbooks**

| | |
|---|---|
| 1 | Khar, R.P., Vyas, S.P., Ahmad, F.J., Lachman & Lieberman The Theory and Practice of Industrial Pharmacy, 4th Edition, CBS Publisher, India, 2020. |

| | |
|---|---|
| 2 | Sambamurthy, K., Pharmaceutical Engineering, 2nd Edition, New Age Publishers, India, 2019. |
| 3 | Ray, A.K., Coulson and Richardson's Chemical Engineering: Volume 2B: Separation Processes, 6th Edition, Butterworth-Heinemann Ltd, 2023 |
| **Reference Books** | |
| 1. | Bharath S., Pharmaceutical Technology: Concepts and Applications, 2013, 1st ed., Pearson Education, India. |
| 2. | Agarwal G., Kaushik A., Pharmaceutical Technology, Volume I, 2017, 1st ed., CBS Publishers & Distributors, India |
| 3. | Murthy R.S.R., Kar A., Pharmaceutical Technology, Volume II, 2017, 2nd ed., New Age International Private Limited, India. |

**Mode of Evaluation:** Quiz, Case studies, Continuous Assessment Test, and Final Assessment Test

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22.9.2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE323** | **Fermentation Technology** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To introduce the principles and scope of industrial fermentation processes and microbial growth kinetics.
2. To provide knowledge of bioreactor design, operation, and process control in fermentation systems.
3. To develop an understanding of the downstream processing techniques used in product recovery and purification.

**Course Outcomes**

1. Explain the fundamental principles of fermentation and microbial metabolism relevant to industrial processes.
2. Apply microbial growth kinetics and substrate utilization in batch, fed-batch, and continuous cultures.
3. Design and evaluate different bioreactor configurations, including sterilization, aeration, agitation, and monitoring techniques for effective bioreactor operations
4. Evaluate appropriate downstream processing techniques for the isolation and purification of a given fermentation product.
5. Analyze common industrial fermentation processes and suggest solutions for process improvement.

| | | |
|---|---|---|
| **Module:1** | **Introduction to Fermentation Technology** | **8 hours** |
| Historical perspective and scope of fermentation technology - types of fermentation processes: submerged, solid-state, batch, fed-batch, continuous - overview of industrially important microorganisms: bacteria, fungi, yeasts, algae - fermentation products: primary and secondary metabolites, enzymes, biopharmaceuticals, biofuels, food products. | | |
| **Module:2** | **Microbial Physiology and Metabolism for Fermentation** | **12 hours** |
| Microbial growth kinetics: growth phases, specific growth rate, yield coefficients - factors affecting microbial growth: temperature, pH, aeration, nutrient availability - stoichiometry of microbial growth and product formation - energetics of microbial metabolism: central metabolic pathways (glycolysis, TCA cycle, pentose phosphate pathway) - regulation of metabolism and product biosynthesis - strain improvement strategies for industrial microorganisms. | | |
| **Module:3** | **Bioreactor Design and Operation** | **14 hours** |
| Principles of bioreactor design: materials of construction, agitation, aeration - mass transfer in bioreactors: oxygen transfer, kLa measurement and estimation - Heat transfer in bioreactors: cooling and heating requirements - sterilization techniques for media, air, and bioreactors - types of bioreactors: stirred tank, airlift, packed bed, fluidized bed, photobioreactors - instrumentation and control in bioreactors: sensors for pH, DO, temperature. | | |
| **Module:4** | **Bio separations and Purification** | **12 hours** |
| Introduction: unit operations for product recovery - cell separation: centrifugation, filtration (microfiltration, ultrafiltration) - cell disruption techniques: mechanical and non-mechanical methods - product concentration: evaporation, membrane filtration (reverse osmosis, nanofiltration) - product purification: chromatography (ion-exchange, gel filtration, affinity), crystallization, solvent extraction - drying and formulation of products. | | |
| **Module:5** | **Industrial Applications of Fermentation Technology** | **12 hours** |
| Production of alcohols: ethanol, butanol - production of organic acids: citric acid, lactic acid, acetic acid - production of amino acids: glutamic acid, lysine - production of antibiotics: penicillin, streptomycin - production of enzymes: amylases, proteases, cellulases - fermented foods and beverages: bread, cheese, yogurt, beer, wine - biofuels and bioplastics. | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Guest lectures of the experts from Industry and R &D organizations | | |
| | **Total Lecture hours:** | **60 hours** |

| Text Book(s) | | | |
|---|---|---|---|
| 1. | Stanbury, P. F., Whitaker, A., & Hall, S. J. (2017). *Principles of Fermentation Technology* (3rd ed.). Butterworth-Heinemann. | | |
| **Reference Books** | | | |
| 1. | Shuler, M. L., & Kargi, F. (2006). *Bioprocess Engineering: Basic Concepts* (2nd ed.). Prentice Hall. | | |
| 2 | Doran, P. M. (1995). *Bioprocess Engineering Principles*. Academic Press. | | |
| Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test | | | |
| Recommended by the Board of Studies | 22.9.2025 | | |
| Approved by the Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHExxxx** | **Finance for Engineers** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Explain fundamental principles of managerial economics and their application in business decision-making.
2. Apply cost and production analysis techniques to evaluate operational efficiency.
3. Analyze financial statements and capital budgeting methods for effective financial decision-making.

**Course Outcomes**

1. Apply key concepts of managerial economics, including demand forecasting and market structures.
2. Assess demand and supply functions, elasticity, and forecasting techniques in an engineering context.
3. Perform production and cost analysis methods to optimize resource allocation.
4. Implement pricing strategies under various market conditions and objectives.
5. Compute financial ratios, investment returns, and capital budgeting metrics.

| Module:1 | Fundamental Concepts of Managerial Economics | 12 hours |
|---|---|---|

Introduction: Factors influencing managerial decision – managerial economics – objectives of the firm – managerial decisions – theoretical concepts, Problems in Time Value of Money (TVM)

| Module:2 | Demand-Utility Analysis and Forecasting | 12 hours |
|---|---|---|

Meaning of demand – determinants of demand – demand function – demand elasticity – demand forecasting – forecasting methods. Problems in Law of Demand, Marginal Utility, and Consumer Equilibrium (Utility Maximization Rule)

| Module:3 | Production and Cost Analysis | 12 hours |
|---|---|---|

Production function – least cost combination of inputs – factor productivities and return to scale – statistical production function – managerial uses of production function – cost concepts – accounting and economic costs – cost determinations – cost-output relationship – estimation of cost-output. Break-Even Analysis- Return on Investment (ROI)- Compound Interest -Earnings Before Interest and Taxes (EBIT) – Problems in Current Ratio - Dividend Discount Model (DDM), Cost of Goods Sold (COGS), Weighted Average Cost of Capital (WACC), Cost of Equity (CAPM), Cost of Debt (After-Tax), and Marginal Cost

| Module:4 | Pricing | 12 hours |
|---|---|---|

Determinants of price – pricing under different objectives – pricing under different market structures – price discrimination – pricing methods in practice. Problems in Cost-Plus Pricing, Break-Even Pricing, Target Return Pricing, Contribution Margin Pricing, Value-Based Pricing, Dynamic Pricing, Premium Pricing, Geographic Pricing, and Auction-Based Pricing

| Module:5 | Financial Accounting & Capital Budgeting | 10 hours |
|---|---|---|

The balance sheet concepts – the profit and loss statements – financial ratio analysis – cash flow analysis – fund flow analysis – Investments – risks and return evaluation of investment decision – average rate of return – payback period – net present value and internal rate of return, Problems in Operating Budget, Cash Flow Budget, Sales Budget, Capital Budgeting and Budget Variance Analysis- Financing and business development for hard tech startups - Startup Valuation

| Module:6 | Contemporary Topics | 2 hours |
|---|---|---|

Expert Lectures by Finance Experts

| | Total Lecture hours: | 60 hours |
|---|---|---|

**Text Book(s)**

| | |
|---|---|
| 1. | A Ramachandra Aryasri and V V Ramana Murthy, "Engineering Economics and Financial Accounting," Tata McGraw-Hill, New Delhi (2004). |
| 2. | Prasanna Chandra, "Financial Management: Theory and Practice" 8th Edition, Tata McGraw-Hill, New Delhi (2011). |

**Reference Books**

| | |
|---|---|
| 1. | Ambrish Gupta, "Financial Accounting for Management", 6th Edition, Pearson Education (2018) |

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE325** | **Fluidization Engineering** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To understand the physical and chemical aspects of the fluidization process
2. To identify the various fluidization regimes and describe their behaviour
3. To design the various types of fluidized bed widely used in industrial practice

**Course Outcomes**

1. Identify the behavior of fluidization process under various operating conditions
2. Determine minimum fluidization velocity and terminal velocity in fluidized bed
3. Design suitable distributor for fluidized beds
4. Apply various models for designing the fluidized bed systems
5. Analyze the performance of fluidized bed reactor systems

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Introduction** | **12 hours** |
| Concept of Fluidization - Special Features of Fluidization - Comparison with other Contacting Methods - Advantages and Disadvantages of Fluidized Beds - Industrial Applications of Fluidized Beds - Historical Highlights - Physical Operation - Chemical Operations. | | |
| **Module:2** | **Characteristics of solids** | **12 hours** |
| Geldart Classifications of Particles - Flow characteristics and its outline in the different types of fluidizations – Gas-solid system - Liquid-solid system | | |
| **Module:3** | **Characterization of Fluidization I** | **12 hours** |
| Mapping of Fluidization Flow pattern – Transition regime - Behaviour of Fluidized Beds – Minimum and Terminal Velocities in Fluidized Beds - Frictional pressure drop and its model – analysis - Solid movement, mixing, segregation and Staging - Gas distribution - small and large scale industries - Design of Distributors – Power Consumption | | |
| **Module:4** | **Entrainment and Elutriation** | **12 hours** |
| Free Board Behaviour - Entrainment from Tall and Short Vessels - Constant Approach - Flow Pattern of Gases through Fluidized Beds - Solid Movement - Mixing, Segregation and Staging | | |
| **Module:5** | **Miscellaneous systems** | **10 hours** |
| Conical fluidized bed - Inverse fluidized bed – Draft tube systems; Semi fluidized bed systems - Design of fluidized bed reactors | | |
| **Module:6** | **Contemporary Issues:** | **2 hours** |
| | Guest lecture from industry and R & D organizations | |
| | **Total Lecture hours:** | **60 hours** |

**Text Books**

| | |
|---|---|
| 1 | Kunii D and Levenspiel O., Fluidization Engineering, 2013, 2nd ed., Butterworth Heinemann, USA. |
| 2 | John Grace, Xiaotao Bi, Naoko Ellis, Essentials of Fluidization Technology, 2020, Wiley-VCH Verlag GmbH & Co, Germany |

**Reference Books**

| | |
|---|---|
| 1. | Yang W.C., Handbook of Fluidization and Fluid – Particle System, 2003, 1st ed., CRC Press, USA. |
| 2. | Grace J.R., Avidan A.A., Knowlton T.M., Circulating Fluidized Beds, 2011, 1st ed., Springer, USA. |

**Mode of Evaluation: Quiz, Case studies, Design Project, Case Study, Seminar, CAT and FAT**

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22.9.2025 | | |
| **Approved by Academic Council** | | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE326** | **FUELS AND COMBUSTION** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Develop the understanding levels of fuels and combustion fundamentals
2. Classify and introduce different types of fuel and fuel analysis techniques that assists the students to choose most convenient fuel for a process involving combustion`
3. Engage the students in designing various control techniques for handling various environmental issues resulting from combustion of fuels

**Course Outcomes**

1. Classify and compare various types of fuels and their properties
2. Choose the right type of fuel depends on various factors such as availability, storage, handling, pollution and cost of fuel
3. Describe various treatment processes of liquid and gaseous fuels
4. Explain various parameters that are utilized to recognize and assess the combustion process.
5. Interpret various air pollution controlling techniques for reducing the pollution generated from combustion of various fuels

| **Module:1** | **Classification and Properties of Fuels** | **10 hours** |
|---|---|---|

Fuels-Types and characteristics of fuels-Determination of properties of fuels-Fuel analysis-Proximate and ultimate analysis-Calorific value (CV)-Gross and net calorific values (GCV, NCV)-Bomb Calorimetry-empirical equations for CV estimation

| **Module:2** | **Solid Fuels** | **12 hours** |
|---|---|---|

Origin of coal-Ranking of coal-Washing, cleaning and storage of coal-Renewable Solid Fuels-comparative study of Solid, liquid and gaseous fuels-selection of coal for different industrial applications-carbonization of coal

| **Module:3** | **Liquid and Gaseous Fuels** | **12 hours** |
|---|---|---|

Origin of crude oil-composition of crude petroleum-classification of crude petroleum-Removal of salt from crude oil-processing of crude petroleum-Fractionation distillation-ADU and VDU- Cracking-Hydrotreatment and Reforming- Rich and lean gas-Wobbe Index-Natural Gas-Dry and wet natural gas-Foul and sweet NG-LPG-LNG-CNG-Methane-Producer Gas-Water gas-Coal Gasification-Gasification Efficiency

| **Module:4** | **Combustion** | **12 hours** |
|---|---|---|

General principles of combustion-types of combustion processes-Combustion chemistry-Combustion equations-Kinetics of combustion-combustion of solid fuels-Combustion calculations-air fuel ratio-Excess air calculation- Analysis of flue gases by Orsat apparatus

| **Module:5** | **Air Pollution Associated Due to Combustion** | **12 hours** |
|---|---|---|

Types of pollution-Combustion generated air pollution-Effects of air pollution-Pollution of fossil fuels and its control-Pollution from automobiles and its control using various controlling techniques

| **Module:6** | **Contemporary Issues** | **2 hours** |
|---|---|---|
| | Guest lecture from industry and R & D organizations | |
| | **Total Lecture hours:** | **60 hours** |

**Text Books**

| | |
|---|---|
| 1. | Kenneth K.K., Principles of Combustion, 2nd ed., Wiley Publications, USA, 2012 |
| 2. | Phillips H.J.,Fuels-solid, liquid and gases–Their analysis and valuation,1st ed., Foster Press,USA, 2010 |

**Reference Books**

| | |
|---|---|
| 1. | Speight J.G., The Chemistry and Technology of Coal, 3rd ed., Taylor and Francis Ltd., USA, 2016 |
| 2. | Sarkar S., Fuels and combustion, 3rd ed., Universities Press, India, 2009 |

**Mode of Evaluation: Quiz, Seminars, CAT and FAT**

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22.09.2025 | | |
| **Approved by Academic Council** | | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| BACHE327 | Fundamentals of Nanotechnology | 4 | 0 | 0 | 4 |
| Pre-requisite | NIL | Syllabus Version | | | |
| | | 1.0 | | | |

**Course Objectives**

1. To understand the foundational concepts of nanotechnology by exploring the unique properties of materials at the nanoscale
2. To provide an insight into the chemical materials and fabrication techniques used in nanotechnology
3. To emphasize the design concepts and strategies to build molecular machines

**Course Outcomes**

1. Describe the basic knowledge of nanotechnology based on their properties
2. Explain the nanoscale paradigm in terms of properties at the nanoscale dimension
3. Describe major top-down and bottom-up strategies in making the stable nanomaterials
4. Apply the concepts of basic chemistry and physics to design various nanomaterials
5. Choose various characterization techniques for estimating the properties of nanomaterials

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Introduction: Types of nanostructures and their properties** | **12 hours** |
| Definition of Nano and history of nanotechnology, Scientific revolution - Atomic Structure and atomic size, influence of nano over micro/macro, size effects and crystals, large surface to volume ratio, surface effects on the properties - One dimensional, Two dimensional and Three dimensional nanostructured materials, Quantum Dots shell structures, metal oxides, semiconductors, composites, mechanical – physical - chemical properties. | | |
| **Module:2** | **Synthesis and stability of nanomaterials** | **12 hours** |
| Top down and bottom-up methods, chemical methods, physical methods, Vapor Phase Synthesis, Green synthesis, self-assembly, Hybrid Approaches and Emerging Techniques – electrospinning – atomic layer deposition, electrostatic stabilization, steric stabilization, electrosteric stabilization, Depletion stabilization | | |
| **Module:3** | **Fullerenes, carbon based, metal, semiconductor and magnetic nanomaterials** | **12 hours** |
| Discovery of Fullerenes, properties of fullerenes, structure and analysis of bonding in fullerene, other forms of fullerene, history and structure of carbon nanotubes (CNT's), synthesis of CNT's and CNT composites, application of CNT's - Size, properties and shape control of metal, semiconductor and magnetic nanoparticles, Core-Shell structured and semiconductor nanoparticles | | |
| **Module:4** | **Characterization techniques** | **12 hours** |
| UV-Vis Spectroscopy, dynamic light scattering, transmission electron microscopy, scanning electron microscopy, X-ray diffraction, X-ray spectroscopy, Atomic force spectroscopy, Lithography techniques | | |
| **Module:5** | **Application of nanomaterials** | **10 hours** |
| Ferroelectric materials, coating, molecular electronics and nanoelectronics, biological, environmental, membrane-based application, polymer-based application, Energy and Sustainability. | | |
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Guest lecture from industry and R & D organizations | |
| | **Total Lecture hours:** | **60 hours** |

**Text Books**

| | |
|---|---|
| 1. | CNR Rao, Achim Müller and Anthony K. Cheetham, The Chemistry of nanomaterials: Synthesis, properties and applications, 2004, 1st ed., Wiley-VCH Verlag GmbH & Co. KGaA, Germany |
| 2. | Charles P. Poole, Jr., Frank J. Owens., Introduction to Nanotechnology, 2003, 1st ed., John Wiley & Sons, Inc., USA. |

**Reference Books**

| | |
|---|---|
| 1. | Sulabha K Kulkarni, Nanotechnology: Principles and Practices, 2019, 3rd edition, Springer International Publishing, USA. |
| 2. | Chris Binns, Introduction to Nanoscience and Nanotechnology, 2010, 1st edition, John Wiley & Sons Inc, USA. |

**Mode of Evaluation: Quiz, Case studies, CAT and FAT**

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22.9.2025 | | |
| **Approved by Academic Council** | | **Date** | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE328** | **Start-ups in Chemical Engineering** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Develop entrepreneurship critical skills in students
2. Enabling students with the knowledge and tools to launch start-ups in chemical engineering.
3. Introduce lean startup principles and strategies of practical startup development.
4. Understand the commercialization of chemical innovations and market strategies.

**Course Outcomes**

1. Evaluate the opportunities and challenges of start-ups in chemical engineering.
2. Validate business ideas via integrating lean startup methodologies.
3. Explain the transformation of business models to chemical product ventures.
4. Evaluate funding options and IP strategies for chemical start-ups.
5. Develop the practical innovation-to-market project with possible validations.

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Foundations of Chemical Entrepreneurship** | **10 hours** |

Importance of entrepreneurship in the chemical industry- Creativity and design thinking (identify the vertical for business opportunity, understand your customers, accurately assess market opportunity)- Traits of successful chemical entrepreneurs.

| Module | Title | Hours |
|---|---|---|
| **Module:2** | **Market Discovery and Lean Startups Principles** | **12 hours** |

Build-Measure-Learn Cycle- Validated learning- Minimum viable product (MVP)- Customer feedback- Pivot decision- economic need for chemical-based startup companies

| Module | Title | Hours |
|---|---|---|
| **Module:3** | **Technology Transfer and Commercialization** | **12 hours** |

Technology readiness- Market timing- Intellectual Property (IP): Licensing strategies, patents- Transferring technology from lab to market- in transforming innovations

| Module | Title | Hours |
|---|---|---|
| **Module:4** | **Financial Planning and Expansion for Startups** | **12 hours** |

Financing and business development for hard tech startups- Legal, regulatory, CSR, standards, and taxes- Startup Fundraising Methods- Business Growth- Strategic Collaborations- Startup Valuation- Investment Readiness- Battery entrepreneurship: Roadmap from lab to market

| Module | Title | Hours |
|---|---|---|
| **Module:5** | **Project-Based Learning: Creating a Chemical Startup** | **12 hours** |

Growing a business in the chemical industry- New models to foster big pharma and chemistry entrepreneurship- Student activity: Selection of start-up idea with team- Project work: Business model canvas, lean validation- Pitching the start-up: Business plan presentation

| Module | Title | Hours |
|---|---|---|
| **Module:6** | **Contemporary Topics** | **2 hours** |

Industry Expert Lectures

| | | |
|---|---|---|
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | García-Martínez J. & Li K., Chemistry Entrepreneurship, 2021, 1st ed., Wiley-VCH, Germany. |
| 2. | Ries E., The Lean Startup, 2011, 1st ed., Crown Business, United States. |

**Reference Books**

| | |
|---|---|
| 1. | West R.E. & Shuler B., Chemical Engineering Economics, 1st ed., Wiley, United States. |
| 2 | Harnish V., Scaling Up, 2014, 1st ed., Gazelles Inc., United States. |
| 3. | Engel J.S. et al., Commercializing Innovation, 2017, 1st ed., World Scientific Publishing, Singapore. |
| 4. | Metrick A. & Yasuda A., Venture Capital and the Finance of Innovation, 3rd ed., Wiley, United States. |

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE329** | **Computational Fluid Dynamics for Chemical Engineers** | **4** | **0** | **0** | **4** |
| **Prerequisite** | **BACHE302** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. Formulate and understand the governing equations for fluid flow and transport phenomena in chemical engineering.
2. Apply numerical discretization methods to solve partial differential equations effectively.
3. Utilize appropriate CFD techniques and validate simulation results using commercial and open-source CFD tools.

**Course Outcomes**

1. Explain the governing equations and various discretization techniques used in CFD.
2. Analyze and evaluate different mesh and solver options critically for their suitability in simulations.
3. Apply knowledge to set up and simulate CFD models using commercial and open-source software tools.
4. Develop CFD models tailored for chemical engineering systems.
5. Analyze and interpret simulation results by validating them against experimental data.

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Introduction to CFD** | **10 hours** |
| Importance of CFD in Chemical engineering – Introduction and mathematical importance of governing equations for heat, mass and fluid transfer – Classification of partial differential equations. | | |
| **Module:2** | **Discretization methods and mesh generation** | **12 hours** |
| Finite difference method (FDM) – finite volume method (FVM) – finite element method (FEM) | | |
| **Module:3** | **CFD techniques** | **12 hours** |
| Lax-Wendroff – MacCormack's – Viscous flows, conservation form, space marching – Relaxation technique – Artificial viscosity – Altering direction implicit (ADI) – Pressure correction. | | |
| **Module:4** | **Applications of CFD** | **12 hours** |
| CFD applications in reactor modelling, heat transfer and mass transfer with reactions, turbulence – solution of the Navier-Stokes equation, heat conduction, convection and diffusion. | | |
| **Module:5** | **CFD software** | **12 hours** |
| Introduction to available CFD software like Ansys Fluent, OpenFOAM, COMSOL | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Guest lectures of the experts from Industry and R &D organizations | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | J. D. Anderson Jr., Computational Fluid Dynamics, McGraw-Hill International Edition, 2017. |
| 2. | S.V. Patankar, Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing Corporation, 2017. |

**Reference Books**

| | |
|---|---|
| 1. | H. K. Versteeg and W. Malalasekera, An introduction to computational fluid dynamics: The finite volume method 3e, Pearson Education, 2007. |
| 2 | Chaurasia, A.S. (2021). Computational Fluid Dynamics and COMSOL Multiphysics: A Step-by-Step Approach for Chemical Engineers (1st ed.). Apple Academic Press. https://doi.org/10.1201/9781003180500 |
| 3. | T. J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2010. |
| 4. | Hämäläinen J, Kuzmin D. Finite Element Methods for Computational Fluid Dynamics: A Practical Guide. SIAM (Computational Science & Engineering), Philadelphia. 2014. |

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

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|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
| --- | --- | --- | --- | --- | --- |
| **BACHE330** | **Petrochemical Technology** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To introduce students to the fundamentals of petrochemicals, including their precursors, selection criteria, conversion processes, and associated safety and environmental concerns within the petrochemical value chain.
2. To provide a comprehensive understanding of hydrocarbon building blocks (alkanes, alkenes, aromatics) and their derivatives, focusing on their manufacturing processes, industrial applications, and relevant process engineering aspects.
3. To enable students to analyze the synthesis pathways and applications of various petrochemical derivatives, and to understand the economic, environmental, safety, and quality control considerations within the petrochemical and polymer industries.

**Course Outcomes**

1. Identify and classify various petrochemical precursors, describe their conversion processes, and discuss the safety, environmental, and value chain aspects pertinent to petrochemical production.
2. Explain the manufacturing processes and applications of $C_1$-$C_4$ hydrocarbons and their derivatives and construct basic process diagrams and mass balances for their production.
3. Describe the synthesis and industrial applications of major aromatic petrochemicals such as Benzene, Toluene, Xylenes (BTX), and Styrene, and differentiate their derived products.
4. Analyse the synthesis pathways and process engineering considerations for various industrial petrochemical derivatives, incorporating environmental waste treatment, health, and safety standards.
5. Evaluate the production techniques, properties, and applications of polymers, plastics, and fibres, and assess the economic feasibility of petrochemical products through market analysis and cost/margin analysis.

| Module:1 | Fundamentals of Petrochemicals and Precursors | 10 hours |
| --- | --- | --- |

Introduction to Petrochemicals**;** Precursors to Petrochemicals**;** Selection and Properties of Precursors; Conversion of Precursors to Petrochemicals**;** Petrochemicals Value Chain**;** Safety and Environmental Concerns.

| Module:2 | Hydrocarbon Building Blocks – Alkanes, Alkenes & Derivatives | 12 hours |
| --- | --- | --- |

Overview of $C_1$–$C_4$ Hydrocarbons; Manufacture & Uses of $C_1$–$C_4$ Derivatives; Technologies and Routes; Process Diagrams & Mass Balance; (Ethylene to polyethylene; Propylene to polypropylene); Environmental and Energy Considerations**.**

| Module:3 | Aromatics and Their Petrochemical Derivatives | 12 hours |
| --- | --- | --- |

Introduction to Aromatic Compounds**;** Key Aromatics: Benzene, Toluene, Xylenes (BTX) & Styrene; Derivative Manufacturing Routes (Benzene to phenol; Toluene to benzaldehyde; Xylenes to phthalic anhydride); Styrene and its Applications**;** Advanced Aromatics Chemistry; Industry Applications and Trends.

| Module:4 | Petrochemical Derivatives – Synthesis & Applications | 12 hours |
| --- | --- | --- |

Industrial Derivatives of Petrochemicals; Synthesis Pathways; Process Engineering Aspects; Environmental and Waste Treatment; Health and Safety Considerations; Product Standards and Quality Control.

| Module:5 | Polymers, Plastics, Fibres, and Industry Economics | 12 hours |
| --- | --- | --- |

Polymers and Plastics - Introduction to Polymerization; Production Techniques **(**Polybutadiene rubber, SBR, SAN, etc); Polymer Properties and Applications. Specialty Plastics and Fibers - High-performance Resins; Explosives and SNG; Reinforced and Composite Fibers. Petrochemical Industry Economics- Global and Indian Petrochemical Market Overview; Cost and Margin Analysis; Product Selection and Feasibility; Case study.

| | | |
|---|---|---|
| **Module:6** | **Contemporary Issues** | **2 hours** |
| | Industry Expert Lecture | |
| | **Total Lecture hours** | **60 hours** |

| | |
|---|---|
| **Text Books** | |
| 1 | I. D. Mall, Petrochemical Process Technology, 2017, 2nd ed., Macmillan Publishers, India. |
| 2 | S. Maitra and 0. P. Gupta, Elements of Petrochemical Engineering, 2018, Khanna Publishers, India. |
| **Reference Books** | |
| 1. | V. Patel, Advances in Petrochemicals, 2015, lntech Open Publications, India. |
| 2. | I D Mall, Petroleum Refining Technology, 2017, CBS Publishers, India. |

**Mode of Evaluation: Continuous Assessment Test, Quizzes, Case studies, Final Assessment Test**

| | | | |
|---|---|---|---|
| **Recommended by Board of Studies** | 22.9.2025 | | |
| **Approved by Academic Council** | | **Date** | |

| Course code | Course title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE331** | **Process Intensification** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **BACHE204** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives:**

1. To understand the concept of Process Intensification.
2. To apply the techniques of intensification to a range of chemical processes
3. To infer alternative solutions keeping in view point, the environmental protection, economic viability and social acceptance

**Course Outcomes:**

1. Explain the scientific background, techniques and applications of intensification in the process industries
2. Apply process intensification in industrial processes
3. Implement methodologies for process intensification
4. Identify scale up issues in the chemical process
5. Interpret the feasibility of the process intensification.

| **Module:1** | **Introduction to process Intensification** | **10 hours** |
|---|---|---|

History of Process Intensification - Definitions and Interpretations of Process Intensification - Fundamentals of Process Intensification – Principles, Approaches, Domains, and Scales - Techniques of Process Intensification (PI) Applications - The philosophy and opportunities of Process Intensification -Main benefits from process intensification - Process Intensifying Equipment -Process intensification toolbox - Techniques for PI application.

| **Module:2** | **Process intensification in Reaction engineering** | **12 hours** |
|---|---|---|

Introduction to spinning disc reactor - Rotor stator reactors: the STT reactor - Taylor– Couette reactor - Rotating packed-bed reactors - Oscillatory baffled reactors (OBRs) - Micro-reactors (The catalytic plate reactor (CPR), HEX-reactors) - Hydrodynamic Cavitation Reactors.

| **Module:3** | **Intensive Mixers** | **12 hours** |
|---|---|---|

Intensive mixers: special types of mixers - Ultrasound mixers, Mixing in intensified equipment - Chemical Processing in High-Gravity Fields Atomizer - Ultrasound Atomization – Nebulizers - High intensity inline mixers reactors - Static mixers – Ejectors - Tee mixers - Impinging jets - Rotor stator mixers

| **Module:4** | **Combined chemical reactor heat exchangers and reactor separators** | **10 hours** |
|---|---|---|

Principles of operation, Applications - Reactive absorption - Reactive distillation - Applications of RD Processes - Classification of compact heat exchangers - Plate heat exchangers - Spiral heat exchangers - Flat tube-and-fin heat exchangers - Microchannel heat exchangers - Phase-change heat transfer - Selection of heat exchanger technology - Feed/effluent heat exchangers - Integrated heat exchangers in separation processes - Design of compact heat exchanger - examples.

| **Module:5** | **Enhanced fields & Case Studies** | **14 hours** |
|---|---|---|

Energy based intensifications in distillation - Sono-chemistry - Cavitation Reactors - Flow over a rotating surface - Hydrodynamic cavitation applications -Cavitation reactor design - Nusselt-flow model and mass transfer -Sono crystallization - Reactive separations - Reaction separation of Plastic/Biomass pyrolysis - Petrochemicals and Fine Chemicals – Refineries -Bulk Chemicals, -Nuclear Industry

| **Module:6** | **Contemporary issues** | **2 hours** |
|---|---|---|

Guest lecture from industry/ R&D organizations

| | | |
|---|---|---|
| | **Total Lecture hours:** | **60 hours** |

**Textbook(s)**

| | |
|---|---|
| 1. | Reay D, Ramshaw C, Harvey A., Process Intensification Engineering for Efficacy, Sustainability and Flexibility, 2013, 2$^{nd}$ ed., Butterworth Heinemann, USA. |
| 2 | Dominic C. Y.F, El-Halwagi M.M., Process Intensification and Integration for Sustainable Design, 2021, 1$^{st}$ ed., Wiley-VCH, USA. |

| **Reference Books** | | | |
|---|---|---|---|
| 1. | Hernández S, Gabriel J, Petriciolet B, Adrián., Process Intensification in Chemical Engineering Design Optimization and Control, 2016, 1st ed., Springer, Switzerland | | |
| 2. | Boodhoo K, Harvey A., Process Intensification Technologies for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, 2013, 1st ed., Wiley, USA. | | |
| Mode of evaluation: Continuous Assessment Test, Quiz, Case studies, Final Assessment Test | | | |
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BCHE332** | **Heterogenous Reaction Engineering** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **BACHE203** | **Syllabus version** | | | |
| | | **x.x** | | | |

**Course Objectives**

1. To train the students in designing reactors for heterogeneous reactors
2. To facilitate understanding of nonisothermal reactors.
3. To familiarize the student with critical parameters affecting the performance of and design heterogeneous and multi-phase reactors

**Course Outcomes**

1. Evaluate the behavior of non-isothermal reactors.
2. Analyze the heterogeneous reaction systems and design the reactors for fluid-solid reactions
3. Explain the role of catalyst in reactions and analyze the transport mechanism in heterogeneous catalysts
4. Design and characterize catalyst surface properties for better activation of the catalyst
5. Identify critical parameters affecting the performance of and design heterogeneous and multi-phase reactors

| | | |
|---|---|---|
| **Module:1** | **Non-isothermal Reactors** | **12 hours** |

Steady state non-isothermal reactors, CSTR, PFR - Mole balance, energy balance, Adiabatic reactors: CSTR, PFR Batch reactor – Multiple steady states – Multiple chemical reactions.

| | | |
|---|---|---|
| **Module:2** | **Introduction to Heterogeneous Reaction Engineering** | **12 hours** |

Introduction to heterogeneous reacting systems-Non-catalytic solid-fluid reactions- Sharp interface and volume reaction models, determination of rate-controlling steps and application to design of reactors.

| | | |
|---|---|---|
| **Module:3** | **Heterogeneous Catalytic Reactions** | **12 hours** |

Definition and properties - Steps involved in catalytic reactions - Rate laws mechanisms - Rate limiting step - Transport effects in heterogeneous catalysis: Internal effectiveness, External transport limitations and overall effectiveness

| | | |
|---|---|---|
| **Module:4** | **Catalyst Preparation, Characterization and Deactivation** | **12 hours** |

Definition and types of catalysts – Industrial catalysts – Preparation and characterization of the catalysts, Surface area and pore volume determination - Types of catalyst deactivation – Determining the order of deactivation – Catalyst regeneration methods.

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|---|---|---|
| **Module:5** | **Design of Reactors for Fluid-Solid reactions** | **10 hours** |

Reactor design fundamentals and methodology, rate data analysis - Overall view of Fluidized, Packed and Moving bed reactors- Fluid-liquid reactions: Film and Penetration theories - Fluid-solid catalytic reactions.

| | | |
|---|---|---|
| **Module:6** | **Contemporary Topics** | **2 hours** |

Guest lectures of the experts from Industry and R &D organizations

| | | |
|---|---|---|
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1. | H. Scott Fogler, Elements of Chemical Reaction Engineering. $4^{th}$ ed., Pearson, 2015 |

**Reference Books**

| | |
|---|---|
| 1. | G. T. Miller, Chemical Reaction Engineering, CRS publications, 2016 |
| 2 | M. Albert Vannice, Kinetics of Catalytic Reactions. 2nd ed., Springer, 2010 |

Mode of Evaluation: CAT / written Case studies / Quiz / FAT / Seminar / group discussion.

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BCHE333** | **Transport Phenomena** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To introduce the fundamental principles and mechanisms of momentum, heat, and mass transport.
2. To develop analytical skills for solving transport problems using the shell balance and equation of change approaches.
3. To enable students to apply transport equations and analogies in complex systems involving steady-state conduction, diffusion, and chemical reactions.

**Course Outcomes**

1. Explain the fundamental principles of momentum, heat, and mass transport.
2. Apply shell momentum balances to determine velocity distributions for various laminar flow systems.
3. Formulate and solve fluid flow problems using the equations of continuity and motion.
4. Apply shell energy balances to determine temperature distributions in systems with various heat sources.
5. Solve steady-state mass transfer problems using shell mass balances, and apply dimensionless analysis and transport analogies to interpret mass transfer behaviour.

| **Module:1** | **Introduction to Transport Phenomena** | **10 hours** |
|---|---|---|

Introduction – Mechanisms of Transport Phenomena – Molecular, microscopic, and macroscopic levels – Momentum, heat, and mass transport – Governing equations – Newtonian and non-Newtonian fluids – Time-dependent and time-independent fluids – Rheological models – Effect of temperature and pressure on molecular transport properties of gases and liquids.

| **Module:2** | **Shell Momentum Balances** | **12 hours** |
|---|---|---|

Shell momentum balances and boundary conditions – Momentum flux and velocity distribution – Flow of a falling film on an inclined flat plate – Flow through a vertical circular tube – Flow through an annulus – Flow of two adjacent immiscible fluids – Laminar slit flow with stationary and with a moving wall – Flow around a sphere.

| **Module:3** | **Equations of Change** | **12 hours** |
|---|---|---|

Vector and Tensor Analysis – Basic concepts – Eulerian and Lagrangian viewpoint –Equation of Continuity – Equation of Motion – Simplified form of Equation of Motion – Navier-Stokes Equation – Use of Equations of Change to solve different flow problems (at least six).

| **Module:4** | **Shell Energy Balances** | **12 hours** |
|---|---|---|

Shell energy balances and boundary conditions – Steady state temperature distribution – Heat conduction with an electrical heat source – Heat conduction with a viscous heat source – Heat conduction with a chemical reaction heat source – Heat conduction with a nuclear heat source – Heat conduction from a sphere to a stagnant fluid.

| **Module:5** | **Shell Mass Balances** | **12 hours** |
|---|---|---|

Molecular mass transport – Convective mass transport – Dimensionless numbers and dimensional analysis in mass transfer – Analogies among mass, energy, and momentum transfer – Shell mass balances and boundary conditions – Steady state concentration distribution – Diffusion through a stagnant gas film – Diffusion with a homogeneous chemical reaction – Diffusion with a heterogeneous chemical reaction.

| **Module:6** | **Contemporary Topics** | **2 hours** |
|---|---|---|

Guest lectures of the experts from Industry and R &D organizations

| | **Total Lecture hours:** | **60 hours** |
|---|---|---|

**Text Book(s)**

| | |
|---|---|
| 1. | Bird, R.B., Stewart, W.E., Lightfoot, E.N., Transport Phenomena, 2012, 2nd ed., John Wiley & Sons Inc., India. |

**Reference Books**

| | |
|---|---|
| 1. | Welty, J., Rorrer, G.L., Foster, D.G., Fundamentals of Momentum, Heat, and Mass Transfer, 2019, 7th ed., John Wiley & Sons Inc., India. |
| 2 | Plawsky, J.L., Transport Phenomena Fundamentals, 2020, 4th ed., CRC Press, USA. |

| | | | |
|---|---|---|---|
| Mode of Evaluation: Continuous Assessment Test / Written Case studies / Quiz / Final Assessment Test | | | |
| Recommended by the Board of Studies | 22.9.2025 | | |
| Approved by the Academic Council | | Date | |

| Course code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHE334** | **Chemical sensors for Industrial applications** | **4** | **0** | **0** | **4** |
| **Pre-requisites** | **NIL** | **Syllabus version** | | | |
| | | 1.0 | | | |

**Course Objectives:**

1. Understand the priniciple of chemical and biological sensors
2. Design modern sensors for the industries
3. Assemble and apply IoT based sensors for real time application

**Course Outcome:**

Upon successful completion of the course the students will be able to

1. Develop understanding of sensor components
2. Demonstrate the principles of sensors
3. Design the electrodes for the sensors
4. Construct sensors for the chemical industries
5. Build schemes to develop IoT based sensors for chemical industries

| Module | Title | Hours |
|---|---|---|
| **Module:1** | **Basics of chemical sensors** | **10 hours** |
| Sensor types, Electrochemical sensors, Biosensors, Urea and glucose sensor, Carbon nanomaterials-based FETs, Monolithic graphine FET sensors, fuel cell-based sensors, ceramic sensor, IOT sensors, and Problems in electrochemical and bio sensors | | |
| **Module:2** | **Electrodes and thin films for sensors** | **12 hours** |
| Reference electrode, counter electrode, ionic electrodes, transparent electrodes, flexible electrodes, thin film, micro fluidics, and Probems related to micro electrode design | | |
| **Module:3** | **Materials and fabrication procedures** | **12 hours** |
| Preparation of Polymers and composite materials, calibration of Transducers, Wafers preparation, Substrate preparation, interconnects, fabrication of silicon on insualtors, 3D printing, E-Jet printing, material printing, and High resolution E-jet printing, and steps to make printed electronic circuit board | | |
| **Module:4** | **Sensor Assembly and Sensor testing** | **12 hours** |
| Device assembly, Steps in sensor calibration, potentiometric ion selective sensors, current – voltage curve, Problems in voltametric and conductometric techniques as chemical sensors to obtain electrical properties, optical properties, impedance measurement of sensors | | |
| **Module:5** | **Molecule recognition in sensors** | **12 hours** |
| Chemical agents, Spectroscopic methods, Biological agents. Thermodynamic and kinetic interaction, visible absorption spectroscopy, flurocent reagents, and light scattering methods, Problems related to sensor characteritics, sensor selectivity, time factors, precision, and sensitivity, and artefact and prototype demonstration of modern sensors and Machine learning tools. | | |
| **Module:6** | **Contemporary Topics** | **2 hours** |
| Guest lectures of the experts from Industry and R&D organizations | | |
| | **Total Lecture hours:** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1 | Brian Eggins (2004), Chemical sensors and biochemical sensors, John Wiley & Sons |

**Reference Books**

| | |
|---|---|
| 1. | Jerome S. Schultz and R.F Taylor, (1996), Handbook of Chemical and Biological Sensors, CRC press. |

| | | | |
|---|---|---|---|
| Recommended by Board of Studies | 22.9.2025 | | |
| Approved by Academic Council | | Date | |

| Course Code | Course Title | L | T | P | C |
|---|---|---|---|---|---|
| **BACHEXXX** | **Introduction to Clean Energy Systems and Policies** | **4** | **0** | **0** | **4** |
| **Pre-requisite** | **NIL** | **Syllabus Version** | | | |
| | | **1.0** | | | |

**Course Objectives**

1. To provide an engineering overview of the major renewable energy technologies (Solar, Wind, Bioenergy, etc.), focusing on their principles, components, and conversion processes.
2. To equip students with an understanding of energy storage, grid integration, and the critical role of chemical engineering processes in industrial decarbonization (e.g., CCUS, Green Hydrogen).
3. To analyze the key national and international energy policies and economic frameworks that govern the development and deployment of clean energy systems.

**Course Outcomes**

1. Explain the fundamentals of energy conversion, the global climate goals, and the role of thermodynamics (e.g., exergy analysis) in assessing energy system efficiency.
2. Analyze the operation, design constraints, and economic viability of solar (PV/thermal) and wind energy systems for utility-scale and decentralized applications.
3. Evaluate the pathways for bioenergy, hydrogen, and fuel cell production and storage, identifying the key chemical reaction engineering and material science challenges.
4. Develop strategies and apply process integration tools for industrial decarbonization in hard-to-abate sectors (e.g., cement, steel, chemical industries).
5. Discuss the impact of major national and international energy policies, regulations, and market mechanisms on accelerating the transition to a net-zero energy system.

| **Module:1** | **Global Energy Landscape and Policy Drivers** | **10 hours** |
|---|---|---|

**Energy Fundamentals:** Global energy demand and mix, energy security. **Thermodynamics in Energy:** First and Second Laws, Exergy analysis for system assessment. **Climate Context:** Global warming, greenhouse gases, Paris Agreement, COP mechanisms. **Energy Policy:** Policy drivers, market mechanisms (e.g., Carbon Tax, Emissions Trading Schemes)

| **Module:2** | **Solar and Wind Energy Systems** | **12 hours** |
|---|---|---|

**Solar PV:** Solar radiation fundamentals, material and operational principles of photovoltaic cells, system components (inverters, batteries). Solar Thermal: Principles, collectors, and applications (heating, cooling). **Wind Energy:** Global wind patterns, aerodynamic principles of wind turbines, classification, grid integration challenges.

| **Module:3** | **Biomass and Other Renewable Sources** | **14 hours** |
|---|---|---|

**Bioenergy & Biofuels:** Biomass resources, thermochemical (pyrolysis, gasification) and biochemical (fermentation, anaerobic digestion) conversion processes. **Hydro and Geothermal:** Principles, technologies, and applications. **Ocean Energy:** Tidal and wave energy concepts.

| **Module:4** | **Chemical Engineering for Decarbonization** | **12 hours** |
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Industrial Decarbonization: Pathways and challenges for hard-to-abate sectors (e.g., chemical, cement, iron/steel). Carbon Capture, Utilization, and Storage (CCUS): Post-combustion, pre-combustion, and oxy-fuel capture, chemical solvents and membranes, CCU applications. Green Hydrogen Production: Chemical engineering unit operations, process efficiency, and techno-economic analysis. Process Integration: Energy efficiency in chemical plants (heat exchanger networks).

| **Module:5** | **Energy Economics and Sustainability** | **10 hours** |
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**Project Appraisal:** Life Cycle Assessment (LCA) for clean energy technologies, techno-economic analysis (TEA), Levelized Cost of Energy (LCOE). **Sustainability Metrics:** Triple Bottom Line (TBL) concept. **Future Trends:** Digitalization in energy systems, role of AI/ML, and emerging low-carbon technologies.

| **Module:6** | **Contemporary Issues** | **2 hours** |
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| | Guest lecture from industry and R&D organizations | |
| | **Total Lecture hours:** | **60 hours** |

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| **Text Books** | |
| 1 | Ibrahim Dincer and Dogan Erdemir, **Introduction to Energy Systems** Wiley (USA/UK), 2023, 1st Edition |
| 2 | Charles F. Kutscher, Jana B. Milford, and Frank Kreith, **Principles of Sustainable Energy Systems**CRC Press (USA), 2025, 4th Edition |
| **Reference Books** | |
| 1. | Nick Jenkins and Janaka Ekanayake, **Renewable Energy Engineering**Cambridge University Press (UK)2024, 2nd Edition |
| 2. | Suresh Sundaramurthy, Sakthivel Sundaresan, Sarat Kumar Swain, **Industrial Decarbonization and the Energy Transition,** Elsevier (USA)2025, 1st Edition |
| **Mode of Evaluation: Quiz, Assignment, CAT, Seminar, Presentation and FAT** | |

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| **Recommended by Board of Studies** | 22-9-2025 | | |
| **Approved by Academic Council** | **No.** | **Date** | |