CBE/MSE 5774 Polymer Membranes Spring 2024

Description

Polymer membranes have wide applications ranging from selective molecular separations to the removal and recovery of target materials including solvents, proteins, and particulates. This course will allow students to acquire in-depth knowledge in the area of membrane separation mechanisms, transport models, membrane permeability computations / measurements, membrane materials / types / modules, membrane contactors / reactors, and applications. This course will in turn enable the students to understand and solve membrane-based separation / reaction problems.

Level	Credits	Weekly Class Time Distribution	Quarters Offered	Prerequisites	Cross-Listings
Undergraduate/ Graduate	3	two 80-min lectures	Spring	CBE 3508 (Thermodynamics) or equivalent	MSE and CBE

Textbook

W.S. Winston Ho and Kamalesh K. Sirkar, Eds., *Membrane Handbook*, Chapman & Hall, New York, 1992 (ISBN 0-412-98871-2), Kluwer Academic Publishers, Boston, reprint edition, 2001, Springer US, New York, reprint edition, 2012 (recommended, not required).

Reference Books / Journals

Marcel Mulder, *Basic Principles of Membrane Technology*, 2nd Ed., Kluwer Academic Publishers, 1996.

Robert E. Kesting, *Synthetic Polymeric Membranes: A Structural Perspective*, 2nd Ed., John Wiley & Sons, Inc., 1985.

Journal of Membrane Science; Industrial & Engineering Chemistry Research; AIChE Journal; Desalination.

Instructor

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Course Learning Outcomes

- Acquire in-depth knowledge in the areas of membrane separation mechanisms, transport models, membrane permeability computations / measurements, membrane materials / types / modules, membrane contactors / reactors, and applications.
- Develop skills in applying transport models for the calculation of membrane permeability, flux, and the extent of separation for various membrane separations / systems.

- Be able to determine the types of experimental data needed for the calculation of membrane permeability parameters.
- Be able to select membrane processes for solving relevant separation / reaction problems.
- Be able to use polymer membranes for solving environmental / energy problems.
- Use a computer tool to calculate and analyze membrane separation characteristics.

ABET Related Student Learning Outcomes	Course contribution		
	Some	Substantial	Significant
1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics			X
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors		X	
3. an ability to communicate effectively with a range of audiences		X	
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	X		
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	X		
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions			
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.		X	

NACE Related Student Learning Outcomes	Course contribution		
	Some	Substantial	Significant
• Critical thinking/problem solving			X
• Oral/written communications		X	
• Teamwork/collaboration	X		
• Digital technology		X	
• Leadership	X		
• Professionalism/work-ethic	X		
• Career management			
• Global/intercultural fluency			

Evaluation/Grading

Homework / Project:	15%
Midterm Exam I (4:10 PM – 5:30 PM, Thursday, March 7, 2024):	28%
Midterm Exam II (4:10 PM – 5:30 PM, Thursday, April 4, 2024):	28%
Midterm Exam III (4:10 PM – 5:30 PM, Thursday, April 18, 2024):	29%

Make-up Classes

If necessary, they will be announced.

Homework

Homework is due at the beginning of the class period (it should be left on the table in the front if we have an in-person class). Its submission at any other time or late homework for whatever the reason will not be counted. For each homework set, follow the following guidelines: (1) work this on one side of 8.5 x 11 inch paper, (2) include all units of all factors, (3) the final answer should be clearly underlined, (4) mark the number for each of the problems clearly, (5) place your name on the top, right corner of the first page, and (6) staple the set together at the top, left corner (if applicable and doable).

The primary objective in completing homework assignments is learning, i.e., to develop an understanding of the material so as to effectively apply the concepts and fundamental principles presented. Your ability to apply the concepts and fundamental principles for solving problems is the very best way to learn the material and to measure the depth of your understanding of these concepts and fundamental principles. This is best achieved through disciplined, independent effort on the assignments. Copying or routinely consulting the work of others is very ineffective and usually results in poor performance on exams. You are advised to work on all of your own homework problems. Interactive learning is effective, however, and is encouraged.

Attendance

Attendance is required at all class sessions, and it is considered important. Those who are not in class for any reason are responsible for all materials covered, homework assigned, etc. in that class.

Make-up Exam Policy

No makeup exams will be given. A student with a ***documented excuse for an absence*** will be given a score for the missed exam equal to the average of the remaining exams in the course. For example, if you have an excused absence for Exam I, your score for that exam will be equal to your average for Exam II and Exam III; if you have an excused absence for Exam II, your score for that exam will be equal to your Exam III. On the other hand, if you have an excused absence for Exam III, your score for that exam will be equal to your average for Exam I and Exam II.

Tentative Schedule

Week	Topics
1	Introduction to Membrane Separation Concepts: diffusion across a thin film, terminology, driving force, modules, separation processes. Selection of Membrane Processes: separation goal, species retained / transported, major / minor components, transport / selectivity mechanism.
2	Membrane Materials: polymers, polymer-inorganic hybrids, inorganics. Membrane Preparation: coating, phase inversion, liquid-liquid demixing, interfacial polymerization.

3	Gas Permeation: definitions, rubbery and glassy membranes, theory, dual-mode model, free-volume model, resistance-in-series model.
4	Gas Permeation: membrane modules, gas permeation performance modeling, applications.
5	Pervaporation: definitions, membranes, membrane properties, theory, concentration polarization, temperature polarization, applications, organics dehydration, azeotrope splitting.
6	Dialysis: polymer types, membranes, theory, applications, artificial kidney. Electrodialysis: definitions, ion-exchange membranes, theory, cell resistances, limiting current, Donnan equilibrium, applications.
7	Membrane Electrolysis: chlor-alkali process, bipolar membranes, fuel cells. Reverse Osmosis: osmotic pressure, solution-diffusion model.
8	Reverse Osmosis: concentration polarization, modules, interfacially polymerized membranes, applications, desalination, nanofiltration, water softening.
9	Ultrafiltration: definitions, membranes, theory, concentration polarization, feed-and-bleed operation, applications, electrophoretic paint recovery, protein fractionation / concentration.
10	Microfiltration: particulates, crossflow vs. deadend microfiltration, membranes, theory, transport through porous membranes, Darcy's law, concentration polarization, applications, sterilization of beverages and pharmaceuticals.
11	Membrane Contactors: height and number of transfer unit, applications, drug recovery, beverage carbonization, stripping of oxygen from boiler water, acid gas removal, oxygen transfer / blood oxygenation.
12	Supported Liquid Membranes: configurations, immobolized liquid membranes, transport models, facilitated transport, applications, metal removal and recovery, Penicillin G recovery.
13	Facilitated Transport Membranes: transport mechanisms, theory, drug / antibiotic recovery, carbon dioxide-selective membranes, applications, hydrogen purification for fuel cells, synthesis gas purification with carbon capture, olefin/paraffin separation, recent developments.
14	Controlled Release Membranes: transport mechanisms, zero-order release rate / single file diffusion, special geometry for near zero-order release rate, membrane preparation, nanoporous membranes, fibroblast adhesion, biofouling resistant membranes, applications. Membrane Reactors: water-gas-shift membrane reactors, catalytic/enzymatic membranes, applications, product separation and enrichment for amino acid resolution.

Mode of Delivery

This course will be taught in-person. The lecture sessions will be given in-person. Attendance of the course and participation in the classes are critical, and you are expected to attend the classes.

Health and Safety Requirements

All students, faculty and staff are required to comply with and stay up to date on all university safety and health guidance (https://safeandhealthy.osu.edu). Non-compliance will be warned first and disciplinary actions will be taken for repeated offenses.

Copyright Disclaimer

The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

Accessibility Accommodations for Students with Disabilities

Requesting accommodations

The university strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability including mental health, chronic or temporary medical conditions, please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services (SLDS). After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. **SLDS contact information:** slds@osu.edu; 614-292-3307; 098 Baker Hall, 113 W. 12th Avenue.

Ohio State Academic Integrity Policy

Academic integrity is essential to maintaining an environment that fosters excellence in teaching, research, and other educational and scholarly activities. Thus, The Ohio State University and the Committee on Academic Misconduct (COAM) expect that all students have read and understand the university's *Code of Student Conduct*, and that all students will complete all academic and scholarly assignments with fairness and honesty. Students must recognize that failure to follow the rules and guidelines established in the university's *Code of Student Conduct* and this syllabus may constitute "Academic Misconduct."

The Ohio State University's *Code of Student Conduct* (Section 3335-23-04) defines academic misconduct as: "Any activity that tends to compromise the academic integrity of the university or subvert the educational process." Examples of academic misconduct include (but are not limited to) plagiarism, collusion (unauthorized collaboration), copying the work of another student, and possession of unauthorized materials during an examination. Ignorance of the university's *Code of Student Conduct* is never considered an excuse for academic misconduct, so I recommend that you review the *Code of Student Conduct* and, specifically, the sections dealing with academic misconduct.

If I suspect that a student has committed academic misconduct in this course, I am obligated by university rules to report my suspicions to the Committee on Academic Misconduct. If COAM determines that you have violated the university's *Code of Student Conduct* (i.e., committed academic misconduct), the sanctions for the misconduct could include a failing grade in this course and suspension or dismissal from the university.

If you have any questions about the above policy or what constitutes academic misconduct in this course, please contact me.

Other sources of information on academic misconduct (integrity) to which you can refer include:

- The Committee on Academic Misconduct web pages (COAM Home)
- *Ten Suggestions for Preserving Academic Integrity (Ten Suggestions)*
- *Eight Cardinal Rules of Academic Integrity* (www.northwestern.edu/uacc/8cards.htm)

Statement on Title IX

All students and employees at Ohio State have the right to work and learn in an environment free from harassment and discrimination based on sex or gender, and the university can arrange interim measures, provide support resources, and explain investigation options, including referral to confidential resources.

If you or someone you know has been harassed or discriminated against based on your sex or gender, including sexual harassment, sexual assault, relationship violence, stalking, or sexual exploitation, you may find information about your rights and options at titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu. Title IX is part of the Office of Institutional Equity (OIE) at Ohio State, which responds to all bias-motivated incidents of harassment and discrimination, such as race, religion, national origin and disability. For more information on OIE, visit equity.osu.edu or email equity@osu.edu.

Your Mental Health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you find yourself feeling isolated, anxious or overwhelmed, please know that there are resources to help at Counseling and Consultation Service (CCS): ccs.osu.edu. You can reach an on-call counselor when CCS is closed at (614) 292-5766 and 24 hour emergency help is also available through the 24/7 National Prevention Hotline at 1-(800)-273-TALK or at suicidepreventionlifeline.org. The Ohio State Wellness app is also a great resource available at go.osu.edu/wellnessapp.

Student Emergency Financial Support

The **Student Advocacy Center** staff members are continuing to serve students during normal business hours and are accepting online appointments.

The **Student Emergency Fund** is available to students who may otherwise be at risk of dropping out of college due to an unexpected financial emergency. If you, or a student you know, are experiencing an unplanned expense, the Student Emergency Fund may be an option. Their office is accepting applications and may be able to award up to $1,000 to eligible students. **Learn more and apply**.

The Together As Buckeyes emergency grants program, funded primarily by the federal Coronavirus Aid, Relief and Economic Security (CARES) Act, is available to all students — undergraduate, graduate and professional — through the Student Financial Aid office. To apply for a grant, students need to complete a one-page Emergency Request form and provide any supporting documentation. The Office of Student Financial Aid will process applications after determining

eligibility based on each student's circumstances and guidance from the U.S. Department of Education.

Franklin County Department of Job and Family Services has amended its Prevention, Retention and Contingency (PRC) Program to provide targeted relief for families impacted by the COVID-19 pandemic. The Franklin County COVID-19 Response PRC Program provides eligible families with $500 in one-time cash assistance to help address emergent needs and expenses brought about by the public health emergency. Families can apply online today.

The **Student Wellness Center** offers financial coaching through the Scarlet and Gray Financial nationally recognized peer financial coaching program. Through the program, students will learn about financial goal setting, banking basics, budgeting, credit education, debt repayment education and saving and retirement education. Learn more.

Food Assistance

It's a common idea that pervades American culture: when you're in college, it's simply a rite of passage to sustain yourself on cheap, unhealthy food. We disagree. We highly recommend OSU's **Buckeye Food Alliance** Lincoln Tower 150 food pantry (https://www.buckeyefoodalliance.org) and the MidOhio Foodbank (https://www.midohiofoodbank.org). The **Buckeye Food Alliance** will remain open to support students in need. Starting Monday, March 23 the pantry will be open Monday/Thursday 10 a.m. – 2 p.m., Tuesday/Wednesday 4 – 8 p.m., and Friday 11 a.m. – 3 p.m. If these times do not work for your schedule, you can schedule a special appointment by contacting Nick Fowler at fowler.318@osu.edu.

Statement on Diversity

Diversity is a fundamental part of our profession, valued by our university, college, department, professional organizations, and industry members that hire our students. Many academic studies highlight the importance of diversity in the engineering profession. This peer-reviewed research directly supports the value of working with individuals whose viewpoints are formed by their unique perspective on the world. In this course, you will work in groups. You will do yourself and your group a disservice if you do not fully utilize the resources that each individual provides to the group. Further, I strongly encourage you to consider forming a diverse peer network outside your group to discuss and review course materials. We need all hands on deck to solve the world's challenging engineering problems!

Peer Reviewed Research Highlighting the Importance of Diversity in Engineering
https://www.nap.edu/read/10377/chapter/4
https://search.informit.com.au/documentSummary;dn=199154901624228;res=IELENG
https://doi.org/10.24908/pceea.v0i0.9486
https://www.pnas.org/content/117/17/9284
(and many more!!!)

University and College Resources:
The Ohio State University affirms the importance and value of diversity in the student body. Our programs and curricula reflect our multicultural society and global economy and seek to provide opportunities for students to learn more about persons who are different from them. We are committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among each member of our

community; and encourages each individual to strive to reach his or her own potential. Discrimination against any individual based upon protected status, which is defined as age, color, disability, gender identity or expression, national origin, race, religion, sex, sexual orientation, or veteran status, is prohibited.
https://www.osu.edu/initiatives/diversity.html
https://engineering.osu.edu/diversity

The AIChE states:
"We work towards a better future for all — not just through our technical expertise but through how we inspire, engage, retain and advance future talent, and how we treat each other within and beyond the profession…We believe that some groups experiencing historical and present discrimination continue to face specific challenges in entry to or participation in engineering and science professions. AIChE holds forth a vision of the profession in which discrimination and conscious or unconscious bias is unwelcome and unacceptable. Efforts to support and promote diversity must also address root causes of inequities and narrow gaps, not just their manifestations."
https://www.aiche.org/equity-diversity-inclusion/statement

Similarly, ACS recognizes the importance of diversity:
"We encourage inclusivity and oppose discrimination in scientific learning and practice based on - but not limited to - race, religion, country or ethnic origin, citizenship, language, political opinion, sex, gender identity and expression, sexual orientation, disability, age, and economic class in academic, industrial, and government workplaces. The Society believes that an enduring commitment to diversity enables excellence, innovation, and transformative action in current and future generations of chemical professionals."
https://www.acs.org/content/acs/en/membership-and-networks/acs/welcoming/diversity.html

Title IX
Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator, Kellie Brennan, at titleix@osu.edu.

Reporting
To report an issue with Title IX or any other form of discrimination (e.g., racial, gender, sexuality, religion), please reach out to me or the department chair Umit Ozkan (ozkan.1@osu.edu). We are committed to an equitable, supportive, and nurturing educational environment.

Religious Accommodations

It is Ohio State's policy to reasonably accommodate the sincerely held religious beliefs and practices of all students. The policy permits a student to be absent for up to three days each academic semester for reasons of faith or religious or spiritual belief. Students planning to use religious beliefs or practices accommodations for course requirements must inform the instructor in writing no later than 14 days after the course begins. The instructor is then responsible for scheduling an alternative time and date for the course requirement, which may be before or after the original time and date of the course requirement. These alternative accommodations will remain confidential. It is the student's responsibility to ensure that all course assignments are completed.