ME EN 5960-6960 Nanoscale Heat Transfer
Department of Mechanical Engineering
University of Utah
Fall 2011

Instructor: Prof. Mathieu Francoeur
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Office Hours: By appointment via e-mail

Class Schedule: Tuesday and Thursday
10:45 am – 12:05 pm
WEB L126

Prerequisite: ME EN 3650 (Heat Transfer)

Course Summary: Traditional macroscale thermal science is based on classical equilibrium and continuum assumptions. These assumptions break down at the molecular and atomic length scales, and the classical theories, such as Fourier's law for heat conduction or Planck's blackbody distribution for radiation, are no longer applicable at micro/nanoscale. With the major progress over the past two decades in controlling matter at nanoscale, nanotechnology is becoming an integral part of almost all engineering disciplines. This course will provide a self-contained overview of thermal transport and thermophysical properties at nanoscale, and will introduce the elements of quantum mechanics, solid state physics, statistical thermodynamics, and electrodynamics necessary to understand these phenomena.

Objectives: At the end of the course, the students are expected to:

- understand the limits of macroscopic heat transfer based on continuum and classical equilibrium assumptions;
- understand the Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac statistics;
- understand the concept of energy quantization;
- describe the classical transport coefficients via the kinetic theory;
- understand the Boltzmann Transport Equation;
- be able to identify the appropriate equations for solving heat conduction problems at prescribed length and time scales;

- understand Maxwell's equations and electromagnetic wave propagation in planar media;
- understand the concepts of evanescent waves and surface polaritons;
- understand fluctuational electrodynamics and the fluctuation-dissipation theorem;
- understand near-field radiative heat transfer in planar geometry.

Required Textbook: Z.M. Zhang, Nano/Microscale Heat Transfer, McGraw-Hill, 2007.

Other Textbook: G. Chen, Nanoscale Energy Transport and Conversion, Oxford, 2005.

Class Notes: PowerPoint presentations, homework assignments, homework solutions and other useful documentation will be posted on WebCT.

Homework: In general, homework will be assigned on a weekly basis. Homework will be collected at the beginning of the class period when due. No late homework will be accepted, unless the student has a valid reason.

Exams: There will be two exams.

Project (G): Graduate students are allowed to choose their own project following their research interests, subject to approval of the instructor. At the end of the semester, the student is expected to submit a report consisting of an extensive literature review of the chosen subject. The student should be able to identify the researchers in the field of interest, understand the scientific literature, and summarize it in a comprehensive document (including associated physical and mathematical modeling if applicable). The report should be made as professional as possible. At the end of the semester, the student will give a 10-15 minute oral presentation.

Grading (UG):

Homework:	60%
Exams:	40% (20% each)

Grading (G):

Homework:	40%
Exams:	40% (20% each)
Project:	20%

Grading Scale:

93 – 100%:	A
90 – 92%:	A-
87 – 89%:	B+
83 – 86%:	B
80 – 82%:	B-
77 – 79%:	C+
73 – 76%:	C
70 – 72%:	C-

67 – 69%:	D+
63 – 66%:	D
60 – 62%:	D-
below 60%:	E

Final grading scale may be lowered down by the instructor based on the overall class performance, but will not be raised.

Cheating Policy: Since engineering is a group activity, students are highly encouraged to help each other to learn the course material and to discuss the homework assignments. However, all homework and exams submitted <u>must be each student's personal work</u>. Students submitting work showing evidence of copying will receive zero credit.

Classroom Conduct: Laptop computers may only be used to take notes. The use of cell phones is strictly prohibited in the classroom.
During the lectures, students are expected and encouraged to ask questions and participate in discussions. However, it may happen that some individuals have different points of view. While such an interactive and animated environment is usually beneficial from a learning standpoint, any disrespectful behavior toward the instructor or a classmate will not be tolerated. Any student showing such disrespectful behavior will be asked to leave the classroom.

Americans with Disabilities Act of 1990:
The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability Services.

Topics (*The specific sections to read in the textbook will be provided in the class notes*):

1. Introduction and Review of Macroscopic Thermal Sciences (**Chapters 1 and 2**)

2. Elements of Statistical Thermodynamics and Quantum Theory (**Chapter 3**)

3. Kinetic Theory (**Chapter 4**)

4. Thermal Properties of Solids and the Size Effect (**Chapter 5**)

5. Electrical Transport in Semiconductors (**Chapter 6**)

6. Non-equilibrium Energy Transfer (**Chapter 7**)

7. Fundamentals of Thermal Radiation and Energy Transfer by Electromagnetic Waves (**Chapters 8 and 9**)

8. Near-Field Thermal Radiation (**Chapter 10**)

Class Schedule (Tentative):

Week	Dates	Topic	Remark
1	08/22 – 08/26	Syllabus, 1	
2	08/29 – 09/02	1, 2	
3	09/05 – 09/09	2	Labor Day (09/05)
4	09/12 – 09/16	2, 3	Project Topic (09/15)
5	09/19 – 09/23	3	
6	09/26 – 09/30	3, 4	
7	10/03 – 10/07	4	Midterm Exam (10/06)
8	10/10 – 10/14		Fall Break (No class)
9	10/17 – 10/21	4, 5	
10	10/24 – 10/28	5, 6	
11	10/31 – 11/04	6	
12	11/07 – 11/11	7	
13	11/14 – 11/18	7	
14	11/21 – 11/25	7	Thanksgiving (No class on 11/24)
15	11/28 – 12/02	8	Project Report (12/01)
16	12/05 – 12/09	8	Oral Presentations (12/08)
17	12/12 – 12/16		Final Exam (12/16, 10:30 am-12:30 pm)