Program Name : **Diploma in Chemical Engineering**

Program Code : **CH**

Semester : **Fifth**

Course Title : **Membrane Technology (Elective)**

Course Code : **22513**

1. RATIONALE

Chemical Technologists deal with the various separation processes. Separation of liquid from liquid, important operation in Chemical Engineering. Separation at ionic level and Nano level. Waste water treatment is another area, where membrane technology plays an important role. Design and development of membrane a new area, where chemical engineer can play important role. Various types of membrane and module are available in market to separate the compounds at ionic level. Purification of drinking water done all the way by membrane. Ultrafiltration, microfiltration, Nano filtration are various operations involved in membrane technology.

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 membrane technology principles for separation in Chemical Process.**

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 the relevant membrane for various chemical processes.
b. Apply membrane technology in process industries.
c. Use appropriate method to reduce membrane fouling.
d. Apply concept of economics and feasibility to membrane technology.
e. Interpret concept of advance membrane technology and nanotechnology.

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	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment 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.

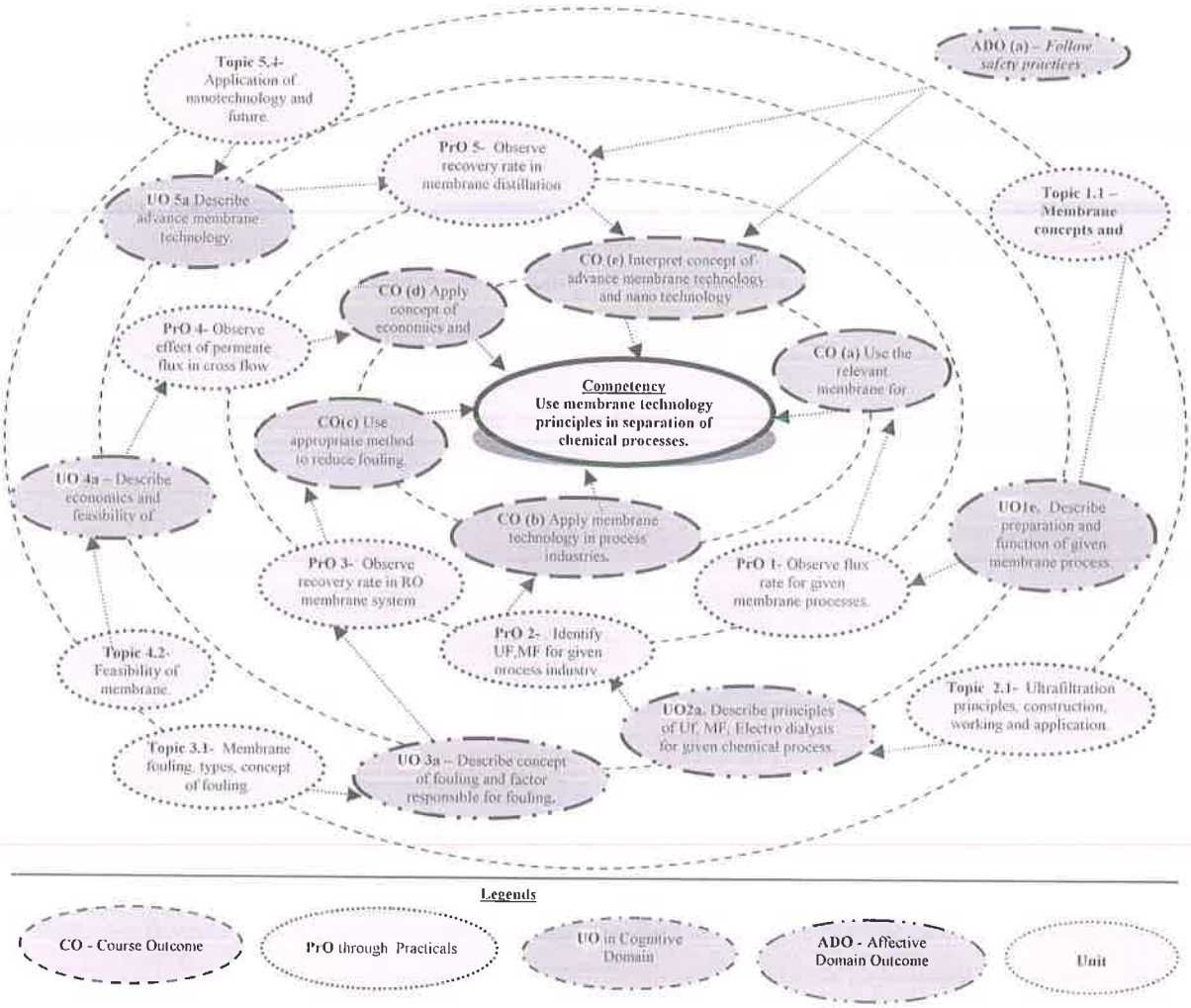

Figure 1 - Course Map

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 feed flux, retentate flux and permeate flux in RO.	I	02*
2.	Determine feed flux, retentate flux and permeate flux in NF.	II	02
3.	Determine feed flux, retentate flux and permeate flux in UF.	II	02*
4.	Determine feed flux, retentate flux and permeate flux in MF.	II	02*
5.	Determine feed flux, retentate flux and permeate flux in pervaporation.	III	02*
6.	Determine recovery rate in RO membrane system.	III	02*
7.	Determine retention, efficiency of membrane in RO membrane system.	III	02*
8.	Determine trans membrane pressure in UF membrane system.	III	02*
9.	Determine membrane permeability using different membrane.	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
10.	Prepare membrane (polymeric, ceramic, composite or liquid)(Any one)	III	02
11.	Determine effect of permeate flux in dead end membrane process.	IV	02*
12.	Determine effect of permeate flux in cross flow membrane process.	IV	02
13.	Determine the recovery rate of permeate by using membrane distillation.	IV	02*
14.	Determine the recovery rate of permeate by using membrane bioreactor.	IV	02*
15.	Determine feed flux, retentate flux and permeate flux in pervaporation.	IV	02*
16.	Determine recovery rate in membrane bioreactor.	V	02
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1.	Selection of suitable component, apparatus/instrument	20
2.	Preparation of experimental set up	10
3.	Setting and operation	10
4.	Safety measures	10
5.	Observations and Recording	10
6.	Interpretation of result and Conclusion	20
7.	Answer to sample questions	10
8.	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. Work as a leader/a team member.
d. 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

- 'Organizing Level' in 2nd year
- 'Characterizing 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	UF test rig: Hallow fiber, UF model, provided with feed and backwash pump, compact and table top mounted.	3,8
2	Membrane Bioreactor: Submerged Hallow fiber MBR. Compact and table top mounted (Pump on ground)	4,14,16
3	Membrane Distillation: Hydrophobic membrane of composite membrane. Hallow fiber membrane module.	6
4	RO test rig: Membrane material Composite membrane (Polyamide) Permeate flux and MWCO characteristic study provided with high pressure pump. Compact and table top mounted (Pump on ground)	1,7
5	Pervaporation: 1 lit (consist of 2 half, 500 ml each). Glass flange vessel. ID 90 mm, OD 100 mm. Length 125 mm. SS 316 perforated membrane support plate Teflon gaskets.	5

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 Introduction to Membrane.	1a. Describe the function of given membrane 1b. Identify preparation of membrane from given material. 1c. Explain with sketches the use of given type of membrane processes with sketches. 1d. Describe with sketches the working of given membrane module.	1.1 Membrane concepts, energy for membrane process. 1.2 Synthetic material (Hydrophobic and hydrophilic), Inorganic materials (oxides, metal,carbon, aluminosilicates), Advanced materials (Mixed matrix membrane, carbon nanomaterials). 1.3 Application of membrane in water treatment, pharmaceutical industry, chemical industry. 1.4 Plate and frame module, tubular module, Hollow fiber module, spiral wound module.
Unit– II Industrial Membrane processes.	2a. Describe with sketches principle of reverse osmosis for given process. 2b. Describe with sketches principle of ultra and microfiltration for given process. 2c. Describe with sketches principle of Micro filtration for given	2.1 Reverse osmosis principle, construction, working, application. 2.2 Ultrafiltration principle, construction, working, application. 2.3 Micro filtration principle, construction, working.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	process. 2d. Describe with sketches principle of dialysis and electro dialysis for given process.	application. 2.4 Dialysis, Electro dialysis principle, construction, working, application.
Unit– III Membrane Fouling	3a. Describe with sketches concept of fouling for given membrane. 3b. Identify factor responsible for fouling of given membrane. 3c. Describe with sketches mechanism of fouling for given membrane. 3d. Describe with sketches concept of bio fouling for given membrane	3.1 Membrane fouling, concept, types of fouling. 3.2 Factor responsible for fouling such as temperature, pressure, materials used for fouling, concentration of feed. 3.3 Mechanism involved effect of fouling, reversible, irreversible fouling. 3.4 Concept of bio fouling factor responsible for bio fouling, control of bio fouling.
Unit-IV Economics and feasibility of membrane technology.	4a. Describe economics of given membrane technology 4b. Describe feasibility of given membrane technology 4c. Compare given membrane technology with other separation methods 4d. Write scope of given membrane technology in future.	4.1 Economics of membrane, cost of membrane 4.2 Feasibility of membrane. 4.3 Compare membrane with conventional processes. 4.4 Scope of membrane, future to membrane technology.
Unit –V Advanced membrane technology and Nano technology.	5a. Describe with sketches given Ion exchange process. 5b. Describe with sketches given advance membrane technology. 5c. Describe with sketches given process of nanotechnology. 5d. Describe application, future scope of given nanotechnology process.	5.1 Concept of Ion exchange, cation, anion exchange resins, equipment available. 5.2 Membrane bioreactor, distillation principle, construction, working. 5.3 Concept of nanotechnology, nano scale materials, organic and inorganic nano structure. 5.4 Application of nanotechnology, future scope of nanotechnology.

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	Introduction to membrane	10	02	06	04	12
II	Industrial Membrane Processes.	12	02	08	10	20
III	Membrane Fouling	08	04	04	04	12
IV	Economics and feasibility of membrane technology	08	02	04	04	10

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
V	Advanced membrane technology and nano technology.	10	04	06	06	16
	Total	48	**14**	**28**	**28**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student 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) List different names and types of membrane material.
b) Identify membrane process for dehydration of ethanol.
c) List membrane module and draw any one of them.
d) Identify membrane material for desalination of water.
e) Identify the methods of cleaning of membrane.
f) List the factors which affect the performance of membrane.
g) Identify the formulae of TMP, recovery rate, rejection efficiency and water permeability of membrane.
h) List the advantages of membrane technology over conventional processes.
i) List types of bioreactor with diagram.

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 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) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.

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) Preparation of model: Prepare working model of RO/UF/NF/MF.
b) Fabricate dead end membrane process in laboratory.
c) Collect the used membrane housing from market. Clean the housing and check water quality obtained from it. Prepare detail report.
d) Fabricate cross flow membrane process with membrane material used, membrane module used in laboratory.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Membrane technology and application	Baker, Richard W.	Wiley 2004, New Delhi, 2014 ISBN: 9780470020395
2	Basic principles of Membrane Technology	Mulder ,Marcel	Kluwer Academic Publisher 2014 ISBN:9780792309790s
3	Materials science of membranes for gas and vapour separarion.	Yampolskii, Y. I.pinnau, B.D. Freeman	Wiley Publication New Delhi, 2014 ISBN: 9780470853450
4	Membrane Technology and application	Baker, R.	John Wiley and Sons New Delhi, 2014 ISBN:9780470743720
5	Membrane and desalination technology	Wang, K. and J P chen	Humana Press ISBN: 9781597452786
6	Handbook of industrial membrane technology	Porter, M. C.	Noyes Publications Springers ISBN: 9780815517559 ISBN: 9780815512059
7	Membrane Handbook	Ho, W. S. K.K. Sirkar	Kluver Academic Publishers ISBN:0781461535485

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a) https://en.wikipedia.org/wiki/Membrane_technology
b) https://www.journals.elsevier.com/membrane-technology.
c) http://gpcb.gov.in/images/pdf/ZLD_PRESENTATION_8.PDF
d) https://www.appliedmembranes.com/ultrafiltration-membranes-uf-membranes.htm
e) https://www.nano.gov/nanotech-101/what/definition
f) https://en.wikipedia.org/wiki/Nanotechnology


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