GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering

Level: UG

Branch: Chemical Engineering

Subject Code: BE05005021

Subject Name: Mass Transfer Operation-I

w.e.f. Academic Year:	2024-25
Semester:	5
Category of the Course:	Professional Core Courses

Prerequisite:	Basics of fluid dynamics, heat transfer and thermodynamics.
Rationale:	The objective of this course is to study the principles of mass transfer and their applications for separation and purification processes in chemical industry. This course is intended to explain detailed fundamentals of mass transfer operations such as diffusion, mass transfer coefficient, inter phase mass transfer etc. and its application for in-depth study and for solving problems pertaining to some mass transfer operations like gas absorption, extraction, humidification etc. in detail. This course also enables the students to understand principal and working of various mass transfer equipment like gas absorption columns, extractors and cooling towers etc.

Course Outcome:

After Completion of the Course, Students will be able to:

No	Course Outcomes
01	Interpret the fundamental concepts of mass transfer like diffusion, mass transfer coefficient and interphase mass transfer.
02	Apply the fundamentals concepts of mass transfer in various unit operations like solvent extraction, humidification and gas absorption.
03	Examine various mass transfer equipment used in the chemical industries and their selection criteria for gas liquid, liquid-liquid and liquid-solid systems.
04	Analyze various design aspects of mass transfer equipment using analytical techniques.

Teaching and Examination Scheme:

Teaching/Learning Scheme in hrs/semester					Total Credits	Assessment Pattern and Marks					Total Marks
						Theory		Practical			
L	T	P	PBL*	TH	TH/30	ESE (E)	PA (M)	PA (I)	PBL(I)	ESE (V)	
45	0	30	15	90	3	70	30	20	30	50	200

Where L = Lecture, T= Tutorial, P= Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, ESE = End-Semester Examination, PA = Progressive Assessment

*** Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.**

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	**Introduction:** Definition and importance of mass transfer operations, classification of mass transfer operations with examples, direct vs indirect mass transfer operations, choice of separation method, methods of conducting mass transfer operations, design principles	3	6
2	**Molecular Diffusion in Fluids:** Definition of molecular and eddy diffusion, Fick's law, concept of N and J flux, steady state molecular diffusion in fluids at rest and in laminar flow, concept of effective diffusivity, diffusivity of gases, diffusivity of liquids.	5	11
3	**Mass Transfer Coefficients:** F and k type mass transfer coefficients, relation between mass transfer coefficients, mass transfer coefficients in laminar and turbulent regions, film, penetration and surface renewal theories, analogies between momentum, heat and mass transfer, dimensionless numbers, simultaneous mass and heat transfer.	5	11
4	**Inter Phase Mass Transfer:** Concept of equilibrium, diffusion between phases, two resistance theory, local and overall mass transfer coefficient, controlling mass transfer resistances.	3	7
5	**Equipment for Gas Liquid Operations:** Gas Dispersed: sparged vessels, mechanically agitated vessels, gas-liquid contact, tray tower, tray tower internals, different types of trays, weirs, downcomers and criteria of their selection, flooding, loading, coning, weeping and dumping in tray tower, tray efficiency. Liquid Dispersed: venturi scrubber, wetted wall towers, spray towers, packed towers, packed tower internals, different types of packings and their selection criteria, mass transfer coefficient for packed towers, co-current flow of gas and liquid, end effects and axial mixing, tray tower vs. packed tower.	5	11

6	**Gas Absorption:** Equilibrium solubility of gases in liquids, ideal and non-ideal solutions, choice of solvent for absorption, material balance and liquid to gas ratio for absorption, countercurrent multistage operation (isothermal), absorption factor, continuous contact equipment, overall coefficient and transfer units, concept of HETP, HTU, NTU and j_H factor, industrial absorbers, dilute solutions, absorption with chemical reaction, problem solving using software.	8	18
7	**Liquid-Liquid Extraction:** Equilateral triangular coordinates, ternary liquid- liquid equilibrium and tie line data, system of three liquids-one pair partially soluble, two pair partially soluble, two partially soluble liquids and one solid, rectangular coordinates, choice of solvent, stage wise contact, single stage & multistage extraction, multistage cross current extraction, insoluble liquids, continuous counter current multistage extraction with and without reflux, theory & performance of continuous contact equipment, single stage & multistage equipment, applications of liquid-liquid extraction, problem solving using software.	8	18
8	**Humidification:** Vapour-liquid equilibrium and enthalpy for a pure substance, saturated and unsaturated vapour-gas mixtures and related terminologies such as absolute humidity, dry bulb temperature, dew point, wet bulb temperature, percentage & relative saturation, adiabatic saturation temperature, humid heat, humid volume etc., psychrometric chart & psychrometric relations for air-water system, adiabatic saturation curves, wet bulb temperature theory, Lewis relation, adiabatic operations, cooling towers.	8	18

Sustainability alignment: This course addresses SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) by mastering separation techniques essential for industrial operations.

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
10	25	15	10	10	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze; E: Evaluate and C: Create and above Levels (Revised Bloom's Taxonomy)

Problem based learning activity can include the following:

Sr. No.	Description	No. Of hours	Total Hrs.
1	Solving numerical and graphical procedures using MATLAB/Scilab/MS-Excel software. For eg: calculation of number of theoretical stages required in absorption and extraction.	Free self-paced certification courses offered by Mathworks (for MATLAB like "MATLAB On-ramp") or Scilab for syntax familiarity: 3 h Solving problems in MATLAB/Scilab/MS-Excel online: 7 h	**10**
2	Discussion on research paper based on relevant subject topics. Summarize research paper and evaluation critical parameters	Research papers on 5 different topics: 1 h each.	**05**
3	Learning based on real world case- studies	Data collection/study: 2h Report preparation: 3h	**05**
4	Poster/Chart/PowerPoint preparation on technical topics	Poster/Chart/Powerpoint preparation 5h and presentation (any one topic to be considered)	**05**
5	Self-learning on-line course related to the subject	Minimum duration of the course should be 10h	**10**
6	Simulation of a mass transfer operation followed by sensitivity analysis in Aspen Plus/DWSIM	Learn basics of simulation in Aspen Plus/DWSIM through NPTEL/Youtube channels: 5 h Carry out simulation and sensitivity analysis to see the effect of varying process parameters: 5 h	**10**
		Max. Hours to be allotted	**15**

Reference Books:

1. R. E. Treybal, Mass transfer operations, 3rd edition, Mc-Graw Hill international, NewDelhi, 1983.2.
2. J. F. Richardson, J H Harkar, Coulson and Richardson's Chemical Engineering, Volume-2, 5th edition, Butterworth Heinemann, 2002.3.
3. Binay K. Dutta, Principles of mass transfer and separation processes, 2nd edition, PrenticeHall of India, 2007.4.
4. W. L. McCabe, J.C .Smith & Harriott, Unit Operations of Chemical Engineering, 6thedition Mc-Graw Hill international, 2001.5.

5. C. J. Geankoplis, Transport processes and unit operations, 3rd edition, Prentice Hall ofIndia, 1993.

List of Experiments: (Minimum 10 experiments to be performed)

1. To evaluate the diffusivity of compound in stagnant air at room temperature.
2. To evaluate the diffusivity of compound at elevated temperature. Analyze the results for room temperature and elevated temperature.
3. To evaluate the mass transfer co-efficient of liquid/water and air system.
4. Determine diffusivity using theoretical equation.
5. To evaluate efficiency for single stage liquid-liquid extraction of acetic acid from the mixture of acetic acid and water.
6. To evaluate efficiency for multi- stage liquid-liquid extraction of acetic acid from the mixture of acetic acid and water. Compare and analyze the results for single stage and multi-stage operation.
7. To study the humidification operation and to calculate all psychrometric parameters of air-water system using psychrometric chart.
8. Study experiment- Packed Tower.
9. Study experiment- Types of Cooling Tower
10. Virtual Lab – Vapour in air diffusion.
11. Virtual Lab – Gas-liquid absorption.
12. Virtual Lab – Water cooling tower

Major Equipment:

Gas absorption column, water cooling tower, diffusion assembly, packed column, extraction unit etc.

List of Open-Source Software/learning website:

1. Students can refer to video lectures available on the websites including NPTEL (https://nptel.ac.in/courses/103103145 and https://nptel.ac.in/courses/103103154).

2. Students can perform experiments on Virtual Lab (https://ce-iitb.vlabs.ac.in/List%20of%20experiments.html?domain=Chemical%20Engineering OR https://vmt-iitg.vlabs.ac.in/) .

3. Students can access https://learncheme.com/ (website by University of Colorado Boulder) for screencasts, interactive simulations and self-study modules related to Mass Transfer Operations.

Suggested Activities for Students: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide.

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