Program	Water & Environmental Engineering
Course Code	WEN 504
Course Title	Desalination
Credit Hours	3
Name of Faculty	Prof. Dr. Hassan E. S. Fath
Contact	hfath@masdar.ac.ae Tel. (+971 (0)50 69 88 667)
Course Description	Introduces the fundamental science and technology of desalinating saline water to overcome water scarcity and ensure sustainable water supplies. The course covers: i- Water scarcity and desalination, ii- Saline water properties, iii- Fundamentals of desalination, iv- Thermal desalination processes (Multi Stage Flash-MSF, Multi Effect Distillation-MED- and Vapor Compression-VC) , v- Membrane desalination processes (Reverse Osmosis-RO-, Electro Dialysis-ED), vi- Introduction to alternative driving energies (solar and nuclear) and Future Technologies (H-DH, MD, FO, CDI, NF), vii- Introduction to desalination problems (scaling, fouling, corrosion), and their mitigation, and viii- Process Calculations and performance parameters of the main desalination processes.
Pre-requisites	Undergraduate thermo-fluids courses (Thermodynamics, Heat Transfer and fluid mechanics)
Co-requisites	None
Course Objectives (Learning Outcomes of the course)	Upon successful completion of the course, the students will be able to: • Identify the world and regional areas of water shortage and be able to select the proper desalination method to solve a water shortage problem. • Classify the different technologies for saline water desalination. • Carry out the basic process calculations of the main desalination processes • Define the performance of different desalination processes and the factors affecting them • Define the different alternative energy sources to drive desalination processes • Define the different Promising Future Desalination Processes

Week	**Course Topics and Contents**
1	Introduction to water resources & Desalination processes
2	Thermal Technologies: Single and Multi-Stage Flash (MSF) Technology
3	Process calculations and MSF performance parameters
4	Single and Multi-Effect Distillation (MED) Technology
5	Process calculations and MED performance parameters
6	Membrane Technologies: Osmosis and Reverse Osmosis (RO)
7	RO system performance parameters, Energy Recovery and pretreatment
8	*Mid semester break*
9	Electro dialysis
10	Solar –Desalination Systems
11	Process calculations of Solar –Desalination Systems
12	Nuclear - Desalination Systems
13	Introduction to Future Technologies (H-DH, MD, FO, CDI, NF)
14	Introduction to desalination problems (scaling, fouling, corrosion), and their mitigation
15	*Final project presentations*

16	*Final Examination*

Relationship of course to program outcomes	
Program Outcome 1	Successfully apply advanced concepts of fundamental sciences and engineering to identify, formulate, and solve water and environmental engineering problems, and understand the impact of such solutions on sustainable development.
Program Outcome 2	Successfully apply advanced concepts of water and environmental engineering and fundamental sciences to design, analyze, and develop technologies, processes or systems to meet desired needs of society, both, professionally and ethically.
Program Outcome 4	Be knowledgeable of contemporary issues and research challenges / opportunities related to water and environmental engineering, and engage in life-long learning to keep abreast of such issues.
Program Outcome 5	Use advanced techniques, skills, and modern scientific and engineering tools for problems related to professional practice in the field of water and environmental engineering.
Program Outcome 6	Communicate effectively and professionally in written and oral form, both, individually and as a member of a multidisciplinary team.

Out – of – Class assignment	
Home Work	Four Home Work assignments, each is due at the end of each main topic of the course Weeks; 5, 10, 12 & 14)
Course Project	A report & presentation including literature survey, basic process design of one typical operating or new desalination technology and related topics.

Course Grading	
Homework	30 %
Course Project	50 %
Final Exam	20 %
Total	100 %

Class/Laboratory schedule and Methodology	
Class	The class meets 14 weeks, 2 lectures per week, 75 minutes each.
Laboratory	Available laboratory training aids and typical operating plants visits may be used to introduce the desalination components & systems.
Teaching and learning Methodology	A combination of white board use, Power-point slide presentation, and interactive class discussions to encourage student participation and enhance the learning. Real Plants and available pilots test unit will enhance the engineering process designs.

Course Materials	
Textbook(s)	The following reference texts will be made available to students through the library: • H. El-Dessouky & H. Ettouney ," Fundamentals of Salts Water Desalination", Elsevier (2002). • DESWARE (Encyclopedia of Desalination & Water Reuse)

Recommended Readings	• GWI & www.DesalData.com • Mark Wilf, *The Guide Book to membrane Desalination Technology*, Balaban desalination publications, 2007. (ISBN: 0-86689-065-3) • S.I. Sandler, *Chemical, Biochemical, and Engineering Thermodynamics*, 4th edition, Wiley, 2006. • R.W. Baker, *Membrane Technology and Applications*, McGraw-Hill, 2000. • Any other desalination & water treatment textbook • The Combustion Institute publications The International Flame Research Institute publications General articles on water: • Specter, M., "The Last Drop", *New Yorker*, pp. 60-71, 23 October 2006. • United Nations, "Water for People, Water for Life", *World Water Development Report*, UNESCO Publications, 2003. • Gardner-Outlaw, T., and R. Engelman, "Sustaining water, easing scarcity: A second update", Population Action International, Washington, D.C., 1997. General surveys of desalination: • Miller, J. E., "Review of Water Resources and Desalination Technologies", Report prepared by Sandia National Laboratories, SAND 2003-0800, 2003. Reverse osmosis: • Fritzmann, C., J. Lowenberg, T. Wintgens, and T. Melin, "State-of-the-art of reverse osmosis desalination", *Desalination*, Vol. 16, pp. 1-76, 2007. • Butterwort, *Physicochemical Hydrodynamics*, 1st Edition, Section 4.4, 1989. • Paul, D. R., "Reformulation of the solution-diffusion theory of reverse osmosis", *J. Membrane Science*, Vol. 241, pp. 371-386, 2004. • Sauvet-Goichon, B., "Ashkelon desalination plant – a successful challenge", *Desalination*, Vol. 203, pp. 75-81, 2007. Multistage flash evaporation and multiple effect distillation: • El-Sayed, Y. M., and R. S. Silver, "Fundamentals of distillation", In: *Fundamentals of Desalination*, 2nd Edition, Vol. A, Spielger and Laird (Editors), Academic Press, 1980. • Wade, N. M., "Distillation plant development and cost update", Desalination, Vol. 136, pp. 3-12, 2001. • Ophir, A. and F. Lokiec, "Advanced MED process for most economical seawater desalination", *Desalination*, Vol. 182, pp. 187-198, 2005. • El-Dessouky, H., and H. Ettouney, "Flash desalination processes", In: *Heat Exchanger Design Handbook*, G. F. Hewitt (Editor), Begell House, New York, 2001. Irreversibility in desalination: • Kahraman, N., Y. A. Cengel, B. Wood, and Y. Cerci, "Exergy analysis of a combined RO, NF, and EDR desalination plant", *Desalination*, Vol. 171, pp. 217-232, 2004.

- Spielger, K. S. and Y. M. El-Sayed, "The energetics of desalination processes", *Desalination*, Vol. 134, pp. 109-128, 2001.

Nanofiltration:

- Hilal, N., H. Al-Zoubi, N. A. Darwish, A. W. Mohammad, and M. Abu Arabi, "A comprehensive review of nanofiltration membranes: Treatment, pretreatment, modeling, and atomic force microscopy", Desalination, Vol. 170, pp. 281-308, 2004.
- Asatekin, A., A. Menniti, S. Kang, M. Elimelech, E. Morgenroth, and A. A. Mayes, "Antifouling membranes for membrane bioreactors…", *J. Membrane Science*, Vol. 285, pp. 81-89, 2006.
- Asatekin, A. and A. A. Mayes, "Amphiphilic graft copolymers for nanofiltration membranes with tunable pore size", MRS meeting, Fall 2006.

Solar desalination:

- Fath, H. E. S., S. M. Elsherbiny, A. A. Hassan, M. Rommel, Wieghaus, M., J. Koschikowski, M. Vatansever, "PV and thermally driven small-scale, stand-alone solar desalination systems with very low maintenance needs", *Desalination*, Vol. 225, pp. 58-69, 2008.
- Alarcon-Padilla, D., J. Blanco-Galvez, L. Garcia-Rodriguez, W. Gernjak, and S. Malato-Rodriguez, "First experimental results of a new hybrid solar/gas muti-effect distillation system: The AQUASOL project, *Desalination*, Vol. 220, pp. 619-625, 2008.
- Ettouney, H., and L. Rizzuti, "Solar desalination: A challenge for sustainable fresh water…", In : *Solar Desalination for the 21st Century*, L. Rizzuti and H. M. Ettouney (Editors), Springer, pp. 1-18, 2007.
- Koschikowski, J., M. Wieghaus, and M. Rommel, "Solar thermal-driven desalination plants based on membrane distillation", Desalination, Vol. 156, pp. 295-304, 2003.
- Koning, J.D., and S. Thiesen, "Aqua Solaris – an optimized small scale desalination system with 40 litres output per square meter based upon solar-thermal distillation, *Desalination*, Vol. 182, pp. 503-509, 2005.

Electrodialysis and capacitative deionization:

- Probstein, R. F., *Physicochemical Hydrodynamics*, Butterworth, 1989.

Water quality standards:

- World Health Organization, *Guidelines for Drinking-water Quality*, Volume 1: Recommendations, 3rd Edition, 2006.
- World Health Organization, *Desalination for Safe Water Supply: Guidance for the Health and Environment Aspects Applicable to Desalination*, Geneva, 2007.
- USEPA, *Primary and Secondary Drinking Water Standards*, 2003.
- Hooley, J. P., Pittner, G. A., and Z. Amjad, "The importance of water analysis for reverse osmosis design and operation", In: *Reverse Osmosis*, Z. Amjad (Editor), Van Nostrand Reinhold, New York, 1993.

	Properties of salt water and seawater: • Pitzer, K. S., J. C. Peiper, and R. H. Busey, "Thermodynamics of aqueous sodium chloride solutions", *J. Phys. Chem. Ref. Data*, Vol. 13, No. 1, pp. 1-102, 1984. • Bromley, L. A., et al., "Thermodynamics of sea salt solutions", *AICHE Journal*, Vol. 20, No. 2, pp. 326-335, 1974. •
Instructional material and resources	Trip to local desalination plant(s).

Prepared by: Prof. Dr. Hassan Fath
Date: May 2011