WEN617: Membrane Technology

Program and Course Code	Water and Environment Engineering WEN 617
Course Title	Membrane Technology
Credit Hours	3
Instructor	Nidal Hilal
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Bulletin Course Description	The course will describe in details membrane separation technology and wide range of applications including water treatment and desalination. The course covers: global water shortages and need for membrane technology, Microfiltration, ultrafiltration, nanofiltration and reverse osmosis membrane processes and current applications in water treatment. It also describes operational issues, limitations and System Configuration and Design.
Pre-requisites	WEN504 or equivalent with permission of Instructor
Co-requisites	None
Course Objectives (Learning Outcomes of the Course)	**Aims:** The objective of the course is to give the students the technical background on membrane technology and to provide wide level of understanding that will allow them to design, using appropriate combinations of unit processes and water treatment plant. The practical component will provide the students with a range of laboratory skills together with an understanding of the need for rigorous experimental design of membrane modules for water treatment plant. **Learning Outcomes:** ***Knowledge and understanding of***: • Depth and breadth of knowledge that is at the frontier of their disciplines • Resources and Need for membrane technology in water treatment and other process engineering plants. ***Professional practical skills*** – ability to: • Evaluate critically current diverse approaches to solving critical problems in research and to creating new knowledge judged by international standards. • Evaluate methodologies and develop critiques of them. Acquire substantial quantities of information systematically and process it effectively. • Work effectively in a multidisciplinary collaborative environment using highly developed cognitive and creative expert skills and intellectual independence. ***General transferable skills*** – ability to: • Independently tackle and solve problems. • Communicate effectively, in written and oral forms, their research results and/or critique highly complex and diverse matters to diverse audiences. • Exercise time and resource management. ***Intellectual skills*** – ability to: • Deal with complex issues both systematically and creatively. • Make sound judgments in the absence of complex data. • Communicate conclusions clearly to both specialist and non-specialist audiences. • Use self-development for personal and professional improvement in their field and contribute to its future advancement. • Carry out research in an area of water treatment.

Week	Course Topics and Contents
1	• Introduction • Water shortages and need for membrane technology
2	• Classification of membranes • Membrane processes • Principle of membrane filtration
3	• Microfiltration membranes: introduction to frontal and cross flow filtration, development of knowledge and understanding of solid liquid separations and cake filtration, general membrane equations and adaptation to cake filtration, calculation of cake properties, time of filtration, bed depth and process optimisation, case studies
4	• Ultrafiltration membranes: introduction to ultrafiltration processes, mass transfer and concentration polarisation effects, simple gel theory, osmotic pressure effects, effects of membrane charge, optimisation of separations, case studies
5	• Applications of MF and UF • Membrane performance
6	• Modes of MF/UF operations • MF/UF performance parameters
7	• Membrane fouling • Trans-membrane pressure • Filtration/Fouling mechanisms
8	• Filter cakes • Types of foulants and scalants • Natural organic matter fouling
9	• Impact of membrane material on fouling • Reversible and irreversible fouling • Prevention of fouling • Fouling control
10	• Backwashing • Chemically enhanced backwash • Cleaning optimization • Water recovery
11	• Nanofiltration: introduction to nanofiltration processes, equilibrium partitioning, pore models for neutral solute rejection, effects of membrane charge, confinement issues and effects on physical properties, pore size distributions, case studies
12	• Reverse Osmosis: what is osmosis, introduction to reverse osmosis, the solution diffusion mechanism of transport, case studies • Osmotic pressure • Water flow/flux • Salt flow, salt passage and salt rejection
13	• Recovery/conversion • Concentration polarization • Membrane Modules
14	• RO System Configuration and Design
15	• Membrane formation

Out-of-class assignments	
Homework	A project will be assigned to individual students early in the semester. The students will be asked to develop a project plan and will work on project throughout the course and present his results during the final exams week. Grading of course projects will be based on presentations as well as written reports. Grading criteria will be announced early on during the semester.

Course Grading	
Homework	30%
Exams	70%
Total	100 %

Class/Laboratory schedule and Methodology	
Class	The class meets 15 weeks, 2 lectures per week, Sunday and Wednesday 10 am – 11.15 am (Meeting Room 2)
Laboratory	Students will be shown a variety of membrane equipment in the laboratory
Teaching and learning methodologies	A combination of white board use, Power-point slide presentation, and interactive class discussions to encourage student participation and enhance the learning. Acquisition of the Course outcomes takes place through a combination of lectures, laboratory classes, individual consultations, lecture study, discussion and learning through self-directed study.

Course Materials	
Textbooks	No one book is singled out as a textbook for the course. However, several books will be consulted during the course and the students will be referred to them frequently. These include: • Membrane Modification: Technology and Applications" by CRC Press (ISBN-13: 978-1439866351), 2012 . N. Hilal, M. Khayet and C. J. Wright • Membrane Distillation: Principles and Applications, M. Khayet and T. Matsuura, Elsevier, 2011. • Nanofiltration, Elsevier, M. Schaefer • Separation Process Principles, Henly, Seader, Roper • Handbook of membrane separations, Pabby, Rizvi, Sastre • Ultrafiltration Handbook, Munir Cheryan • Membrane processes, Rautenbach and Albrecht
Recommended Readings	A number of journal reviews covering MF, UF, NF and RO will be provided to the students. • "A comprehensive review of nanofiltration membranes: Treatment, pretreatment, modeling, and atomic force microscopy", N. Hilal, H. Al-Zoubi, N.A. Darwish, A.W. Mohammad, M. Abu Arabi, Desalination 170 (2004) 281–308 • Current Patents of Forward Osmosis Membrane Process, Leilei Liu, Meng Wang, Duo Wang and Congjie Gao, Recent Patents on Chemical Engineering, 2009, 2, 76-82 • 'A review of atomic force microscopy applied to cell interactions with membranes'. N. Hilal, W. R. Bowen, L. Al-Khatib and O. Ogunbiyi. Trans IChemE, Part A, Chemical Engineering Research and Design. Volume 84(A4) (2006) pp 282-292. • "Methods employed for control of fouling in MF and UF membranes: A Comprehensive Review", N. Hilal, O. Ogunbiyi, N. J. Miles and R. Nigmatullin. Separation Science and Technology. Volume 40 (10)(2005) pp 1957-2005.
Instructional material and resources	A course website will be set on Moodle at the beginning of the semester where all course necessary material will be posted including course notes and project instructions.