Fall 2013

Department of Chemical Engineering
West Virginia University

ChE 311
Process Heat Transfer

Class Time:

Monday, Wednesday	11:00 - 11:50	Room 205 MRB
Tuesday	12:00 - 1:50	Room 205 MRB

Instructor:

John W. Zondlo
Office: Room 415 ESB, 293-9366
Office Hours: Monday and Wednesday 10:00 – 11:00 or preferably by appointment. Please feel free to stop in at any time and discuss any problems you are having**. If you have trouble with the material, don't wait till the end of the semester to come and ask for help!!!!**

Required Text:

Transport Processes and Separation Process Principles, Fourth Edition, C.J. Geankoplis, Prentice Hall-Pearson, 2003.

Reference Texts:

*Heat Transfer, Ninth Edition, J.P. Holman, McGraw-Hill, 2002. (A really good book!!)

*Unit Operations of Chemical Engineering, Sixth Edition, W.L. McCabe, J.C. Smith and P. Harriot, McGraw-Hill, 2001. (A standard text for CHE)

Principles of Heat Transfer, Seventh Edition, F. Kreith, R.M. Manglik and M.S. Bohn, Cengage Learning, 2011.

Fundamentals of Heat and Mass Transfer, Fourth Edition, F.P. Incropera and D.P. DeWatt, J.Wiley & Sons, 1996.

Transport Phenomena, R. B. Bird, W. E. Stewart and E. N. Lightfoot, Second Edition, John Wiley & Sons, 2010.

Heat Transfer - A Basic Approach, M. N. Ozisik, McGraw-Hill, 1985.

*Process Heat Transfer, D. Q. Kern, McGraw-Hill, 1950. (The best for heat-exchanger design)

*Heat Transmission, Third Edition, W. H. McAdams, McGraw-Hill, 1954. (Probably the first great heat-transfer text—a classic!!)

Fundamentals of Momentum, Heat & Mass Transfer, J. R. Welty, C. E. Wicks and R. E. Wilson, John Wiley & Sons, 1984.

*Chemical Engineering: Volume I, Fluid Flow, Heat Transfer and Mass Transfer, Third Edition, J. M. Coulson and J. F. Richardson, Pergamon Press.

*Chemical Engineering, Volume 2, Unit Operations, Third Edition, J. M. Coulson and J. F. Richardson, Pergamon Press.

*Chemical Engineering, Volume 6, Chemical Engineering Design, Second Edition, R. K. Sinnott, Pergamon Press, 1993. (A good text especially for design)

Radiation Heat Transfer Notes, D. K. Edwards, Hemisphere Publishing Corp., 1981.

Heat Transfer, D. R. Pitts and L. E. Sissom, Schaum's Outline Series, McGraw-Hill, 1977. (Lots of sample and practice problems)

Chemical Process Equipment - Selection & Design, Stanley M. Walas, Butterworths, 1988.

Other References:

Chemical Engineers Handbook, Sixth Edition, J. H. Perry, McGraw-Hill, 1985.

**Applied Process Design for Chemical and Petrochemical Plants, Volume 3, Second Edition, E. E. Ludwig, Gulf Publishing Co., 1983. (The old standard for design. Has many examples. It is housed in the Undergrad Computer room)

In addition to the above required and reference texts there will be class handouts illustrating special topics or detailing lecture material as needed. This is because the text is either too brief on some topics or it does not cover them at all!! **You should obtain a three-ring binder to help keep track of the handouts.**

Basis for Course Grade:

Hour Exam I	= 15%
Hour Exam II	= 15%
Hour Exam III	= 15%
Final Exam	= 20%
Homework	= 15%
Design Project	= 20%
	100%

Course Goals:

"If you don't know where you are going, you probably won't get there."

- To obtain a fundamental appreciation of the transfer of heat by the three main modes of conduction, convection and radiation as demonstrated by successful calculations.

- To have a detailed understanding of steady- and unsteady-state conduction heat transfer and to perform calculations on both.

- To have a detailed understanding of the convective heat-transfer coefficient and the various modes of forced and natural convective heat transfer; to perform calculations involving convection.

- To have a good appreciation of heat transfer by boiling and condensation, and successfully perform calculations for both.

- To learn the basic principles of heat exchanger operation, construction and design and to demonstrate proficiency by performing design calculations.

- To integrate knowledge and application of heat transfer principles into an open-ended design project involving the design of a specified heat exchanger.

- To increase proficiency in oral and written communication skills by presenting the results of the open-ended design both orally and in writing.

- To raise awareness of process safety issues by incorporating aspects of safety in the open-ended design project.

- To have fun learning about Heat Transfer!

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Course Outline

TEXT: Transport Processes and Separation Process Principles, Fourth Edition, C.J. Geankoplis, Prentice Hall-Pearson, 2003.

		Text Reading
I.	Introduction to Heat Transfer	Class Notes, Chapter 4.1
	A. Thermodynamics vs. Heat Transfer	
	B. Modes of Heat Transfer	
	C. Units	
II.	Conduction Heat Transfer	Chapter 4.1
	A. Formulation of Conduction Problems	
	i. Fourier's Law	
	ii. Thermal Conductivity and Diffusivity	
	iii. Coordinate Systems (slabs, cylinders and spheres)	
	B. Steady State Conduction - one dimension	Chapters 4.2 & 4.3
	i. Rectangular Slab	
	ii. Cylindrical and Spherical Surfaces	
	iii. Resistances in Series	
	iv. Convective Resistance - Overall heat transfer coefficient	
	v. Energy Generation	
	vi. Extended Surfaces - Fins	
	vii. Contact Resistance	
	C. Unsteady or Transient Conduction	Chapter 5
	i. Lumped System (A Bonus!!)	
	ii. Solution to Transient, One Dimensional Problem (PDE)	
	iii. Dimensionless Groups and Charts	

HOUR EXAM I

III. Convective Heat Transfer
- A. General Concepts — Chapters 4.5 & 4.9
  - i. Types of Heat Exchangers
  - ii. Energy Balances
  - iii. Overall and Individual Heat Transfer Coefficients
  - iv. Log-mean Temperature Difference (LMTD)
  - v. Fouling Factors
- B. Heat Transfer Coefficients – No Phase Change — Chapters 4.5, 4.6, & 4.7
  - i. Boundary Layer Phenomena
  - ii. Flow Inside Ducts - Laminar and Turbulent Flow
  - iii. Hydraulic Diameter (ex. DPHE)
  - iv. Flow Outside and Around Objects (ex. Tube banks)
  - v. Liquid Metals
  - vi. Reynolds Analogy (A really neat trick!!)
  - vii. Natural Convection
- C. Heat Transfer with Phase Change — Chapter 4.8
  - i. Condensation
  - ii. Boiling
  - iii. OTEC Discussion (The past repeats itself!!)

HOUR EXAM II

IV. Heat Exchanger Design
- A. General Overview of Heat Exchangers
- B. Slide Show on Equipment — Chapters 4.9, 4.13 & Class Notes
- C. Shell-and-Tube Calculations
- D. NTU Method
- E. Examples of Heat Exchanger Design
  - i. Liquid-liquid exchanger
  - ii. Evaporator or condenser
  - iii. Plate and frame exchangers
  - iv. Fired heaters
  - v. Agitated vessels
- F. Cross-flow Exchangers
- G. Macroscopic Energy Balances
- H. Heat Transfer Fluids
- I. Steam Traps

HOUR EXAM III

V. Radiation Heat Transfer — Chapters 4.10 & 4.11
- A. Basic Principles
  - i. Emission and Absorption
  - ii. Radiation Between Surfaces

Note: Depending on availability of time, some of the above topics may be omitted.

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Instructions for Homework Problems

1. Paper: Use standard 8 1/2" x 11" paper. Write on one side only. Do not use spiral bound notebook paper.

2. References: All data not given in the problem statement must be referenced. Example: McCabe, W. L., and J. C. Smith. Unit Operations of Chemical Engineering, 3rd ed., McGraw-Hill, New York, 1978, pp. 279-285.

3. Final Answer: Box the final answer.

4. Intermediate answers: Underlined with a single line all intermediate answers.

5. Arrangement of problem:

   a. Given: all data given in the original statement of the problem.

   b. Required: answer sought (if more than one, list separately).

   c. Solution: all calculations arranged chronologically.

6. **Due Date: 1 week after problems are handed out, even if it's not specifically stated. Late work will not be accepted without prior notice to the instructor.**

7. Submission:

   a. If an assignment consists of more than one page, it must be stapled and handed in FLAT (not folded).

   b. Record in the upper right corner of each page

      (1) Name
      (2) Course Number
      (3) Date Due
      (4) Problem Number and Page

   c. Each problem should begin on a new page except if problem is very short.

   d. Please **make your work neat and legible**.