24-322 Heat Transfer

Fall 2015, 10 Units

Department of Mechanical Engineering, Carnegie Mellon University

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Office hours: Wednesday, 7:30-9:30 PM in Hunt Library 1st floor next to the cafe

Lecture: Doherty Hall A302, Tuesday & Thursday, 3:00-4:20 PM

Recitation:

- A: Scaife Hall 208, Wednesday 9:30 AM-10:20 PM
- B: Scaife Hall 208, Wednesday 10:30 AM-11:20 PM
- C: Scaife Hall 214, Wednesday 12:30 PM-1:20 PM
- D: Baker Hall 235A, Wednesday 4:30 PM-5:20 PM

Required textbook: *Fundamentals of Heat and Mass Transfer*, Seventh Edition by T. L. Bergman, A. S. Lavine, F. P. Incropera, and D. P. Dewitt (Wiley, 2011), ISBN: 978-0470501979

I. DESCRIPTION AND OBJECTIVES

Heat transfer is the study of thermal energy transfer between materials due to a temperature difference. It involves heat propagation through solids and fluids, or can take place through a vacuum. The objective of this course is to provide a first exposure for undergraduate mechanical engineering students to the study of heat transfer. Both the underlying physical mechanism of heat transfer and techniques for analyzing heat transfer in engineering systems will be presented. The pre-requisites for this course are undergraduate-level differential equations (21-260), thermodynamics (24-221) and fluid mechanics (24-231). It is expected that students are proficient in differential and integral calculus.

Students successfully completing this course will be able to:

- Identify the modes of heat transfer in engineering systems and the associated atomistic energy carriers
- Predict the rate of heat transfer by conduction in solids and fluids
- Predict the rate of heat transfer by convection (conduction with a moving fluid) between a solid and an internal or external fluid flow
- Predict the rate of heat transfer by radiation between solids
- Analyze the performance of heat exchangers

II. LOGISTICS

A. Class Time

There are two lectures per week, each lasting 1 hour and 20 minutes. You are responsible for all material discussed in class, whether you attended or not. The tentative course calendar contains the sections of the textbook to be covered in every lecture. You are required to read these sections, and strongly advised to do so before the lecture as they will help you to better understand the materials presented.

Every student is assigned to one of four 50-minute recitation sections, which will begin meeting on Wednesday, Sept 3 (no recitations in week 1). The recitations will focus on problem solving. Most weeks, the TA will give your recitation, but 3 times a semester the instructor will substitute. The recitation given by the instructor will rotate.

Use of electronic devices (cell phones, laptop computers, mp3 players, etc.) is not permitted in lecture or recitation. No student may record or tape any classroom activity without the express written consent of the instructor. If a student believes that he/she is disabled and needs to record or tape classroom activities, the student should contact the Office of Disability Resources to request an appropriate accommodation. In the event that such an accommodation has been arranged, the material may not be further copied, distributed, published, or otherwise used for any other purpose without the express written consent of the instructor.

B. Website

Materials related to the course will be found on Blackboard. You are responsible for all material posted to blackboard.

C. Communication

The subject of any email sent to the instructor or TA should start with "24-322:". Do not send the instructor or TA emails regarding homework as these questions should be openly discussed on Blackboard (see below).

D. Grades

A: 90-100, B:80-89, C: 70-79, D: 60-69, R: <60

Any grading disputes will be handled by the instructor. Any request for a grade change should be made to the instructor, in writing, within one week after the graded work is returned. Your entire submission will be subject to regrading.

Cheating and plagiarism is unethical behavior and is not tolerated in this course or at Carnegie Mellon University. The Carnegie Mellon University policy on cheating and plagiarism will be strictly followed. Students are advised to read and adhere to the policy, which can be found at http://www.cmu.edu/policies/documents/Cheating.html.

(a) Homework assignments: 10@1.5%

There will be 10 homework assignments of equal weight. Homework will be assigned on a Thursday and due at the beginning of class the following Thursday. Homework submitted after the end of class will not be graded. Solutions will be posted to Blackboard after the homework has been submitted. Graded homework will be available in the mailboxes on the 4th floor of Scaife Hall one week after submission.

Students may work together but must submit their own work for grading. Discussion about the homework will take place on Blackboard discussion boards. ***Do not email the instructor or TA with questions.*** They will check the boards at the end of most days.

To pass the course, you must receive a grade of at least 50% on the homework. Homework grading will be effort-based. For each problem, you will receive a grade of one (1) if you made significant effort to solve the problem and zero (0) otherwise. Significant effort includes the proper use of the homework format described below.

- Name, assignment number, due date, and problem numbers must be written neatly in the upper right corner of the first page.
- Pages must be stapled in the upper left corner. Assignments that are not stapled will not be graded and will receive a score of zero.
- Write neatly and show all of your work.
- Solution format:
  1. Known: state briefly what is known about the problem
  2. Find: state briefly what must be found
  3. Schematic: draw a sketch of the physical system and the corresponding thermal circuit (where appropriate)
  4. Assumptions: state all assumptions
  5. Analysis: apply theory and perform calculations to obtain the results
  6. Answer: box the final answer and don't forget to include units

(b) Midterm Exams 2@25%

In-class exams will be held on 10/1 ~~9/30~~ and 11/12 ~~11/6~~. The exams are open book and you will be permitted a calculator and one 1-sided 8.5″×11″ formula sheet for each exam. You must make the instructor aware of conflicts as soon as possible.

(c) Final Exam 35%

A cumulative final exam will be held in the final exam slot (time/place to be announced). The final exam is also open book and you will be permitted a calculator and one additional 1-sided 8.5″×11″ formula sheet, plus your sheets from the midterms.

III. TEACHING PHILOSOPHY

Students are welcome to ask questions at all times. Don't be afraid to interrupt if a point is not clear, or you've got a relevant addition to the lecture.

IV. COURSE CONTENTS

There are 29 set lectures during the semester. The following topics will tentatively be covered (see next page for more detail):

- Introduction (1 class): Chapter 1
- Conduction (7 classes): Chapters 2, 3, 5
- Convection (7 classes): Chapters 6, 7, 8, 9
- Heat Exchangers (4 classes): Chapter 11
- Radiation (7 classes): Chapter 12, 13
- Nanoscale Thermal Transport (1): Notes
- In-class exams (2)

Dates	Tuesday	Thursday
9/1, 9/3	Introduction: Modes of heat transfer and atomistic carriers (1.1-1.7)	Conduction: Fourier law (2.1), thermal conductivity (2.2), energy equation (2.3, 2.4), plane wall (3.1)
9/8, 9/10	Conduction: Radial systems (3.3)	Conduction: Extended surfaces (3.6) **[HW#1 Due]**
9/15, 9/17	Conduction: Extended surfaces (3.6)	Conduction: Transient- lumped capacitance, **[HW#2 Due]**
9/22, 9/24	Conduction: Transient- spatial effects (5.4-5.8)	Convection: Introduction, review of fluid mechanics and boundary layers (6.1-6.4, 6.6), **[HW#3 Due]**
9/29*, 10/1	Conduction: Review for Midterm #1*	**Midterm #1**
10/6, 10/8	Convection: Thermal boundary layer and flat plate (7.1-7.3)	Convection: Correlations for external flows (7.4-7.8)
10/13, 10/15	Convection: Laminar tube flow with heat transfer (8.1-8.3)	Convection: Correlations for internal flows (8.4-8.6), **[HW#4 Due]**
10/20, 10/22	Heat Exchangers: Introduction, overall heat transfer coefficient, log-mean temp difference (11.1-11.3)	Heat Exchangers: Introduction, overall heat transfer coefficient, log-mean temp difference (11.1-11.3) **[HW#5 Due]**
10/27, 10/29	Heat Exchangers: Effectiveness- NTU method (11.4)	Heat Exchangers: more on effectiveness-NTU method (11.5) **[HW#6 Due]**
11/3, 11/5	Convection: Free convection (9.1-9.9)	Radiation: Introduction (12.1-12.9) **[HW#7 Due]**
11/10*, 11/12	Convection & Heat Exchangers: Review for Midterm #2*	**Midterm #2**
11/17, 11/19	Radiation: View factor (13.1)	Radiation: Thermal circuits, two-surface enclosures (13.2, 13.3), **[HW#8 Due]**
11/24, 11/26	Radiation: Three-surface enclosures (13.3)	**Thanksgiving**
12/1, 12/3	Radiation: Three-surface enclosures (13.4)	Radiation: Multi-mode heat transfer (13.4) **[HW#9 Due]**
12/8, 12/10	Nanoscale Thermal Transport	Course Review: (Focus on Radiation) **[HW#10 Due]**

*Professor Malen will give a portion of the review followed by a TA review session where past exams are solved.
All information is subject to change.