Lahore University of Management Sciences

ChE412 – Membrane Science and Engineering

Spring 2022

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Course URL (if any)	

Course Teaching Methodology
• Teaching Methodology: Teaching methodology will be in-person.

Course Basics				
Credit Hours	03			
Lecture(s)	Nbr of Lec(s) Per Week	02	Duration	75 min
Recitation/Lab (per week)	Nbr of Lec(s) Per Week		Duration	

Course Distribution	
Core	BS Chemical Engineering
Elective	
Open for Student Category	Senior Year ChE course (Elective)
Close for Student Category	

Course Description
The course will cover the basic principles of membrane science and the corresponding membrane processes (microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and gas permeation). A brief introduction on the historical development of membranes and membrane processes will be given. Membrane structures and their functionalities developed for specific processes will be covered. The transport principles for porous and nonporous membranes (viscous flow, Knudsen diffusion, Fick's law, solution/diffusion) will be discussed in detail with respect to their driving forces and how this knowledge can be applied to design advanced membrane materials/structures. A significant fraction of the course will be dedicated to covering membrane processes, including pressure-driven processes, concentration-driven processes, and thermally driven processes, focusing on the formation of integral-asymmetric and thin-film composite membranes and hollow fiber technology. General analytical techniques to evaluate membranes will be introduced for reverse osmosis and gas permeation membranes, followed by lab demonstrations.

Course Prerequisite(s)	
•	ChE 320 Separation Processes

Course Objectives	
•	Provide students with fundamental concepts of membrane science and technology with a focus on membrane processes (microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and gas permeation), membrane structures for various separations, transport principles of porous and dense membranes, pressure-driven, concentration-driven processes and design parameters for various membrane modules.

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Learning Outcomes	
CLO1: CLO2: CLO3:	On successful completion of this course, students will be able to: **Identify** different types of membranes in a given process and make appropriate assumptions to **calculate** rates and/or transport properties. **Analyze** the relationship between membrane processes and the membrane materials **Evaluate** membrane technologies for various processes, including pressure-driven and concentration-driven processes.

Grading Breakup and Policy
Assignments: 10 % (4 assignments) Design Project: 10% Midterm Examination-I: 20 % Midterm Examination-II: 20 % Final Examination: 40 %

Relation to Program Outcomes				
CLOs	Related PLOs	Levels of Learning	Teaching Methods	CLO Attainment checked in
CLO1	PLO1, PLO2, PLO3, PLO7, PLO8, PLO9, PLO10, PLO11	C3	Instruction, Problem Solving, Assignments	Assignments, Project, Midterms, Final Term
CLO2	PLO1, PLO2, PLO3, PLO7, PLO8, PLO9, PLO10, PLO11	C4	Instruction, Problem Solving, Assignments	Assignments, Project, Midterms, Final Term
CLO3	PLO1, PLO2, PLO3, PLO7, PLO8, PLO9, PLO10, PLO11	C5	Instruction, Problem Solving, Assignments	Assignments, Project, Midterms, Final Term

Examination Detail	
Midterm Exam	Yes/No: Yes Combine Separate: Duration: 75 min Preferred Date: Exam Specifications: In-class
Final Exam	Yes/No: Yes, comprehensive Combine Separate: Duration: 3 h Exam Specifications: In-class

Course Overview			
Week/ Lecture/ Module	Topics	Recommended Readings	Objectives/ Application
Week # 01	a. Course overview, introduction to membrane science b. Membrane processes overview (Liquid, gas, vapor)	Marcel Mulder, Chapter 1	Introductory discussion to the membrane science and membrane processes
Week # 02	a. Membrane materials b. Material properties	Marcel Mulder, Chapter 2	Introduction to membrane materials and their properties

Week # 03	a. Composite, organic membranes b. Inorganic membranes	Marcel Mulder, Chapter 3	Study various types of physical membranes
Week # 04	a. Phase inversion membranes (NIPS, TIPS, VIPS, RIPS, CIPS, etc.) b. Phase inversion in polymers	Marcel Mulder, Chapter 3	Study different membranes and membrane morphologies and phase inversion.
Week # 05	a. Phase inversion and the various parameters b. Dense membranes	Marcel Mulder, Chapter 3	Study different membranes and membrane morphologies and phase inversion.
Week # 06	a. *Worked examples* b. **Midterm Exam I**		
Week # 07	a. Characterization of porous membranes b. Membrane characterization for dense membranes	Marcel Mulder, Chapter 4	Porous and dense membranes
Week # 08	a. Membrane transport through porous membranes b. *Worked examples*	Marcel Mulder, Chapter 5	Transport through membranes based on their morphology
Week # 09	a. Transport through dense membranes, cont'd… b. Transport through dense rubbery and glassy polymers	Marcel Mulder, Chapter 5 Materials Science of Membranes, Chapter 1	Transport through membranes based on their morphology
Week # 10	a. Worked examples b. **Midterm Exam II**		
Week # 11	a. Pressure driven membrane processes, cont'd… b. Pressure driven membrane processes	Marcel Mulder, Chapter 6	Study the membrane processes, including microfiltration, ultrafiltration, nanofiltration and reverse osmosis.
Week # 12	a. Concentration driven membrane processes, cont'd… b. Concentration driven membrane processes	Marcel Mulder, Chapter 6	Study concentration-driven process, including gas separation, and pervaporation
Week # 13	a. Membrane modules and process design, cont'd… b. Membrane modules and process design	Marcel Mulder, Chapter 8	Introduction to membrane modules and process design
Week # 14	a. Lab demonstrations b. Design projects presentations		
Week # 15			
Week # 16	**Final Exam**		

Textbook(s)/Supplementary Readings

Textbook
Marcel Mulder, Basic Principles of Membrane Technology, 2nd Ed. Kluwer Academic Publications, 1996.

Additional Reading:
Richard Baker, Membrane Technology and Applications, 3rd Ed. Wiley-VCH, 2012.
Heinrich Strathmann, Introduction to Membrane Science and Technology, Wiley-VCH, 2011.
Yu. Yampolskii, I. Pinnau, B.D. Freeman, Materials Science of Membranes for Gas and Vapor Separation, Wiley-VCH, 2007.

Harassment Policy

There is absolutely zero tolerance for any behavior that is intended, or has the expected result of making anyone uncomfortable and negatively impacts the class environment, or any individual's ability to work to the best of his/her potential. If you think you may be a victim of harassment, or if you have observed any harassment occurring in the purview of this class, please reach out and speak to me. If you are a victim, I strongly encourage you to reach out to the Office of Accessibility and Inclusion at oai@lums.edu.pk or the sexual harassment inquiry committee at harassment@lums.edu.pk for any queries, clarifications, or advice. You may choose to file an informal or a formal complaint to put an end to offending behavior. You can find more details regarding the LUMS sexual harassment policy here: https://mgshss.lums.edu.pk/lums-harassment-

policy. To file a complaint, please write to harassment@lums.edu.pk. In addition to LUMS resources, SSE's Council on Belonging and Equity is committed to devising ways to provide a safe, inclusive and respectful learning environment for students, faculty and staff. To seek counsel related to any issues, please feel free to approach either a member of the council or email at cbe.sse@lums.edu.pk.