Fall Semester 2014
Conduction Heat Transfer
20-MECH-7090

Catalog Description
Heat transfer by conduction. Mathematical formulation of physical problems; methods of solution, including separation of variables method, superposition techniques, similarity, Laplace transforms, approximate integral method, with application of solutions to analyze physical problems. 3 hrs. lec.

Instructor

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Office Hours: Drop-in (usually available) and/or by appointment (definite).

Textbook / Class Notes
NONE required; undergrad HT textbook and select Chapters from graduate heat conduction textbooks are posted on Blackboard website. Also a very complete set of class notes, and many worked out former HW PROBLEMS and class tests are posted as example problems to study.

References:

1. Conduction of Heat in Solids, HS. Carslaw and JC. Jaeger, Oxford, 2nd ed., 1959.
2. Conduction Heat Transfer, V.S. Arpaci, Addison-Wesley, 1966.
3. Heat Transfer, A. Chapman, Macmillan, 3rd edition, 1974.
4. Heat Conduction, M.N. Ozisik, Wiley, 1993.
5. Heat Conduction and Mass Diffusion, B. Gebhart, McGraw-Hill, 1993.

* **6. Conduction Heat Transfer, D. Poulikakos, Wiley, 1994.**
* **7. Analytical Methods in Conduction HT, G. Myers, AMCHT, 2nd ed., 1998.**
* **8. Heat Conduction, Y. Yener & S. Kakac, Taylor & Francis, 4th ed., 2008.**

** **9. Fundamentals of Heat and Mass Transfer, Bergman, Lavine, Incropera and DeWitt, Wiley, 7th ed., 2011** (and other undergraduate textbooks).

10. Applied Partial Differential Equations, Haberman, 4th Edition, 2004. (or any other standard PDE textbooks)

* Denotes the 3 most useful graduate Conduction textbooks (**on 2-hr reserve,** Eng. Library)
** Undergrad Heat Transfer textbook *(will be used throughout semester & expanded upon)*

Grading System

Homework	25 %	(about 12 or so HW assignments)
Exam #1	25 %	(Week #5 – Thursday 9/25/14)
Exam #2	25 %	(Week #11 – Tuesday 11/4/14)
Exam #3	25 %	(Finals week – Thursday 12/11/14)

Objectives

This is a "core" course for any graduate student majoring in the thermal science field. Through a mixture of homework problems and tests the student will gain working knowledge of conduction heat transfer**. Standard solution techniques to analytically solve** steady 1-D, and 1-D transient heat conduction problems, is the primary focus of this course. However, the **modeling of problems**, the critical evaluation of particular heat conduction solutions to determine the system performance, the ability to determine and understand the important **conduction time scale of the system**, etc., or in other words, to develop a **better physical grasp and insight of conduction heat transfer behavior,** is another important objective of the course.

Prerequisites / Mathematics

Undergraduate heat transfer. Basic knowledge with ordinary differential equations and partial differential equations. A formal course in **partial differential equations will be very helpful, but however, is not absolutely necessary**. Appropriate graduate-level mathematics will be introduced into the course as needed, not for the sake of pure mathematics itself, but rather to solve the particular heat conduction problem of interest (i.e. **problem-driven** as opposed to the usual formal systematic development of mathematical theory typically found in a pure PDE course). Although the mathematical treatment to be presented / used in the course is targeted to be at "just the right level" for most engineers, and is definitely more than adequate for this course, it is still *highly recommended that the students at some point in time during their studies take a rigorous and formal course(s) in the mathematical theory and solutions of PDEs,* ideally simultaneously (or alternatively sequentially) for the benefit of filling in some of the missing "fine mathematical details" and for gaining additional confidence in applying / mastering the required mathematical tools used to theoretically solve advanced heat conduction problems.

Computer Programming and Numerical Methods

The techniques covered in this course are **analytical.** Goal is to formulate problem, analytically solve ODE or PDE, evaluate and plot solution (with just simple spreadsheet or Matlab program) so as to fully understand the theoretical heat conduction solution behavior. *(Note - to make the problems manageable, often simplifying assumptions are needed.)* Numerical analysis (i.e. finite-difference or finite element methods) will not be taught in this class since they are specifically covered in great detail in other courses.

Self Study

The **blackboard website** notes are organized in an orderly fashion (lecture-by-lecture and topic-by-topic) in such a way as to make this class **almost self study**. Nearly every lecture contains a solved problem, or there is a related solved former HW problem(s) in the assignment folder. In general, the **material starts out easy and gradually gets harder, and systematically builds upon itself.** Although there is quite a lot of information posted, the material is fairly easy to learn and is evenly distributed by following the weekly schedule/agenda sheets and studying the related former HW problems. The complete set of exams from the very last year (both with, and without, solutions) are posted for added examples & practice, but provided more so to illustrates the style of your tests to come.

Course Outline

	…... Chapters……	
PART I - Preliminary Information & Steady 1-D Heat Conduction	**Incropera ;**	**Kakac**
Introduction, Fourier's law, Heat Conduction Equation, Derivation & BC.	1,2	**1, 2**
Quick Review of Undergraduate Heat Conduction	3	**3**
Simple Fins, fins with heat generation, and moving fin	3.6	
Fins with Nonuniform Cross Section	3.6.4	**3.6.6**
EXAM #1 *(week 5)*		
PART II - Advanced Transient 1-D Heat Conduction in Finite System		
1-D Transient Heat Conduction in Finite System		
lumped system vs. distributed system	5.1-3	**6.1-2**
Separation of variables solution technique	-	**4**
Transient, 1-D heat conduction in	5.4	
planar geometry, cylindrical, spherical coordinates.	5.5-6	**6.3**
Conduction time scale, system time scales	***suppl.***	
EXAM #2 *(week 11)*		
PART III - Transient 1-D Conduction in Semi-Infinite Solid *(or finite system at very short time)*		
Solutions for sudden change in wall temperature & other BCs obtained by:		
Similarity method (with penetration depth, contact temperature)	5.7	**10.3**
Integral method	-	**10.4**
Laplace transform method	-	**8.8**
Transient heat conduction involving internal heat sources (time-permitting)	*Poulikakos (Chap.7)*	
(i.e. point, line, plane, etc. with constant / instantaneous duration)		
PART IV - Transient 1-D Heat conduction with Freezing / Melting		
Sharp moving solid/liquid phase-change interface condition (pure substance)	-	**11.2**
Formulation & Exact Solution to Stefan-type problems:	-	
Single-region problems ($T_i = T_f$)		**11.3**
Two-region problems ($T_i \neq T_f$)		**11.4**
Quasi-Steady Approximation	-	**11.7**
EXAM #3 *(finals week)*		

Topics not covered:		
Numerical solution (finite-difference) of steady multi-dimensional	*4.4-5*	-
& transient heat conduction	*5.10*	-