Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Sixth**

Course Title : **Mass Transfer Operation**

Course Code : **22609**

1. RATIONALE

After studying this course the student will be able to operate and control various parameters related to mass transfer equipment. As Mass transfer operation is a core subject of chemical engineering, Diploma chemical engineer has to study the Mass Transfer Operations in the chemical process industry. They have to deal with the equipments related to Mass Transfer Operations like Distillation, Extraction, Absorption, Drying, Crystallisation. They have to handle various Mass Transfer Equipment like Distillation column, Dryer, Extractor, Crystalliser and Absorber and Extractor in safe and efficient manner.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Use chemical process plant equipment for mass-transfer operations safely.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency.

a) Use various distillation methods in chemical industry.
b) Use gas absorption operation and relevant equipment in chemical industries.
c) Select relevant solvent for extraction process.
d) Determine the time required for drying process.
e) Determine the yield of crystals obtained.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory							Practical				
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	4	7	3	70	28	30*	00	100	40	50#	20	50	20	100	40

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends:** **L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment.*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the

course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

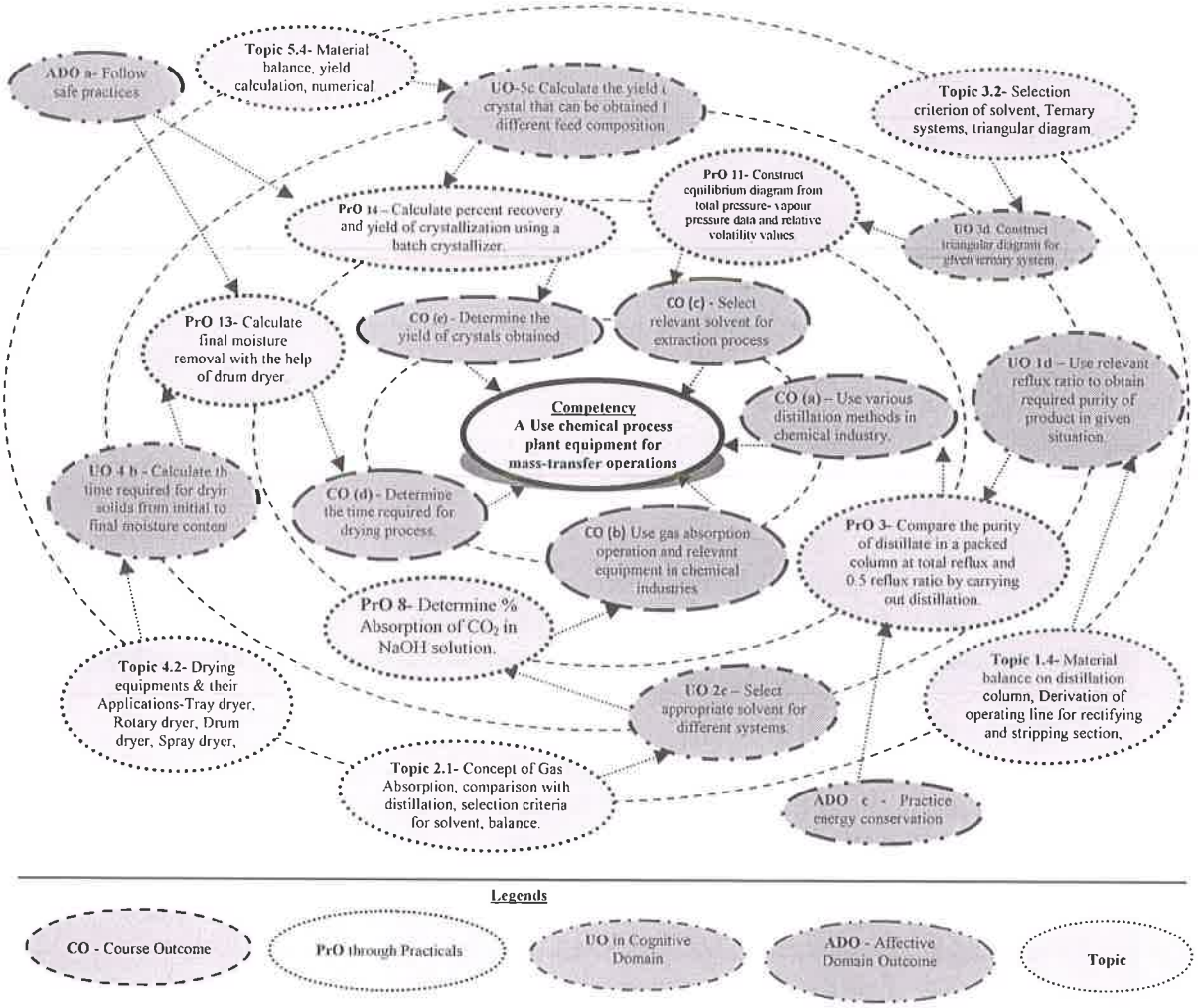

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Determine the diffusivity of given volatile liquids in air.	I	04*
2	Perform the simple distillation of methanol- water system.	I	04*
3	Measure purity of distillate in fractional distillation.	I	04
4	Determine Diffusivity of liquid in liquid mixture.	I	04*
5	Measure the purity of distillate by carrying out Steam Distillation.	I	04*
6	Carry out distillation to compare the purity of distillate in a packed column at total reflux and 0.5 reflux ratio	I	04
7	Construct equilibrium diagram from total pressure- vapour pressure data and relative volatility values.	I	04*
8	Determine % Absorption of CO_2 in NaOH solution.	II	04*
9	Calculate the pressure drop of a given packed column for wet and dry packing.	II	04*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
10	Determine distribution coefficient for toluene- acetic acid and chloroform- acetic acid mixture.	III	04*
11	Construct Ternary Diagram for system of three liquid, one pair partially soluble i.e. Acetic acid-Benzene-Water system.	III	04
12	Carry out drying of wet saw dust or sand in a batch dryer to obtain the drying rate curve.	IV	04*
13	Use the drum dryer to find the final moisture removal.	IV	04
14	Use a batch crystallizer to determine percent recovery and yield of crystallization.	V	04*
15	By heating or cooling method determine the solubility of a salt and obtain the solubility curve.	V	04*
16	Use the process simulator to analyze the parameters of distillation column or Crystalliser.	All	04
17	Use the process simulator to analyze the parameters of distillation column or Dryer.	All	04*
18	Use the process simulator to analyze the parameters of distillation column or Absorber.	All	04
	Total		**72**

Note

i. *Given in above tables is suggestive list of practical exercises. Teachers can design other similar exercises.*

ii. *To attain the COs and competency, a judicial mix of 12 or more practicals/exercises from the above listed PrOs need to be performed to achieve up to the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy'. Assessment of the 'Process' and 'Product' related skills in the laboratory/workshop/field work should be done as per suggested sample below:*

S. No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	15
2	Setting and operation	20
3	Safety measures	10
4	Observations and recording	15
5	Interpretation of result and conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/ attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/ field based experiences:

a) Follow safety practices.
b) Practice good housekeeping.
c) Practice energy conservation.
d) Work as a leader/a team member.
e) Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organisation Level' in 2nd year
- 'Characterisation Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Packed Distillation Column (Column with provisions for measuring pressure drop, flow rate and different reflux ratio)	06,09
2	Fractionation column with reflux provision.(Reboiler of capacity minimum 1000ml, Plate / packed column, condenser and receiver)	03
3	Tray Dryer.(Drying compartment with weight and temperature indicator and blower)	12
4	Drum Dryer (300mm Dia X 200mm long, coolant provision, Steam Provision, Feeding provision)	13
5	Simple Distillation Set up.(Reboiler of capacity minimum 1000ml, condenser and receiver)	02
6	Batch Crystalliser. (Cap. 2Ltrs. With (Jacketed) conical bottom, Stirrer-FHP, Heater, Cooling Water Tank-Capacity 30 liters-fitted with Pump, Rotameter for cooling water, Pump-FHP, Receiving Tank-Capacity 2 liters, Temp. Sensors-RTD PT-100 type, Control panel comprises of:Digital Temp. Indicator=0-199.9oC, RTD PT-100 Type with multi-channel switch)	14
7	Diffusivity apparatus.(Stefan Tube, hot plate, temperature indicator, blower)	01
8	Absorption column.(Column with provisions for measuring pressure drop and flow rate, compressor)	08
9	Process Simulator software setup.(Triangle Simulation Private Limited Software).	16
10	Steam Distillation set up.(Capacity-2000ml,Water Distiller, Purifier, Hot stove, Condenser)	05
11	Glass wares for titration.(Beaker, Separating funnel, measuring cylinder, conical flask, burette, pipette)	04,10, 15
12	Graph Paper	07,11,13

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit-I Distillation	1a. State the role of diffusion in the given mass transfer	1.1 Definition of diffusion, Ficks Law, Flux equation, Molecular diffusion in gases,

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	operations. 1b. Explain with sketches the relevant distillation method for the given industrial applications. 1c. Calculate number of equilibrium stages in distillation column in the given situation. 1d. Use relevant reflux ratio to obtain required purity of product in the given situation.	Steady state diffusion of A through non diffusing B, Steady state equimolar counter diffusion and Role of Diffusion in Mass Transfer Operations. 1.2 Concept of distillation, Boiling point diagram, Vapour liquid equilibria, Henry's Law, Raoults Law, Computing x – y data, Volatility, relative volatility. 1.3 Methods of distillation, Simple or Differential distillation, Rayleigh's equation, Flash or Equilibrium distillation, Rectification or Fractionation, Azeotropic distillation, Steam distillation. 1.4 Material balance on distillation column, Derivation of operating line for rectifying and stripping section, McCabe – Thiele method, derivation of q line, effect of feed conditions on slope of q line, Reflux ratio – minimum, total and optimum. 1.5 Plate column, packed column, Bubble cap plate, Sieve plate, Valve plate, Down comers and weirs.
Unit– II Gas Absorption	2a. Explain with sketches the given process. 2b. State the relevant characteristics of the given material. 2c. Select relevant solvent for the specified system with justification. 2d. Identify the flooding and loading point in the given type of column.	2.1 Concept of Gas Absorption, comparison with distillation, selection criteria for solvent, Concept of equilibrium, minimum liquid-gas ratio, material balance. 2.2 Hydrodynamics of packed column. Loading and flooding of packed columns. 2.3 Gas absorption equipment- mechanically agitated vessel, packed columns, types of packings, Characteristics of packings, channeling in packed columns, 2.4 Concept of (Height Equivalent to Theoretical Plates)HETP
Unit– III Liquid-Liquid Extraction	3a. Explain with sketches the given process. 3b. State the applications of the give extraction equipment. 3c. Select relevant solvent for the given liquid-liquid mixture. 3d. Prepare the triangular diagram for the given ternary system.	3.1 Extraction and distillation 3.2 Concept of liquid-liquid extraction, comparison between distillation and extraction, distribution coefficient. 3.3 Selection criterion of solvent, Ternary systems, triangular diagram. 3.4 Extraction equipment- mixer settler, spray column, rotating disc contactor.
Unit –IV Drying	4a. State the relevant moisture contents for the specified	4.1 Moisture content on dry and wet basis, Bound, Unbound, Free, critical and

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	conditions. 4b. Calculate the time required for drying solids for the specified moisture content. 4c. Select relevant dryer for the given drying material(s). 4d. Determine the given parameters after plotting the rate of drying curve with the given data.	equilibrium moisture content. 4.2 Rate of drying-Constant and falling rate period, Time required for drying, rate of drying curve. 4.3 Material balance and Numericals based on Time of drying. 4.4 Drying equipments and their Applications- Tray dryer, Rotary dryer, Drum dryer, Spray dryer, Fluidized bed dryer.
Unit– V Crystallization	5a. Explain the mechanism of crystallization for the given materials. 5b. Plot solubility and super solubility curve with the given data. 5c. Calculate the yield of crystal that can be obtained for the given feed composition. 5d. Explain with sketches the construction and working of crystallizer.	5.1 Concept of crystallization, mechanism, saturation, super saturation, solubility curves. 5.2 Methods of super saturation, Mier's super saturation theory. 5.3 Crystallization equipments- Agitated tank crystalliser, vacuum crystalliser, Oslo (cooler and evaporative) crystallizer, Swenson-Walker crystallizer. 5.4 Material balance, numerical based on % yield and % recovery.

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Distillation	20	04	12	12	28
II	Gas Absorption	06	02	06	00	08
III	Liquid -Liquid Extraction	06	02	06	00	08
IV	Drying	08	02	04	08	14
V	Crystallisation	08	00	04	08	12
Total		**48**	**10**	**32**	**28**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note: This specification table provides general guidelines to assist students for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various

outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare practical journals based on practical performed in laboratory.
b) Attend NPTEL / MOOCS / SWAYAM platform for self learning.
c) Refer books available in department or Central library and prepare abstract of it.
d) Prepare power point presentation or animation for understanding different mass transfer operations.
e) See the video lectures and video practicals and make a report.
f) Prepare Technical Journal's abstract on latest mass transfer equipment.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the LOs/COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Use Flash/Animations to explain various instruments for measurement.
f) Guide student(s) in undertaking micro-projects.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) **Prepare report**: Prepare report of local industries where mass transfer operations are carried out.
b) **Prepare model**: Prepare working model / prototype model of equipments like rotary dryer / spray dryer / Swenson-Walker crystallizer etc.
c) **Prepare charts**: Prepare charts of different mass transfer operations and phases involved in it.
d) **Prepare List:** Prepare the list of different mass transfer operations and equipments with specific use in process industry which are not included in board curriculum.

e) **Visit of chemical process plant**: Visit nearby industry to observe mass transfer operations controlled by Simulator system / DCS /SCADA and prepare the report of it.
f) **Prepare Presentation:** Collect the data on recent equipments / technology to run the Mass Transfer Operations.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Introduction to Chemical Engineering	Badger, Walter L.; Banchero, Julius T.	Mc Graw Hill, New Delhi ISBN:978-0070850279
2	Unit Operations of Chemical Engineering.	Mc Cabe, W. L. Smith and Harriott.	Mc Graw Hill International, New York, ISBN-978-007284823
3	Mass Transfer Operations	Treybal, Robert E	Mc Graw Hill International, New York, ISBN978-00705170
4	Chemical Engineering Vol. 2	Coulson and Richardson's	Asian Books Pvt. Ltd., New Delhi ISBN: 978075044457

14. SOFTWARE/LEARNING WEBSITES

a) NPTEL – MTO FAQs - http://nptel.ac.in/Clarify_doubts.php?subjectId=103103035
b) 39Video Lectures on MTO-https://freevideolectures.com/course/3438/mass-transfer-operations-i
c) Virtual Laboratory - http://iitg.vlab.co.in/?sub=58andbrch=160
d) NPTEL Video Lecture 2-https://www.youtube.com/watch?v=EyREi7l5020
e) NPTEL Video Lecture by IIT Professor - https://www.youtube.com/watch?v=EyREi7l5020andlist=PLbMVogVj5nJSOgW8GYe_nJ3MYfnCQ3XXM
f) Introduction to Mass Transfer by IIT Professor - https://www.youtube.com/watch?v=5UT0eqHE578