ME 410, Heat Transfer, Fall 2008, Professor Brasseur

MWF 12:20 - 1:10 PM, 220 Hammond Building

***Dept.. Curriculum Manual**	For departmental description of this course, course objectives and course outcomes, please go to http://www.mne.psu.edu/undergrad/ugmanuals/ME_Manual/ME_Required_Courses/ME410.htm
Text (required)	1/ F.P. Incropera & D.P. DeWitt, *Fundamentals of Heat and Mass Transfer,* 5th or 6th Editions, Wiley, N.Y., 2002/2007, and 2/ Spiegel & Liu, Mathematical Formulas and Tables, from Schaum's Outlines series
2007-2008 Catalog	Heat Transfer (3 cr.) Steady and transient heat conduction; free and forced convection in laminar and turbulent flow regimes; heat exchangers; boiling and condensation.
Prerequisite courses	ME 33/320, CMPSC 201, MATH 220 or NUCE 309, MATH 251
Prerequisites by topic	Engineering Thermodynamics; Fluid Mechanics; Computer Programming; Matrices; Ordinary Differential Equations
Teacher **Office hours**	Professor Brasseur, 205 Reber Building, 865-3159 (office), brasseur@psu.edu ⇒ Wed 5:00-6:30 PM
Teaching Assistant **Office hours**	Brett Ulrich, brettj22@gmail.com, Office 241 Reber (the phone in that room is 863-0609) Tuesdays 4:00 - 5:30 PM; Thursdays 1:15 - 2:45 PM
Student Intern	Matthew Rhudy, mbr5002@psu.edu
Weekly Recitation by Matthew	Mondays 6:00 - 7:00 PM room will be announced
Grading	Weekly assignments: 20% 2 midterm exams (20% each): 40% total 2 25-minute in-class quizzes (7/5% each) 15% Numerical analysis problems 5% total Final exam: 20%
Exams	The exams are a mix of concept-based analysis (~20%) and model-based analysis (~80%). Exams will take place on Wednesday evenings from 8:15-10:15 PM Exam 1: February 27; Exam 2: April 23
Quizes	The quizzes will be in class and a concept + a problem to solve. Quizzes will take place on Quiz 1: February 6; Quiz 2: April 9
Assignments	please see handout on assignments.
Dishonesty	Dishonesty is the purposeful misrepresentation of your work, including the copying of assignments, plagiarism, etc.. I certainly hope that none of you are dishonest so that I need not tell you that I take honesty as a serious issue, and the consequences of dishonesty will be serious.
Help	I am here to help you learn. Please take advantage of my desire for you to learn and see me before problems develop. Please email and set a time to visit for help. Or drop into my office and if I can see you that minute I will, otherwise we can fix a time to get together.
Course Objectives (see *) [Course outcomes are mapped to course outcomes below]	A. Develop both qualitative and quantitative understanding of the three modes of heat transfer. B. Make appropriate approximations, develop and apply simplified model equations for specific applications. C. Apply mathematical and numerical methods to solve heat transfer problems. D. Understand the role of and use dimensionless parameters in heat transfer analysis.

Course Learning Outcomes [mapped to course objectives above]

1. Sketch and interpret temperature distributions and heat flux distributions for mathematical models of heat conduction with planar and radial geometries, including heat generation. [A]
2. Derive fundamental differential thermal energy equations and develop mathematical models for thermal/fluid systems, including:
    Lumped capacitance for unsteady heat transfer
    1D unsteady heat conduction equation with heat generation
    Quasi 1D heat conduction for extended surfaces (fins), including variable cross-sectional areas
    Mean axial temperature variation for internal flows with uniform surface temperature or uniform wall heat flux. [B]
3. Apply ODE solution methods to solve the differential heat transfer equations for applications including:
    Lumped capacitance for unsteady heat transfer
    Steady 1D planar and radial conduction with heat generation
    Quasi 1D fins with variable cross-sectional area
    Internal flows with uniform surface temperature or uniform wall heat flux. [C]
3. Apply existing PDE solutions to analyze 1D and quasi 1D unsteady heat conduction systems. [C]
4. From an energy balance, derive the finite difference equations for conduction with surface convection. Describe numerical solution methods used to solve the finite difference equations. [B]
5. For convective heat transfer over a flat plate with uniform surface or uniform wall heat flux, sketch and interpret:
    Hydrodynamic and thermal boundary layer thicknesses
    Hydrodynamic and thermal boundary layer profiles
6. Local skin friction and local heat transfer coefficient as a function of distance from the leading edge. [A]
7. Sketch and interpret hydrodynamic and thermal profiles for internal flows with uniform surface or uniform wall heat flux. [A]
8. Develop and apply conduction and convection thermal circuits. [B]
9. Choose and apply appropriate dimensionless correlations for external and internal flows to solve convection heat transfer problems. [D]
10. Understand and apply the Reynolds Analogy for convection heat transfer. [B]
11. Analyze thermal sensors such as hot wires and thermocouples. [E]
12. Define and properly apply in an energy balance the following terms: emission, radiosity, irradiation, net radiation heat flux, emissivity, absorptivity, reflectivity, and transmissivity. [A]
13. Understand the spectral characteristics of radiation heat transfer including black and gray surfaces. [A]
14. Develop thermal circuit diagrams for radiation analysis and determine surface temperatures for two and three surface geometries including reradiating surface and radiation shield. [B]
15. Set up and solve combined conduction, convection, and radiation heat transfer problems. [B & C]
16. Apply fundamental heat transfer principles to perform heat exchanger design and performance calculations. [E]
17. Make effective use of spreadsheets as an analysis tool. [C]
18. Demonstrate the ability to solve problems in a clear step-by-step manner and follow policies and instructions as outlined in the syllabus and other course materials. [F]
19. Demonstrate professionalism in interactions with colleagues, faculty, and staff.[F]

Outline, FINAL
ME 410H, HEAT TRANSFER, SPRING 2008
Prof. Brasseur, MWF 12:20-1:10PM, 220 Hammond

Text: F.P. Incropera & D.P. DeWitt, *Fundamentals of Heat and Mass Transfer,* 5th or 6th Editions, Wiley, N.Y.

Notes: **The section numbers for assigned readings are based on 6th edition.**
The equivalent sections from edition 5 are shown in brackets ().

no. of lectures	**topics**	**assigned reading**	**problems on Angel** Ed. 6 (Ed. 5), where the brackets are for Ed. 5 when the #s are different.

14,16,18 Jan

I. BASIC ELEMENTS OF HEAT TRANSFER

1	Introduction	**1.1-1.2**	1.7
1	Heat Transfer and Conservation of Energy (The 1st Law)	**1.3-1.7**	1.13, 1.25
1	Heat Flux at Boundaries	**1.3-1.7** (**1.3.2** is particularly important)	

II. CONDUCTION (HEAT TRANSFER THROUGH NON-MOVING MATTER)

21,25,28,30 Jan

II(A) Basics of Heat Conduction

1	Heat flux is a vector/Fourier's law , heat flow rate is a scalar	**2.1-2.2**	2.8 (2.7)
1	Heat flux and temperature lines: qualitative analysis	**4.1 & Supplemental Material A (4.3)**	
1	The Quasi 1-D Approximation	**3.2** (important)	
1	The First Law Equation for Heat Conduction+ BCs	**2.4-2.5**	2.24

1,4,**6**,8,11,13 Feb

II(B) 1-D and Quasi-1D Steady Heat Conduction

2	Planar and radial 1-dimensional steady heat conduction and the concept and application of thermal resistance	**3.1 - 3.4**	3.3, 3.8a 3.36

QUIZ 1: February 6

1	1-D Steady Conduction w/Internal Heat Generation	**3.5**	3.68
3	Quasi 1-D Conduction through Extended Surfaces and Fins	**3.6**	3.101, 3.116

15,18,20,22,25 Feb

II(C) Analysis of Time-dependent Heat Conduction

2	The "Lumped Capacitance" Approximation and the Convective Time Scale	**5.1-5.3**	5.1,5.5,5.8 (5.7) 5.11 (5.10)
1	The Biot number and the conductive time scale	**5.2**	
2	Mathematical solutions for plane and radial conduction and their applications in engineering analyais	**5.4-5.7**	5.44 (5.41), 5.71

EXAM 1: February 27, evening 8:15 - 10:15 PM

29 Feb, 3,5,7 March

II(D) Finite Difference Methods to solve 2-D Heat Conduction

3	Finite difference calculation of 2-D steady temperature distributions	**4.4-4.5**	4.33 (4.35), 4.34 (4.37) 4.45 (4.47), 4.49 (4.51)
1	Finite difference calculations with time dependence	**5.10 (5.9-5.10)**	5.96 (5.97)

(Spring Break 10 - 14 March)

III. Convective Heat Transfer

17,19,21 March

III(A) Basic Elements Underlying Convective Heat Transfer

1	Convection and the thermal/velocity boundary layers (BL)	**6.1-6.3**	6.4 (6.2), 6.11 (6.7)
1	The Nussult number: how and why it varies under BLs	**6.3, 6.5, 6.8**	6.13 (6.18), 6.15 (6.22)
1	The boundary layer equations, dimensional analysis, similarity, and the Reynolds Analogy	**6.4-6.7**	6.18 (6.27), 6.19 (6.28 6.34 (6.40), 6.36 (6.42)

24,26,28 March

III(B) Heat Transfer from the External Surface of Objects

1	Similarity solution for the laminar flat plate boundary layer	**7.1-7.2.1**	7.2, 7.6
	Correlations for general turbulent boundary layers	**7.2.1-7.3**	**7**.11 (7.14)
1	Heat transfer from single cylinders and spheres	**7.4-7.5**	7.42, 7.78
1	Heat transfer in more complex external flow geometries	**7.6-7.8**	7.83

31 March, 2,4,7 April

III(C) Heat Transfer due to Flow within Tubes

1	The concept of thermally fully developed flow in pipes	**8.1-8.2**	8.5 (8.4)
2	Temperature variatians in pipes: applying the 1st Law	**8.3**	8.12, 8.16
1	Correlations for heat transfer in a tube	**8.4-8.5**	8.22 (8.23),8.26
1	Noncircular pipes and enhancement of heat transfer	**8.6-8.7 (8.6-8.8)**	8.52 (8.54)

QUIZ 2: April 9

9,11,14,16 April

III(D). HEAT EXCHANGERS

1	Types of heat exchangers	**11.1**	
1	The overall heat transfer coefficient and the evaluation of parallel and counter flow heat exchangers	**11.2-11.3**	11.5, 11.9, 11.14 11.32, 11.39
1	Log mean temperature difference method to analyze heat exchangers	**11.3 + Supplemental material B**	
1	Analysis of heat exchangers using "effectiveness" and "NTU"	**11.4-11.5**	11.52 (11.50)

EXAM 2: April 23rd, evening 8:15 - 10:15 PM

III(E) Free Convection : please read through this material

	Free Convection - concepts, equation, and similarity	**9.1-9.3**	9.7, 9.24 (9.23)
	basic correlations	**9.5-9.6**	9.25
	Free convection in enclosures	**9.7-9.8**	9.51, 9.54

IV. HEAT TRANSFER FROM ELECTRO-MAGNETIC RADIATION

18,21,23,25 April

IV(A) Properties and Mathematical Representation of Radiation

1	Concepts, terminology and the greenhouse effect	**12.1,12.2,12.8**	12.6, 12.9, 12.10, 12.11
1	Relationships between intensity and flux: the radiation cone	**12.2**	
1	Blackbody radiation and real surface emmision	**12.3-12.4**	12.29
1	Absorption, reflection, transmission	**12.5**	
	The gray body approximation	**12.6-12.7**	12.45, 12.49

28,30 April, 2 May

IV(B) Computing Radiation Exchange Between Surfaces

1	View factors	**13.1-13.2**	13.1, 13.2
2	Radiation Heat Transfer in Enclosures	**13.2 (13.2-13.2)**	13.16,13.21, 13.22, 13.63

FINAL EXAM: First part: radiation; second part: from rest of course (to be discussed)