GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Branch: Chemical Engineering

Subject Code: ME02030101

Course/ Subject Name: Membrane Separation Processes

W.E.F. Academic Year:	2024-25
Semester:	2
Category of the Course:	Professional Elective Course

Prerequisite:	Students should have a fundamental understanding of mass transfer operations, chemical process industries, material and energy balances, reaction engineering, and industrial safety to comprehend waste generation, treatment, and regulatory aspects effectively.
Rationale:	Membranes are applied in a range of processes from selective separation to solvent and material recovery. This course will enable students to understand membrane-based separation problems by acquiring in-depth knowledge in the area of membrane separation mechanisms, transport models, membrane materials and modules etc. and also provide an insight to the membrane based separation processes that are an integral part of the down-stream processing of various industries.

Course Outcome:

Upon successful completion of this course, students will be able to:

No	Course Outcomes
01	Define and select the appropriate membrane properties, configurations, materials, and operating circumstances
02	Evaluate the effectiveness of membrane separation processes and analyze the properties of membrane separation
03	Select a membrane process and design components to carry out a specific separation process
04	Utilize the cutting-edge membrane technology to address issues in the chemical and environmental sectors

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+(PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial/ Practical		
L	T	PR	C	ESE (E)	PA/ CA (M)	PA/CA(I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	%of Weightage
1	**Introduction to Membrane Separation Processes:** Definition and Types of Membranes, Historical Development, Classification of Membrane Separation Processes, Advantages, Limitations and Applications of Membrane Separation Processes.	4	08
2	**Rate Governed and Equilibrium Governed Membrane Separation Processes:** Different Methods for Synthesis of Membrane, Various Types of Membranes Modules, Flow Patterns and Membrane materials, Membrane Characterization.	4	10
3	**Reverse Osmosis (RO) and Nanofiltration (NF):** Working Principle, Applications, Benefits and Drawbacks of RO and NF. Design and operating parameters, Various Transport Models, Kedem-katchalsky Model, Spiegler-Kedem Model, Solution-Diffusion Model, Concentration Polarization and Flux Decline, Design of an RO module, Forward Osmosis, NF membrane Transport Mechanism and Parameters affecting the Performance, NF membrane mass transfer and Fouling Model.	7	16
4	**Microfiltration(MF) and Ultrafiltration(UF):**Working Principle, Applications, Benefits and Drawbacks of MF and UF Processes, Transport mechanism and Factors affecting Performance of MF and UF, Fouling in MF membranes, Types of devices for UF, Flux equation, Resistance Model and Gel Polarization Model in UF, Fouling and flux Decline in UF, Micellar-Enhanced UF, Affinity UF.	6	14
5	**Membrane Gas Separation and Pervaporation (PV):** Key Aspects of Gas Separation Membranes, Fundamental Mechanism of Gas Transport, Knudsen Diffusion, Molecular Sieving, Solution-Diffusion, Dual Sorption model, Factors affecting Gas Permeation, Applications of Gas Separation. Principle of PV, Mass Transfer and Thermodynamics aspects of PV, Temperature Drop at membrane interface, Design of a PV Module. Applications of PV.	7	16
6	**Dialysis and Electrodialysis(ED):**Principle of Dialysis, Dialysis Systems, Mass transfer in Dialysis, Modeling of Solute Transport in Hem Dialyzer, Advantages and Applications of Diffusion dialysis, Working and Mechanism of ED, Applications of ED, Important Aspects of Membranes for ED.	5	12

7	**Liquid Membrane and Facilitated Transport:** Merits of Liquid Membrane, Bulk, Emulsion, Thin sheet supported and Hollow fiber supported liquid membrane, Recent Advances and Case Studies on Liquid Membrane. Important Aspects and Mechanism of Facilitated Transport, Coupled Transport, Carrier Agents, Competitive Facilitated Transport with Two permeates active and passive transport, Some potential applications of facilitated transport.	7	12
8	**Membrane Distillation (MD) and Electrophoresis (EP):** Introduction to Membrane Distillation and Electrophoresis, Principle of MD and EP. Principle of Electrophoresis, Factors affecting Electrophoresis, Different Typesof Electrophoresis, Applications of MD and EP.	5	12
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
20	28	22	18	10	02

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. Transport Processes and Separation Process principles, Christie J Geankoplis Prentice-Hall of India Private Ltd, New Delhi, 4th Edition 2006.
2. Membrane Separation Processes, Second Edition, by Kaushik Nath, PHI Learning Pvt. Ltd, New Delhi, 2017.
3. Membrane Handbook Eds. By W. S. W. Ho and K. K. Sirkar Springer New York, NY, 1992.
4. Membrane technology and applications, Baker, R.W., 2nd ed., John Wiley 2004
5. Synthetic membranes: Science, Engineering and Applications, Eds. By P. B. Bunge, H. K. Lonsdale and M. N. Depinho, Springer Dordrecht, 1996.
6. Basic Principles of Membrane Separation, Mudler J, (2nd Edition), Springer Dordrecht 1996.
7. Ultrafiltration and Microfiltration Handbook, (2nd Edition), Munir Cheryan, CRC Press.

8. Equilibrium-stage separation operation in chemical engineering by Ernest J. Henley and J.D. Seader, Second edition Wiley India Pvt. Ltd.

(b) Open-source software and website:

1. Video lectures available on the NPTEL website.
2. MIT open course lecture on equipment design.
3. Use of subject relevant software for the problems solving and analyzing the separation processes.

Suggested Course Practical List:

1. Preparation and characterization of polymeric membrane.
2. Swelling characteristics of membrane in aqueous-organic mixture.
3. Determination of Membrane Permeability for different membrane materials.
4. Experimental determination of permeate flux, permeate rejection and permeate characteristics in MF and UF.
5. Experimental determination of permeate flux, permeate rejection and permeate characteristics in NF and RO.
6. The above experiment no. 4 and 5 should be repeated with different membranes and fluxes may be compared.
7. Determination of various mass transfer resistances during pressure driven membrane process.
8. Determination of rate of mass transfer of gases through dense polymeric membrane.
9. Experiment on emulsion liquid membrane using oil-water emulsion or in separation of phenol/ heavy metals etc.
10. Separation efficiency determination using Electrophoresis separation.
11. Numerical / Design problems based on the selected topics of content.
12. Term paper submission on any specific membrane separation processes application in industrial operations.

Major Equipments Laboratory scale membrane film applicator unit, bench-scale cross/tangential flow membrane test cells, pilot plant for nanofiltration, (Flat sheet & Spiral Wound Module) where various flat sheet membranes can be tested with respect to various feed solutions for the operating parameters, lab scale set up for micro and ultrafiltration unit, pervaporation pilot plant with flat sheet membrane, a laboratory-scale filtration unit that is designed to evaluate a variety of Osmotically Driven Membrane Processes (ODMP), including Forward Osmosis (FO) and Pressure Retarded Osmosis (PRO).Setup.

List of Laboratory/ Learning Resources Required:

Laboratory Facilities

1. Water supply facility and facility for proper drainage of water in Lab Area
2. Weighing balance, Vacuum pump
3. Chemical Storage Cabinets
4. Personal Protective Equipment (PPE)

Suggested Project List:

- Fabrication and Characterization of TFC membrane
- Fabrication and Characterization of TFC membrane
- Microfiltration application in separation of solute from waste water of food processing units
- Design of a Pervaporation Unit
- Separation of a selective material from water using Nano-RO Hybrid Systems
- Synthesis and applications of grapheme-based NF membrane
- Modified processes for ultrafiltration for separation of specific solute from waste water
- Correlation of pressure driven membrane separation with zero liquid discharge
- Energy efficient membrane separation processes
- Draw Solute recovery using forward osmosis
- Development of stable emulsion systems for ELM
- Recovery of organic acids using ELM
- Green-Solvent based ELM
- Optimization of performance of different gas separation membrane
- Efffectiveness of membrane separation for radioactive waste treatment

Suggested Activities for Students:

- Explore emerging areas in membrane separation processes
- Learn membrane preparation, modification and characterization
- Apply membrane separation processes effectively for real world separation problems