**INDIAN INSTITUTE OF PETROLEUM AND ENERGY**
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# B.TECH SECOND YEAR SYLLABUS CHEMICAL ENGINEERING Batch 2022

## 3rd SEMESTER

| Sl. No. | Course type | Subject code | Course Name | L | T | P | Credits |
|---|---|---|---|---|---|---|---|
| 1 | **IC** | IC2101 | Numerical Methods & Transform Calculus | 4 | 0 | 0 | 4 |
| 2 | **IC** | IC2102 | Fluid Mechanics & Multiphase Flow | 3 | 1 | 0 | 4 |
| 3 | **IC** | IC2103 | Object Oriented Programming | 2 | 0 | 3 | 4 |
| 4 | **DC** | CH2101 | Chemical Process Calculations | 3 | 1 | 0 | 4 |
| 5 | **DC** | CH2102 | Particle Technology | 3 | 0 | 0 | 3 |
| 6 | **DP** | CH2103 | Fluid Flow Lab | 0 | 0 | 3 | 2 |
| 7 | **Extra Academic Activity** | EA2101 | EAA III | 0 | 0 | 6 | P/F |
| **Total** | | | | **15** | **2** | **6** | **21** |

## 4th SEMESTER

| Sl. No. | Course type | Subject code | Course Name | L | T | P | Credits |
|---|---|---|---|---|---|---|---|
| 1 | **DC** | CH2201 | Heat Transfer | 3 | 1 | 0 | 4 |
| 2 | **DC** | CH2202 | Chemical Engineering Thermodynamics | 4 | 0 | 0 | 4 |
| 3 | **DC** | CH2203 | Chemical Reaction Engineering-I | 3 | 1 | 0 | 4 |
| 4 | **DC** | CH2204 | Mass Transfer-I | 3 | 1 | 0 | 4 |
| 5 | **DP** | CH2205 | Heat Transfer Lab | 0 | 0 | 3 | 2 |
| 6 | **DP** | CH2206 | Particle Technology & Fuel Lab | 0 | 0 | 3 | 2 |
| 7 | **Extra Academic Activity** | EA2201 | EAA IV | 0 | 0 | 0 | P/F |
| **Total** | | | | **13** | **3** | **6** | **20** |

# 3rd SEMESTER

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| Core | IC2101 | **Numerical Methods & Transform Calculus** | 4 | 0 | 0 | 4 |

**Pre-Requisites:** Calculus, Linear Algebra, and Differential equations

| Course Objective |
|---|
| 1. This course is to introduce the basic concepts of numerical methods for a variety of problems such as algebraic equations, linear systems of equations, approximation, ordinary differential equations.<br>2. To make the students understand the basic concepts of Laplace and Fourier transforms, Fourier series and the applications of these transform techniques in solving initial and boundary value problems. |
| **Learning Outcomes** |
| At the end of the course, the student will be able to:<br>1. Understand the numerical error and applicability of a particular method.<br>2. Find roots of a nonlinear equation, and interpolate a function and analyze the variety of direct and iterative methods for solving systems of linear equations.<br>3. Identify different methods to find the approximate integration by quadrature rules.<br>4. Solve ordinary and partial differential equations by finite difference methods<br>5. Solve initial and boundary value problems by using Laplace and Fourier transform techniques.<br>6. Understand the approximation of a function in terms of Sine and Cosine functions. |

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | **Numerical Methods:**<br>**A. Finding roots of equations**: Bisection, Regula-falsi, Newton-Raphson, secant and fixed-point iteration techniques. Lagrange and Newton divided differences methods. Numerical differentiation. Numerical integration: Rectangle, Trapezoidal and Simpson's rules, Composite rules.<br><br>**B. System of Linear Equations:** Gaussian elimination, Gauss-Jordan method, LU decomposition, Iterative methods: Gauss-Seidel and Gauss-Jacobi, Eigenvalue problems: power method. Numerical Solution of ODE: Taylor's, Euler's, Modified-Euler, Runge-Kutta methods. | The student will be able to understand numerical error and applicability of a particular method to find roots of a nonlinear equations, system of linear equations, interpolation of a function, numerical integration, and ODEs. |

| | | |
|---|---|---|
| 2. | **Transform Calculus:**<br>**A. Laplace Transforms:** Definition, linearity property, conditions for existence, shifting properties, Laplace transform of derivatives and integrals, unit step function, Dirac-delta and error function, differentiation and integration of transforms, convolution theorem, inversion, periodic functions, evaluation of integrals by Laplace transforms, solution of initial and boundary value problems.<br><br>**B. Fourier Series and Fourier Transforms:** Fourier series representation of a function and its convergent properties, half range series, sine and cosine series, Fourier integral representation of a function, Parseval's identity. Fourier transform, Fourier sine and cosine transforms, linearity, scaling, shifting properties, convolution theorem, Applications to initial and boundary value problems.<br><br>**C. Introduction to Machine Learning:** Data, models and learning, empirical risk minimization, parameter estimation. | The student will be able to solve initial and boundary value problems by using Laplace and Fourier transform techniques. In addition, the student will be able to approximate a function in terms of Sine and Cosine functions |

**Numerical Methods:**

**Text Books**:

1. S. D. Conte and Carl de Boor, Elementary Numerical Analysis- An Algorithmic Approach (3rd Edition), McGraw-Hill, 1980.
2. K. Atkinson, An Introduction to Numerical Analysis (2nd Edition), John-Wiley & Sons, 1989.
3. E. Kreyszig, Advanced Engineering Mathematics (8th Edition), John Wiley (1999).

**References**:

1. S.S. Sastry, Introductory Methods of Numerical Analysis - Prentice Hall of India

**Transform Calculus:**

**Text Books**:

1. R. K.Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa publisher
2. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley publisher.

**References**:

1. W. Feller, An introduction to Probability theory and its applications
2. Peter V, O'Neil, Advanced Engineering Mathematics, 6th edition.

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| IC | CH20002 | Fluid Mechanics & Multiphase Flow | 3 | 1 | 0 | 4 |

**Course Objective**

1. To understand the basic concept of fluid flow and its application to chemical process industries including pipe flow and fluid machinery.

**Learning Outcomes**

At the completion of this course, every student should be able to:

1. Explain the basic concepts in fluid mechanics; describe the physics and formulate mathematical descriptions of viscous flows.
2. Identify the fundamental concepts in boundary layer theory, and turbulence.
3. Formulate physical model and mathematic model to solve typical fluids problems of engineering importance.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| **Section A:** | | |
| 1. | Definition of Fluid, Lagrangian and Eulerian methods of description; Velocity Field: Streamline and stream function, Vorticity, Stress Field; Rheology: Newtonian/non-Newtonian Fluids. | Students will be introduced to various fluids and their properties. |
| 2. | Viscous/Inviscid, Laminar/Turbulent, Compressible/ Incompressible, Internal/External, Rotational/Irrotational. | Students will acquaint with various flow field. |
| 3. | **Fluid Statics:** Pressure variation in static fluids, manometer, capillary hydrostatics. | Students will have a strong foundation on static fluid. |
| 4. | Macroscopic mass and momentum balance using integral control volume method, Euler & Bernoulli equations, Internal Incompressible Viscous Flow. Fully developed laminar flow in pipes, Couette and annular flows; Hagen Poiseulle Equation. | Students will be able to apply Euler and Bernouli equation to compute pressure drop, friction losses in flow systems of different configurations. |

| | | |
|---|---|---|
| 5. | Eddy viscosity, Universal velocity profile; Skin and Form Friction, friction factor and friction factor versus Reynolds number relation, Calculation of Head Losses in pipes and fittings, Converging and diverging nozzles, Solution of single and multi-path pipe flow systems. | Students will be familiar with head losses in pipes, fittings, converging and diverging nozzles. |
| 6. | Flow around immersed bodies, Drag and Lift, Drag coefficient. | Basic understanding and applications of external incompressible flow. |
| 7. | Valves, Pumps, Compressors, Flow meters (Head/Area): Venturi, Orifice, Rotameter. | Students will be introduced to various flow measuring instruments and pumps. |
| **Section B:** | | |
| 8. | Introduction to Hydrodynamics of Gas-liquid flow: Homogeneous flow model, Separated flow model, Bubble formation and dynamics, Mass bubbling and liquid entrainment. | Students will understand hydrodynamics of gas-liquid and liquid-liquid two-phase flow system. |

**Text Books**:

1. Introduction to Fluid Mechanics by R. W. Fox & Alan T. McDonald, Wiley; 6th edition (2003).
2. Fundamentals of Multiphase Flow by C. E. Brennen, Cambridge University Press; 1st edition (2009).

**References**:

1. Fluid Dynamics and Heat Transfer by James G. Knudsen and Donald L. Katz, McGraw-Hill; First Edition (1958).
2. Coulson & Richardson's Chemical Engineering: Fluid Flow, Heat Transfer & Mass Transfer, Vol.1., Butterworth-Heinemann; 6th edition (1999).

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| IC | IC2103 | Object Oriented Programming | 2 | 0 | 3 | 4 |

**Course Objective**

1. The fundamentals of object-oriented concepts, OO programming, and database concepts.
2. Model real world problems with Object Oriented constructs and solve them.

**Learning Outcomes**

1. Analyse a given problem and model it using objects, inheritance, and other OO constructs.
2. Implement a given OO model using the Python language.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | Fundamental concepts of object oriented programming: Introduction to the principles of object- oriented programming (classes, objects, messages, encapsulation, inheritance, polymorphism, exception handling, and object-oriented containers). | Students will understand: the need for OOP, how the OO constructs help to decompose the complex problems. |
| 2. | Object design implementation in a programming language, e.g., C++ or java or Python. (Currently, Python is used.). | Familiarize with Python basics, built-in data structures, functions, etc.<br>Implement object oriented concepts using Python. |
| 3. | Object oriented database systems: Object oriented data model, query languages, storage organization and indexing techniques; object relational databases. | Familiarize with modelling data, creating Python application to interact with a database. |

**Text Books**:


1. Grady Booch, Object Oriented Analysis and Design, Addison-Wesley.
2. Programming Python: Powerful Object-Oriented Programming (4th Edition), Author: Mark Lutz, O'Reilly.

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DC | CH2101 | Chemical Process Calculations | 3 | 1 | 0 | 4 |

**Course Objective**

This course aims to introduce the material and energy balances for chemical engineers.

**Learning Outcomes**

1. Learn the basic calculations and techniques used in chemical engineering problems.
2. Understand the basics of material and energy balances and will be able to apply them to chemical processes.
3. Understand the behaviour of liquid, gas and solids.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | Numerical techniques for solving material & energy balance equations. | Introduction material and energy balance equations. |
| 2. | Material balance with and without chemical reactions, Recycle, bypass, purge calculations, computer-based calculations. | Solving material balance problems on chemical process units. |
| 3. | Vapor-liquid equilibrium: Bubble point, dew point calculations, phase envelope calculations. | Understand the properties of gas and liquids. Phase envelope diagrams. |
| 4. | Energy balances with and without chemical reactions; fuel calculations, adiabatic flame temperature; computer-based calculations for energy balance. psychrometric calculations. | Solving energy balance problems on chemical process units. |
| 5 | Introduction to Fuels (solid, liquid and gas): Important properties and specifications. | Fuels and their properties. |

**Text Books:**

1. Himmelblau, D. M. and Riggs, J. B. (2012). Basic Principles and Calculations in Chemical Engineering. 8th Ed., PHI, Eastern Economy Edition.
2. Felder R.M. and Rousseau R.W., (2005), Elementary Principles of Chemical Processes, 3rd Ed., John Wiley & Sons.
3. Introduction to Material and Energy Balances, G V Rekliatis, John Wiley & Sons, 1983.

**References:**

1. Chemical Process Principles, Part I by O. A. Hougen, K. M. Watson and R. A. Ragatz

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DC | CH2102 | Particle Technology | 3 | 0 | 0 | 3 |

**Course Objective**

1. To provide students with the concept of unit processes and unit operations, and the importance of mechanical operations in the chemical process industries.
2. To enable students to understand the properties, storage, mixing, and transportation of bulk solids.
3. To provide students with the importance of size reduction, actions involved, and parameters affecting size reduction and industrial size-reduction equipment.
4. To enable students to grasp the importance of separation of solids and the types of separation equipment for solid-solid, solid-liquid, and solid-gas separation.

**Learning Outcomes**

1. Identify unit operations and their role in chemical industries.
2. Select equipment for operations on solid, liquid, and gaseous materials.
3. Understand and analyse unit operation equipment based on mathematical and physical descriptions.
4. Compare performances of existing equipment based on the efficiency and select the best equipment for various unit operations.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | Determinations of mean particle size, Size distribution equations. | Understand the properties, storage, mixing and transportation of bulk solids.<br>Estimate mean/average particle size of a mixture. |
| 2. | Principles and laws of crushing and grinding. Characteristics of industrial crushers and mills. Industrial screening, effectiveness of screens, cyclones. | Understand importance, uses and types of size reduction equipment.<br><br>Understand and use laws of size reduction. |
| 3. | Fluid-particle mechanics, free and hindered settling. Industrial classifiers, clarifiers and thickeners, gravity separation, tabling and jigging. Floatation and its kinetics, magnetic and electrostatic separation and precipitation. Mixing of liquids and solids, power requirement in mixing. | Grasp the importance of separation of solids from other solid and fluids.<br>Will be able to do calculations on solid separation processes.<br>Will master the working principles of separation equipment. |

| | | |
|---|---|---|
| 4. | Principles of filtration, filtration equipment. Flow through packed and fluidized bed. Introduction to storage and conveying, elevating equipment, hydraulic and pneumatic transport. | Will understand different types of mixing equipment for different applications involving solid and fluid. |

**Text Book**:


1. McCabe, W., Smith, J., Harriott, P. Unit Operations of Chemical Engineering, McGraw Hill Education, 2017.


**Reference:**


1. Richardson, J. H., Harker, J.H., Backhurst, J.R., Coulson and Richardson's Chemical Engineering, Volume 2, 5th Edition: Particle Technology and Separation, Elsevier, 2006.

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DP | CH2103 | Fluid Flow Lab | 0 | 0 | 3 | 2 |

**Course Objective**

1. To impart training to use various flow measuring devices for making engineering judgments.

**Learning Outcomes**

1. Estimate the friction and measure the frictional losses in fluid flow.
2. Experiment with flow measurement devices like venturi meter and orifice meters.
3. Predict the coefficient of discharge for flow through pipes.

| Unit N | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | Bernoulli's experiment; | At the end of the course, the student will be able to perform experiment on various fluid flow equipment and machineries. |
| 2 | Flow through square and circular pipes. | |
| 3 | Nozzles; pipe fittings. | |
| 4 | Venturi meter, orifice meter and | |
| 5 | Horizontal V-notch. | |
| 6 | Packed bed. | |
| 7 | Rotameter. | |
| 8 | Pitot tube. | |
| 9 | Characteristics of centrifugal pump. | |
| 10 | Pipe flow Viscometer. | |
| 11 | **Flow in pipes, valves and fittings:** Design studies on valves, pipe fittings and piping networks. | |
| 12 | **Two phase flow.** | |
| 13 | **Design of Fluid Systems:** Mechanical design of pressure vessel, flange, reinforcement for opening, support. | |

**Text Books:**


1. Introduction to Fluid Mechanics by R. W. Fox & Alan T. McDonald, Wiley; 6th edition (2003).
2. Fundamentals of Multiphase Flow by C. E. Brennen, Cambridge University Press; 1st edition (2009).

# 4th SEMESTER

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DC | CH2201 | Heat Transfer | 3 | 1 | 0 | 4 |

| **Course Objective** |
|---|
| 1. The course emphasizes the underlying concepts of the conduction, convection and radiation modes of heat transfer and enumerates the laws, governing equations relating to the rates of heat transfer, based on derivation from fundamentals. |
| **Learning Outcomes** |
| 1. After completion of the course, the students will have a strong foundation on conduction, convection and radiation modes of heat transfer. Students will be able to apply the basic principles, the laws, and the pertinent equations to practical scenarios. |

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | Mechanisms of heat flow - conduction, convection, and radiation. | Students will be introduced to different heat transfer mechanisms. |
| 2. | Steady and unsteady state one, two and three dimensional conduction equations in different geometries. | Students will be able to solve real time conduction and problems. |
| 3. | Dimensional analysis, forced and natural convection. | Students will be able to solve real time convection problems. |
| 4. | Stefan Boltzman law, Kirchoff's Law, and their applications, black body, gray body, exchange of radiant heat between gray bodies. Furnaces, flame temperature, optimum thickness of insulation. | Basic understanding of radiation heat transfer. Students will be able to solve real time radiation problems. |
| 5. | Classification and design, metallic and non-metallic heat exchangers. Evaporators: Types and design features. Design of natural and forced circulation reboilers optimization of heat exchanger design; heat exchanger performance evaluation. Process design and performance evaluation of Double Pipe, Shell and Tube, Plate, Spiral Heat Exchangers; Process design data sheets, Heat pumps. | Design of heat exchangers and evaporators. |

**Text Books:**

1. Process Heat Transfer by D. Q. Kern, McGraw-Hill Inc.,US (1950).

2. Heat Transfer by J. P. Holman, McGraw Hill Education; 10th edition (2017).

3. Unit Operations by G. G. Brown, CBS PUBLISHERS AND DISTRIBUTORS PVT LTD (2005).

**Reference Books:**

1. Unit Operations of Chemical Engineering by W. L. McCabe, J. C. Smith and P. Harriott, McGraw Hill; 7th edition (2004).

2. Process Heat Transfer Principles & Applications by R.W. Serth, Academic Press, (2007).

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DC | CH2202 | Chemical Engineering Thermodynamics | 3 | 1 | 0 | 4 |

**Course Objective**

1. To impart knowledge on relevant concepts in thermodynamics for chemical engineers such as laws of thermodynamic and their applications, property estimation of real fluids, vapor-liquid equilibrium, fugacity, activity coefficient, and reaction equilibrium with specific focus on chemical engineering aspects.

**Learning Outcomes**

1. Understand and apply concepts of thermodynamics relevant to chemical engineers.
2. Compute heat-work and bubble point/ dew point calculations.
3. Estimate Gibbs free energy by selecting appropriate mode.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | **Review:** Basic concepts and scope of thermodynamics; First and Second laws of thermodynamics. Carnot's theorem, and Entropy. Applications of first law to close and open systems; PVT relations; Equations of state. | Understand the concepts of thermodynamics relevant to Chemical Engineers. |
| 2. | **Property estimation of real fluids:** Thermodynamic potentials, Maxwell's relations, Gibbs free energy as generating function; Residual properties; Phase equilibrium; Thermodynamic phase diagram; Heat and work interconversion devices. | Estimate thermodynamic properties of ideal and real fluids. |
| 3. | **Vapor-liquid Equilibrium (VLE):** Phase rule; simple models for VLE; Dew and bubble-point calculations; Flash calculations; Property estimation from VLE. | Compute temperature and pressure at Bubble point and Dew point. |
| 4. | **Solution thermodynamics:** Properties of mixtures; Partial Molar properties; Fugacity; Ideal solutions; Excess properties; Activity coefficients; Models for excess Gibbs free energy. | Apply thermodynamic principles for estimation of solution properties and select system specific model |
| 5. | **Chemical Reaction Equilibrium:** Application of equilibrium criteria to Chemical Reactions; Equilibrium constant; Effect of temperature and compositions; Phase rule for reacting systems. | Estimate the effect of temperature on Reaction and optimize operating conditions |

| | | |
|---|---|---|
| 6. | Introduction to statistical thermodynamics | Idea of statistical behavior of systems |

**Text Books**:


1. Chemical Engineering Thermodynamics by J. M. Smith, H. C. Van Ness and M. M. Abbott, M. T. Swihart, Eighth Edition, McGraw Hill (2018).
2. Chemical Engineering Thermodynamics by Y. V. C. Rao, Second Edition, University Press (2001).


**References**:


1. Chemical Engineering Thermodynamics by B. G. Kyle, Third Edition, Prentice Hall (1999).
2. Engineering Thermodynamics by P. K. Nag, Sixth Edition, McGraw Hill (2017).
3. Engineering and Chemical Thermodynamics by M. D. Koretsky, Second Edition, John Wiley and Sons (2012).

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DC | CH2203 | Chemical Reaction Engineering-I | 4 | 0 | 0 | 4 |

**Course Objective**

1. The objective of the course is to study reaction kinetics and design of ideal reactors for homogeneous reactions.

**Learning Outcomes**

At the end of the course, the student will be able to

1. Learn how to interpret the kinetic data.
2. Design ideal reactors under isothermal and non-isothermal operations.
3. Study Residence Time Distribution and non-ideal reactor models.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | Kinetics of homogeneous reactions; Interpretation of batch reactor data. | Understand the basics of rate equation and interpretation of batch reactor data. |
| 2. | Isothermal reactor design- Batch, plug flow and mixed flow; Chemical reactor analysis. | Design ideal reactors under isothermal operations for single and multiple reactions. |
| 3. | Non-isothermal reactors, steady state multiplicity; Reactor design. | Design ideal reactors under non- isothermal operations for single and multiple reactions. |
| 4. | Non-ideal flow in reactors, Residence time distribution. | Basics of non-ideal flow, tools and models for diagnosis of real reactors. |

**Text Books:**


1. Levenspiel O, Chemical Reaction Engineering, 3rd Edition, Wiley India (1999).
2. Fogler S H, Elements of Chemical Reaction Engineering, 4th Edition, Prentice Hall India (2015).


**References:**


1. Davis M E and Davis R J, Fundamentals of Chemical Reaction Engineering, 1st Edition, McGraw Hill (2003).
2. Schmidt L D, The Engineering of Chemical Reactions, 2nd Edition, Oxford University Press (2005).
3. Froment G F and Bischoff K B, Chemical Reactor Analysis and Design, 2nd Edition, John Wiley & Sons (1990).

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DC | CH2204 | Mass Transfer I | 3 | 1 | 0 | 4 |

**Course Objective**

This course enables the students:

1. To acquire basic knowledge of mass transfer operation and its application.
2. To learn fundamental knowledge of mass transfer involved in various unit operations.
3. To design mass transfer processes and equipment.

**Learning Outcomes**

After the completion of this course, students will be to:

1. Explain the basic mechanism of mass transfer including diffusion and convective mass transfer.
2. Find the mass transfer coefficient and solve problems related to interphase mass transfer.
3. Explain the gas-liquid contacting process and solve related problems including Absorption.
4. Solve problems on VLE and problems related to design calculation of distillation columns.
5. Explain enhanced distillation.
6. Develop a process design for humidification and cooling.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | **Fundamentals of mass transfer:** Diffusional mass transfer, mass transfer coefficients, steady state and unsteady state theories of mass transfer, interphase mass transfer, Whitman's two film theory and its variations, multiphase contacting equipments, concept of transfer unit, unified approach to staged processes. | Fundamental concept of mass transfer, design and problem solving. |
| 2. | **Distillation**: Vapour-liquid Equilibrium, x-y, T-x-y, P-x-y and H-x-y diagrams; Henry's, Raoult's and Dalton's Laws; Ideal and Non-ideal solutions, Azeotropes; Relative Volatility; Flash Vaporization; Differential Distillation: Steam Distillation; Continuous Rectification â Staged Calculation using Ponchon-Savarit and McCabe-Thiele Methods; Complex/Multi-draw Configuration; Packed Distillation Column; Multicomponent Distillation; Azeotropic and Extractive Distillations; Performance Evaluation of Distillation Columns including Reboilers and Condensers. | Fundamental concept of Distillation, design and problem solving. |

| | | |
|---|---|---|
| 3. | **Absorption:** solubility, choice of solvent, concept of rate approach and stagewise approach, stagewise and continuous contact absorbers; rich and lean gasses; absorption with chemical reaction. Counter-current and co-current multistage operations, dilute and concentrated systems, process design and performance evaluation of absorbers. | Fundamental concept of Absorption, design and problem solving. |
| 4. | **Humidification/Dehumidification:** Definitions, Psychrometric chart, Adiabatic saturation and wet-bulb temperatures, Adiabatic and non-adiabatic operations, Dehumidification, Mass and heat balances in bulk and at interfaces, Spray chamber, Cooling towers - counter-current, co-current and cross-current, Performance evaluation of cooling towers, Principles of air conditioning. | Fundamental concept of humidification, design and problem solving. |

**Text Book**:

1. R. E. Treybal, Mass Transfer Operations, McGraw Hill Education 2017.
1. W. L. McCabe, J. C. Smith and P. Harriott, Unit Operations of Chemical Engineering, McGraw Hill Education 2017.
2. E. I. Cussler, Diffusion: Mass Transfer in Fluid Systems, Cambridge University Press 2009.

**Reference**:

1. J.F. Richardson, J. H. Harker, and J. R. Backhurst, Coulson &Richradson's Chemical Engineering, Volume 2 Butterworth-Heinemann 2002.
2. B.K. Dutta, Principles of Mass Transfer and Separation Processes, Prentice Hall India Learning Private Limited, 2006.

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DP | CH2205 | Heat Transfer Lab | 0 | 0 | 3 | 2 |

**Course Objective**

1. Course aims to equip students with hands-on skills of important experiments on heat transfer.

**Learning Outcomes**

1. Do measurements of temperature and do heat transfer calculations.
2. Carry out experiments, observe and analyze data for conduction, convection, and radiation problems.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1. | Heat Transfer experiments: Thermal conductivity of metal rod, overall heat transfer co-efficient in a vertical condenser, natural convection, critical heat flux, overall heat transfer co-efficient in horizontal condenser, heat transfer co-efficient in double pipe heat exchanger, composite wall. | Do measurements of temperature and do heat transfer calculations.<br>Carry out experiments, observe and analyze data for conduction, convection and radiation problems. |

*Depends on number of student groups.

**Text Book**:

1. McCabe, W., Smith, J., Harriott, P. Unit Operations of Chemical Engineering, McGraw Hill Education, 2017.

**Reference:**

**1.** Richardson, J. H., Harker, J.H., Backhurst, J.R., Coulson and Richardson's Chemical Engineering, Volume 2, 5th Edition: Particle Technology and Separation, Elsevier, 2006.

| Course Type | Course Code | Name of Course | L | T | P | Credit |
|---|---|---|---|---|---|---|
| DP | CH2206 | Particle Technology & Fuel Lab | 0 | 0 | 3 | 2 |

**Course Objective**

1. Course aims to equip students with hands-on skills of important experiments on heat particle technology.
2. An ability to identify, analyse and characterize the fuels.

**Learning Outcomes**

1. Understand and carry out experiments in mechanical unit operations involving solid particles.
2. Understand the fuel product specifications, various test methods used to qualify different types of fuels.

| Unit No. | Topics to be Covered | Learning Outcome |
|---|---|---|
| 1 | **Particle Technology Lab:**<br>Experiments on particles: Ball mill performance, roll crusher performance, performance of different types of classifiers, jaw crusher performance, determination of permeability, sampling, solid feeders' performance<br>**Fuel Lab:**<br>Kinematic viscosity by Dynamic viscosity, Calorific Value, Smoke & Flash point, Aniline point, Reid vapour pressure (RVP) | Understand and carry out experiments in mechanical unit operations involving solid particles. |

**Text Book**:

1. McCabe, W., Smith, J., Harriott, P. Unit Operations of Chemical Engineering, McGraw Hill Education, 2017.

**Reference:**

**1.** Richardson, J. H., Harker, J.H., Backhurst, J.R., Coulson and Richardson's Chemical Engineering, Volume 2, 5th Edition: Particle Technology and Separation, Elsevier, 2006