Programme Name/s : **Chemical Engineering**

Programme Code : **CH**

Semester : **Sixth**

Course Title : **MASS TRANSFER OPERATION**

Course Code : **316303**

I. RATIONALE

Mass Transfer Operation is a crucial course in the Diploma in Chemical Engineering program, focusing on the movement of components due to concentration gradients. It plays a vital role in industrial processes like Diffusion, distillation, absorption, extraction, crystallization and drying. The course equips students with the knowledge to design and analyse mass transfer equipment, enhancing their problem-solving and process optimization skills. With applications in petrochemicals, pharmaceuticals, food processing, biotechnology and environmental engineering, this subject prepares students for careers in diverse industries.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

The aim of this course is to help the students to attain the following industry identified competency through a teaching-learning process.

1. Identify the best possible separation process for a given duty or application
2. Operate and maintain the mass transfer equipment involved in upstream and downstream processes in industrial settings.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Analyze mass transfer phenomena in gases and liquids by applying fundamental principles of molecular and eddy diffusion.
- CO2 - Determine number of theoretical stages in distillation columns by evaluating vapour-liquid equilibrium of binary systems.
- CO3 - Select appropriate gas absorption equipment for given gas-liquid separation based on process requirements.
- CO4 - Select appropriate solvent and extraction equipment after analysing liquid equilibrium data for effective extraction
  processes.
- CO5 - Crystallize supersaturated solutions followed by drying of crystallized mass by using appropriate equipment.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme											Total Marks
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
316303	MASS TRANSFER OPERATION	MTO	DSC	4	-	4	2	10	5	03	30	70	100	40	25	10	25#	10	25	10	175

Total IKS Hrs for Sem. : 1 Hrs
Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment
Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination
Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 15 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Define diffusion and its significance in mass transfer operations. TLO 1.2 Differentiate between molecular and eddy diffusion. TLO 1.3 Explain Fick's laws of diffusion and their applications in steady and unsteady-state diffusion. TLO 1.4 Apply diffusion equations to analyze gas and liquid diffusion processes. TLO 1.5 Solve numerical problems on molecular diffusion in gases and liquids.	**Unit - I Diffusion: Fundamentals and Applications in Mass Transfer** 1.1 The concept and significance of diffusion in mass transfer. 1.2 **Types of diffusion:** Molecular and Eddy Diffusion. 1.3 Role of diffusion in industrial processes. 1.4 Fundamental Principles of Diffusion **1.4.1 Fick's First Law of Diffusion:** Diffusional flux, Concentration Gradient, Statement, Equation. **1.4.2 Fick's Second Law of Diffusion:** Unsteady-state diffusion. 1.5 **Steady State Molecular Diffusion in Gases and Liquids:** 1.5.1 Diffusion of a gas A through a stagnant gas B. 1.5.2 Equimolar counter diffusion. 1.5.3 Binary Diffusion in liquids: Diffusivity, Factors affecting diffusivity. 1.5.4 Numerical based on Steady State Molecular Diffusion in Gases and Liquids	Lecture Using Chalk-Board Video Demonstrations Demonstration Flipped Classroom

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
2	TLO 2.1 Apply the principles of vapor-liquid equilibrium to analyze and optimize distillation processes. TLO 2.2 Interpret phase diagrams, including boiling point and equilibrium diagrams. TLO 2.3 Explain different distillation methods such as simple, fractional, and steam distillation. TLO 2.4 Determine the number of theoretical stages in distillation columns using McCabe-Thiele method. TLO 2.5 Solve numerical problems related to distillation operations.	**Unit - II Distillation** 2.1 **Introduction:** 2.1.1 Definition 2.1.2 Concept and the basic principle. 2.2 **Vapour-Liquid Equilibrium (VLE):** 2.2.1 Boiling Point Diagram 2.2.2 Equilibrium Diagram 2.2.3 Relative Volatility 2.2.4 Effect of pressure on VLE 2.2.5 P-x-y diagram: Ideal Solutions: Raoult's Law Non-Ideal Solutions: Henry's Law. 2.3 **Distillation Methods:** 2.3.1 Distillation without fractionation: **Flash Vaporization:** Principle, Operation, Material Balance. **Simple Distillation:** Principle, Operation, Material Balance, Rayleigh's Equation **Steam Distillation:** Principle, Operation, Material Balance 2.3.2 Distillation with fractionation: **Fractional distillation of binary Mixture:**Principle of fractionation **Reflux:** Total, Minimum and Optimum Reflux, **Material Balance:** Overall and component material balance. **Determination of Theoretical Stages/Plates by McCabe Thiele Method:** Operating lines: For Rectifying and Stripping Sections of the column. Feed Line (q Line): Feed Quality, Equation of Feed Line. Effect of feed quality on the slope of feed line. **Numerical:** Based on Determination of Theoretical Stages/Plates by McCabe Thiele Method. **Types of Fractionating**	Lecture Using Chalk-Board Video Demonstrations Demonstration Case Study

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
		column: Plate Column: Bubble Cap, Sieve Plate, Valve Plate Packed Column: Structured Packings and Random Packings, **Components of plates in plate columns:** Wiers and Downcomers.	

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
3	TLO 3.1 Define the concept of gas absorption and distinguish it from adsorption. TLO 3.2 Explain the absorption equilibrium and phase rule governing gas absorption. TLO 3.3 Describe the selection criteria for solvents used in absorption processes. TLO 3.4 Analyze the performance of gas absorption equipment such as packed columns and scrubbers. TLO 3.5 Solve numerical problems on material balance and hydrodynamics in packed columns.	**Unit - III Gas Absorption** 3.1 **Introduction:** 3.1.1 Definition 3.1.2 Concept and the basic principle 3.1.3 Difference between Absorption and Adsorption phenomena. 3.2 **Absorption Equilibrium:** 3.2.1 Solubility of Gases 3.2.2 Phase Rule 3.2.3 Solvents: Selection criteria of solvent for given duty. 3.3 **Gas Absorption Equipment: Types, Principles and Workings.** **3.3.1 Packed Column and Types of Packings:** **Structured Packings:** Metallic or Plastic Corrugated Sheets, Wire Mesh. **Random Packings:** Raschig Rings, Pall Rings, Berl and Intalox Saddles. **Packed Columns Fundamentals:** Packing Characteristics, Material Balance, Channelling in packed columns, Hydrodynamics of Packed Column, Loading and Flooding of Packed Column, Height Equivalent to Theoretical Plates (HETP), **Numerical:** Based on Fundamentals of Packed Column. **3.3.2 Mechanically Agitated Vessels:** Principle, Working and Material Balance **3.3.3 Ventury Scrubber:** Principle, Working and Material Balance.	Lecture Using Chalk-Board Demonstration Video Demonstrations Case Study

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
4	TLO 4.1 Define liquid-liquid extraction and apply its fundamental principles to industrial separation processes. TLO 4.2 Interpret ternary phase diagrams and equilibrium distribution curves. TLO 4.3 Explain the criteria for solvent selection in extraction processes. TLO 4.4 Describe the working principles of different extraction equipment such as mixer-settlers and agitated columns. TLO 4.5 Apply extraction principles to industrial separation processes.	**Unit - IV Liquid-Liquid Extraction** 4.1 **Introduction:** 4.1.1 Definition 4.1.2 Concept and the basic principle 4.2 **Liquid Equilibria** 4.2.1 Equilibrium distribution of solute for immiscible system. 4.2.2 Equilateral triangular coordinates 4.2.3 Ternary Diagram: One Liquid Pair Partially Miscible, Two Liquid Pairs Partially Miscible 4.2.4 Distribution curve 4.2.5 Numerical based on Distribution Coefficient 4.3 **Choice of Solvent:** Selection criteria of solvent. 4.4 **Extraction Equipment:** Principle, Construction, Working and Applications of: 4.4.1 Mixer Settler-Assemblies: Mixer Settler 4.4.2 Static Columns: Spray Column, Sieve Plate Column 4.4.3 Mechanically Agitated Columns: Rotating Disc Contactor, Pulse Column. 4.4.4 Centrifugal Contactors	Lecture Using Chalk-Board Demonstration Video Demonstrations Case Study

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
5	TLO 5.1 Utilize the principles of crystallization and drying in industrial separation and purification processes. TLO 5.2 Explain the mechanisms of crystallization including supersaturation and nucleation. TLO 5.3 Differentiate between types of moisture content and drying equilibrium. TLO 5.4 Analyze the operation of drying equipment such as tray dryers, rotary dryers, and spray dryers. TLO 5.5 Solve numerical problems related to drying kinetics and moisture balance.	**Unit - V Crystallization and Drying** 5.1 **Crystallization:** **5.1.1 Introduction:** Definition, importance and the basic concept of crystallization. **5.1.2 Mechanism:** Saturation, Super Saturation, Mier's Theory of Supersaturation. **5.1.3 Crystallization Equipment:** Principle, Construction and Working of: Agitated Tank Crystallizer, Swenson-Walker Crystallizer 5.2 **Drying:** **5.2.1 Introduction:** Definition, importance and the basic concept of drying. **5.2.2 Drying Equilibrium:** **Basis of Moisture Content:** Dry Basis and Wet Basis. **Relative Humidity and the Moisture Content:** Equilibrium Moisture, Free Moisture, Bound and Unbound Water, Hysteresis, Soluble Solids **Numerical:** Based on Drying Equilibrium **5.2.3 Drying Equipment:** Classification of dryers: Batch and Continuous Dryers Construction, Working and Applications of: Tray Dryer, Rotary Dryer, Drum Dryer, Spray Dryer, Fluidized Bed Dryer.	Lecture Using Chalk-Board Demonstration Video Demonstrations Flipped Classroom

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Explain the principles of molecular diffusion in gases. LLO 1.2 Calculate the diffusion coefficient using experimental data. LLO 1.3 Analyze the effect of temperature and pressure on gas diffusion.	1	Determination of the diffusion coefficient of a given gas or vapour in air using a diffusion cell.*	4	CO1

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 2.1 Describe the factors affecting diffusivity in liquids. LLO 2.2 Measure and interpret the diffusivity of a solute in a given solvent. LLO 2.3 Compare experimental values with theoretical predictions.	2	Determination of the diffusivity of a solute in a liquid medium using a diffusion cell.*	4	CO1
LLO 3.1 Explain the concept of batch distillation and Rayleigh's Equation. LLO 3.2 Perform simple distillation and record the change in composition over time. LLO 3.3 Calculate the theoretical and experimental values of composition changes.	3	Experimental validation of Rayleigh's equation in a binary distillation setup.*	4	CO1
LLO 4.1 Describe the principles of vapor-liquid equilibrium. LLO 4.2 Construct VLE diagrams from experimental data. LLO 4.3 Compare experimental VLE data with theoretical models.	4	Determination of Vapour-Liquid Equilibrium (VLE) Data for a Binary Mixture.*	4	CO1 CO2
LLO 5.1 Explain the operation of a fractional distillation column. LLO 5.2 Determine the number of theoretical stages using the McCabe-Thiele method. LLO 5.3 Analyze the effect of reflux ratio on separation efficiency.	5	Performance Evaluation of a Fractional Distillation Column for separation of binary mixtures.*	4	CO1 CO2
LLO 6.1 Describe the working principles of a packed absorption column. LLO 6.2 Measure the absorption efficiency and pressure drop across the column. LLO 6.3 Analyze the effect of gas and liquid flow rates on mass transfer.	6	Performance Evaluation of a Packed Column for Gas Absorption.*	4	CO1 CO3
LLO 7.1 Explain the concept of equilibrium distribution coefficient. LLO 7.2 Perform liquid-liquid extraction and determine the distribution coefficient. LLO 7.3 Evaluate the efficiency of the extraction process.	7	Determination of distribution coefficient of a solute from a liquid mixture using a suitable solvent for Liquid-Liquid Extraction in a Mixer Settler unit.*	4	CO1 CO4

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 8.1 Describe the principles of crystallization and supersaturation. LLO 8.2 Perform batch crystallization and analyze crystal yield. LLO 8.3 Determine the size distribution of crystals.	8	Determination of the crystal yield and crystal size distribution by performing batch crystallization of a solution in a batch crystallizer.*	4	CO1 CO5
LLO 9.1 Explain the drying process and factors affecting drying rate. LLO 9.2 Measure drying kinetics and determine equilibrium moisture content. LLO 9.3 Analyze the effect of temperature and air velocity on drying rate.	9	Determination of the drying rate and equilibrium moisture content using a tray dryer.*	4	CO1 CO5
LLO 10.1 Describe the hydrodynamic behavior of a packed column. LLO 10.2 Determine the pressure drop and liquid hold-up in the column. LLO 10.3 Identify conditions leading to flooding and channelling.	10	Determination of pressure drop and flooding velocity in a packed absorption column.	4	CO1 CO3
LLO 11.1 Explain the principle and applications of steam distillation. LLO 11.2 Perform steam distillation and measure the recovery of an essential oil. LLO 11.3 Analyze the effect of steam flow rate on oil recovery efficiency.	11	Determination of the percentage recovery of an essential oil by using Steam Distillation Apparatus.*	4	CO1 CO2
LLO 12.1 Explain the concept of HETP and its importance in packed columns. LLO 12.2 Perform distillation and determine the HETP from experimental data. LLO 12.3 Compare HETP values for different types of packing materials.	12	Determination of Height Equivalent to Theoretical Plates (HETP) in a Packed Distillation Column.	4	CO1 CO2
LLO 13.1 Describe the working principle and advantages of fluidized bed drying. LLO 13.2 Measure the drying rate of a wet solid at different airflow rates. LLO 13.3 Analyze the drying characteristics in different drying regimes.	13	Determination of Drying Rate of a wet solid using a Fluidized Bed Dryer.	4	CO1 CO5

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 14.1 Explain the working mechanism of a rotary dryer. LLO 14.2 Determine the residence time and moisture reduction of solids. LLO 14.3 Evaluate the impact of rotational speed and air temperature on drying efficiency.	14	Performance Analysis of a Rotary Dryer to investigate the drying efficiency and residence time of solids in a rotary dryer.	4	CO1 CO5
LLO 15.1 Define azeotropes and describe the need for azeotropic distillation. LLO 15.2 Perform azeotropic distillation using an entrainer. LLO 15.3 Evaluate the effectiveness of different entrainers in separating azeotropes.	15	Analysis of the role of an entrainer in breaking the azeotrope by performing azeotropic distillation.	4	CO1 CO2
LLO 16.1 Explain the significance of solvent-to-feed ratio in extraction processes. LLO 16.2 Perform liquid-liquid extraction at different solvent-to-feed ratios. LLO 16.3 Analyze the relationship between solvent quantity and extraction efficiency.	16	Evaluation of the impact of solvent-to-feed ratio on the efficiency of liquid-liquid extraction.	4	CO1 CO4

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Assignment

- Derivation of Fick’s Laws of Diffusion: Explain the mathematical derivation and significance of Fick’s first and second laws.
- Industrial Applications of Diffusion: Research and document various industrial processes where diffusion plays a key role.
- Comparison of Molecular and Eddy Diffusion: Differentiate between these diffusion mechanisms with examples.
- Vapor-Liquid Equilibrium (VLE) and Its Importance in Distillation: Explain VLE with phase diagrams and case studies.
- Types of Distillation and Their Industrial Applications: Compare simple, fractional, steam, and azeotropic distillation with real-life examples.
- McCabe-Thiele Method for Distillation Column Design: Perform graphical calculations for a binary distillation column.
- Selection Criteria for Absorption Solvents: Identify and explain the factors affecting solvent selection for gas absorption.
- Comparison of Packed and Plate Columns for Gas Absorption: Describe the advantages and limitations of both types of columns.
- Numerical Problems on Mass Transfer in Absorption: Solve numerical problems related to material balance and hydrodynamics of packed columns.

- Ternary Diagrams and Their Applications in Liquid-Liquid Extraction: Construct and interpret ternary diagrams for different extraction systems.
- Comparison of Liquid-Liquid Extraction and Distillation: Discuss the advantages, limitations, and selection criteria for both separation processes.
- Design and Working of Mixer-Settler Units: Explain the construction, working principle, and industrial application of mixer-settler units.
- Mier's Theory of Supersaturation and Its Role in Crystallization: Explain the theory and its significance in industrial crystallization.
- Classification and Working of Different Dryers: Describe tray dryers, rotary dryers, spray dryers, and fluidized bed dryers.
- Numerical Problems on Drying Rate and Moisture Content: Solve numerical problems related to drying kinetics and equilibrium moisture content.

Micro project

- Observe and document mass transfer phenomena in daily life, such as evaporation while boiling water, diffusion of perfume, drying of clothes, or extraction in tea brewing.
- Design and assemble a simple batch distillation unit using laboratory glassware or kitchen utensils to separate a binary mixture (e.g., alcohol-water mixture).
- Prepare a supersaturated salt or sugar solution, induce crystallization by cooling, and analyze crystal growth patterns under different conditions.
- Compare drying rates of different food products (fruits, vegetables, or grains) under sun drying, oven drying, and air drying conditions.
- Conduct an experiment on CO2 absorption in water using soda preparation and study the effect of temperature, agitation, and pressure.
- Build a miniature packed column using glass beads, pebbles, or structured packing materials to demonstrate gas absorption or liquid-liquid extraction.
- Extract essential oils from citrus peels or other natural sources using solvent extraction (ethanol or hexane) and analyze efficiency.
- Study the working principle of supercritical CO2 extraction, its applications in food, pharmaceuticals, and petrochemicals, and prepare a theoretical case study.
- Activity: Collect wastewater samples from local industries and analyze mass transfer-based treatment methods like adsorption, reverse osmosis, or membrane separation.

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	**Vapour in Air Diffusion Apparatus:** The apparatus consists of a vertical glass or acrylic column (30–50 cm height, 3–5 cm diameter) with a vapour source chamber at the bottom and sampling ports along its length. The setup is air-tight, supported on a stable stand, and may include temperature control and ports for concentration measurement.	1
2	**Steam Distillation Apparatus** The steam distillation setup includes a steam generator, a distillation flask or column where the mixture is heated with live steam, a condenser for vapor condensation, and a receiver for collecting the distillate. The apparatus is typically made of glass or stainless steel, with temperature indicators, pressure release valves, and interconnecting pipes resistant to high temperature and corrosion. It is suitable for separating heat-sensitive components like essential oils or organic compounds.	11
3	**Fluidized Bed Dryer** The fluidized bed dryer consists of a perforated distributor plate at the bottom of a vertical cylindrical chamber where hot air is introduced to fluidize solid particles. The unit includes a blower, heater, and temperature control system, along with a filter unit to prevent particle carryover. The contact between air and solids ensures uniform and rapid drying, and the setup is generally made from stainless steel to withstand heat and corrosion. Suitable for drying granular or crystalline materials.	13
4	**Rotary Dryer** The rotary dryer features a slightly inclined, rotating cylindrical shell through which wet material is passed while hot air flows either co-currently or counter-currently. It is equipped with lifting flights inside the drum for cascading the material, a heating system, air blower, and a dust collector or cyclone separator. Made of mild or stainless steel, the unit offers controlled residence time and temperature, making it suitable for drying granular, powdery, or crystalline materials.	14
5	**Azeotropic Distillation Set-Up** The azeotropic distillation setup includes a round-bottom distillation flask, an azeotropic agent addition system, a fractionating column, condenser, phase separator (Dean-Stark apparatus), and receivers. The setup is designed to facilitate the separation of azeotropic mixtures by adding an entrainer that alters relative volatilities. Typically made of borosilicate glass or stainless steel, it features temperature indicators, reflux control, and provisions for solvent recovery, making it ideal for separating components with close boiling points or azeotropic behavior.	15
6	**Packed Extraction Column** A packed extraction column is a vertical cylindrical column filled with packing materials (like Raschig rings, Berl saddles, or structured packings) to enhance contact area between the two immiscible liquid phases. It includes liquid distributors, phase separators, feed and solvent inlets, and product outlets. The column is constructed from glass or stainless steel, with transparent sections for observation, and equipped with flow meters, control valves, and sampling ports to monitor the mass transfer efficiency during liquid-liquid extraction.	16
7	**Liquid in Liquid Diffusion:** This setup includes a graduated vertical glass tube or U-tube filled with a quiescent liquid medium, with another miscible liquid layer introduced gently at the top. It typically features markings or sampling ports for diffusion front observation and may use dyes or color indicators for visual tracking. Temperature control can be incorporated for consistent conditions.	2
8	**Simple Distillation Setup:** The setup includes a round-bottom flask (500 mL to 1 L) as the distillation vessel, a condenser (Liebig or coil type) for vapor condensation, and a receiving flask for collecting the distillate. It also consists of a thermometer for temperature monitoring and a heating mantle or hot plate as the heat source. All joints are typically standard ground glass with clamps for secure connections.	3

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
9	**VLE Cell or Equilibrium Still:** The apparatus comprises an equilibrium still or VLE cell made of glass or stainless steel, with provisions for heating and cooling, a thermowell for temperature measurement, and sampling ports for both vapour and liquid phases. It includes a condenser, stirrer, and pressure control (usually atmospheric or vacuum). Accurate measurement of composition is enabled using refractometers or GC (optional).	4
10	**Fractional Distillation Column with Reflux (Plate Column)** The setup consists of a plate-type distillation column (usually 1–1.5 meters tall) with multiple sieve or bubble cap trays to facilitate stage-wise vapor-liquid contact. It includes a boiling flask or reboiler, a condenser, and a reflux splitter to regulate the reflux ratio. Temperature measuring points are placed at various tray levels, and the setup is typically made of borosilicate glass or stainless steel for visibility and corrosion resistance. A heating mantle provides uniform heating at the bottom, and sampling ports are available for analysis.	5,12
11	**Gas Absorption in Packed Column** The setup includes a vertical packed column (typically 1–1.5 meters high) filled with packing material such as Raschig rings or Berl saddles to enhance surface area for gas-liquid contact. It has gas and liquid inlets and outlets, flow meters to measure and control flow rates, and sampling ports for analysis. The unit is equipped with a liquid distributor at the top and a gas sparger at the bottom, and it is generally made of transparent acrylic or borosilicate glass for visibility during operation.	6,10
12	**Mixer Settler Unit** The mixer-settler unit consists of a mixing chamber equipped with an agitator or stirrer for intimate contact between immiscible liquids, followed by a settler chamber for phase separation based on density differences. The setup includes inlet and outlet ports for both feed and extract phases, transparent acrylic or glass construction for observation, and flow controllers for adjusting feed and solvent rates. The settler is designed with a weir or partition to facilitate clean separation of the two liquid layers.	7
13	**Batch Crystallizer** The batch crystallizer consists of a jacketed vessel made of borosilicate glass or stainless steel, equipped with a mechanical stirrer for uniform mixing. It includes a cooling system (either external or internal coil) to induce supersaturation and promote crystal formation. The unit has temperature control, sampling ports, and a drain valve for product recovery. A sight glass or transparent section allows observation of crystal growth during operation.	8
14	**Tray Dryer** The tray dryer consists of a rectangular drying chamber with multiple perforated trays arranged in a trolley system. It is equipped with a forced air circulation system, heaters for controlled temperature, and a ventilation mechanism for moisture removal. The body is usually made of stainless steel or mild steel with insulated walls and has a temperature range of up to 100–120°C, suitable for drying wet solid samples uniformly.	9

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Diffusion: Fundamentals and Applications in Mass Transfer	CO1	8	2	4	2	8
2	II	Distillation	CO2	16	4	6	10	20
3	III	Gas Absorption	CO3	12	2	4	6	12
4	IV	Liquid-Liquid Extraction	CO4	10	2	6	4	12
5	V	Crystallization and Drying	CO5	14	4	6	8	18

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
Grand Total				60	14	26	30	70

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Theory:

Comprises of a progressive theory test to be assessed out of 30 Marks Maximum.
Laboratory Learning:
Comprises of a continuous assessment of each LLO to be assessed out of 25 Marks Maximum wherein 60% marks are to be awarded for Process related performance and 40% marks to be awarded for product related part of the experiment.

Summative Assessment (Assessment of Learning)

- Theory:

Comprises of End Semester Examination to be assessed out of 70 Marks Maximum.
Laboratory Learning:
Comprises of an End Semester Examination to be assessed out of 25 Marks Maximum.

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PSO-3
CO1	3	2	1	1	1	3	2			
CO2	3	3	3	2	2	3	3			
CO3	3	3	2	2	2	3	2			
CO4	3	3	2	1	2	3	2			
CO5	3	3	2	2	2	3	3			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	K.V. Narayanan, B. Lakshmikutty	Mass Transfer Operations: Theory and Application	CBS Publishers & Distributors Pvt. Ltd. 978-9354666094
2	Robert E. Treybal	Mass Transfer Operations	McGraw-Hill 978-0070666153
3	Warren L. McCabe, Julian C. Smith, Peter Harriott	Unit Operations of Chemical Engineering	McGraw-Hill 978-0072848236
4	Binay K. Dutta	Principles of Mass Transfer and Separation Processes	PHI Learning 978-8120345187

Sr.No	Author	Title	Publisher with ISBN Number
5	Christie J. Geankoplis	Transport Processes and Separation Process Principles	Pearson Education 978-0131013674
6	J.M. Coulson, J.F. Richardson	Chemical Engineering: Volume 1 & 2	Butterworth Heinemann 978-0750644457 (Vol. 1), 978 0750644464 (Vol. 2)
7	J.D. Seader, Ernest J. Henley	Separation Process Principles	Wiley 978-0470481837
8	Morton M. Denn	Process Fluid Mechanics Prentice Hall 978-0137232093	Prentice Hall 978-0137232093

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	COMSOL Multiphysics:	This versatile software is used for simulating various mass transfer processes, including diffusion, heat and mass transfer in packed beds, and distillation column performance. It helps in modeling concentration profiles, velocity distributions, and transport mechanisms in mass transfer systems.
2	Aspen Plus:	A widely used process simulation software in chemical engineering, Aspen Plus allows the modeling and optimization of mass transfer operations such as distillation, absorption, liquid-liquid extraction, and drying. It helps in designing separation columns and evaluating mass transfer efficiency.
3	MATLAB:	MATLAB is a powerful tool for numerical analysis and simulation. It can be used to solve mass transfer equations, develop control algorithms for distillation and absorption processes, and perform data analysis related to separation processes.
4	CHEMCAD:	CHEMCAD is an advanced process modeling software that enables simulation, design, and optimization of distillation, absorption, and extraction processes. It helps engineers analyze phase equilibria and mass transfer coefficients for industrial applications.
5	ANSYS Fluent:	ANSYS Fluent is a Computational Fluid Dynamics (CFD) software used to simulate fluid flow, heat, and mass transfer in separation processes such as packed columns, spray dryers, and evaporators. It is particularly useful for analyzing flow patterns and optimizing mass transfer equipment.
6	LabVIEW:	LabVIEW is widely used for data acquisition and process control in mass transfer experiments. It helps in monitoring distillation column performance, gas absorption rates, and drying kinetics through real-time data analysis.

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students