# ME 151A / 250A
# Advanced Conductive and Radiative Transport

University of California, Berkeley
Department of Mechanical Engineering
Course Information
Fall 2018

***Classes*** TuTh 11:10 am - 12:30 pm
3109 Etcheverry Hall

***Instructor*** Prof. Chris Dames
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6107 Etcheverry Hall
Office Hours: *TBD.*

***Reader*** *TBD.*

***Description*** ME 151A / 250A: Advanced Conductive and Radiative Transport
Fundamentals of conductive heat transfer. Analytical and numerical methods for heat conduction in rigid media. Fundamentals of radiative transfer. Radiative properties of solids, liquids and gas media. Radiative transport modeling in enclosures and participating media.
**Prerequisite**: A first course on heat transfer (e.g. ME109 or equivalent).
**Mathematical Background**: This course requires solving various ODEs and PDEs. If you have had some basic exposure to ODEs and multivariable calculus, you should be fine.

***ME 250A vs. ME 151A?*** ME151A is a room-share course taught concurrently with ME 250A. The courses share a common lecture, but homework assignments for ME 250A will be more challenging than those for ME 151A. Students in ME 151A and ME 250A will be graded separately.

***ME 250A vs. ME 251 / 253?*** ME 250A now represents our core graduate offering in conduction and radiation. ME 251 (Conduction) and ME 253 (Radiation) are not planned to be offered separately in the future. For this semester only, students who have already taken ME251 and still want the radiation parts of ME250A may sign up for ME292E (course number 34638).

***Primary Texts*** For conduction: *Heat Conduction*, by D. W. Hahn and M. N. Ozisik, **3rd (2012) Edition**. Note that this book has major changes from the 2nd (1993) Edition. I will specifically be working out of the **3rd Edition**.

For radiation: Likely *Radiative Heat Transfer*, by M. Modest, 3rd Edition (2013). (To be confirmed.)

***Computational Work*** *Programming*: You will be expected to write simple programs using software of your choice, such as Matlab, Python, Fortran, etc.

*Symbolic Math*: Acquaintance with symbolic math software may be helpful from time to time, in this course and in most research fields. Examples include Maple, MuPAD (used in MATLAB's symbolic math toolbox), and Mathematica (the very basics of which are freely available at www.wolframalpha.com)

***Topics*** See separate handout.

***Evaluation***

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|---|---|
| Homework (roughly every 2 weeks) | 50% |
| Midterm 1 (take home exam) | 25% |
| Midterm 2 (take home exam) | 25% |

***Absences, Late Work, and Make-ups***

**Lectures**: Obtain notes from a classmate.

**Homework**: Due in class at 11:10 am on the due date.

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|---|---|
| Late by less than 1 hr 20 minutes: | 25% penalty |
| Late by 1 hr 20 - 48 hrs: | 50% penalty |
| Late by more than 48 hours: | Not accepted |

**Exams**: Missing an exam will result in a zero grade for that exam unless alternative arrangements are made with the instructor *prior* to the exam. (Exceptions may be made for severe medical or family emergencies.) Makeup exams, when allowed, may be written or oral.

***Other Texts*** A selection of other references which may be helpful.

<u>Conduction</u>

*Conduction Heat Transfer*, by Arpaci (1966). Comprehensive though somewhat dated.

*Conduction of Heat in Solids*, by Carslaw & Jaeger (2nd Ed.: 1959/1986). A classic text known for solving many standard problems. Relatively dense and mathematical.

*Heat Conduction*, by L. Jiji (3rd Ed.: 2009). A lighter treatment, at the senior undergraduate level, which still introduces some specialized topics like approximate integral methods, perturbation theory, bio heat transfer, porous media, and microscale heat conduction.

*Heat Conduction*, by Yener & Kakac (4th Ed.: 2008). Another comprehensive text.

<u>Radiation</u>

*Thermal Radiation Heat Transfer*, by Howell, Menguc, & Siegel (author details may vary in earlier editions). Another extensive standard text, comparable to Modest.

*Thermal Radiative Transfer and Properties*, by M. Quinn Brewster. Not as comprehensive or well known, but can be more accessible on some topics than Modest and Howell et al.

*Principles of Optics*, by M. Born & E. Wolf. A classic advanced textbook on optics. Definitive though can be challenging for self-teaching if you've never studied optics before. At the other extreme is *Optics* by E. Hecht, a popular introductory text.

**ME250A / 151A: Advanced Conductive and Radiative Transport**

**Outline of Topics** (subject to change)

## PART 1: CONDUCTION

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|---|---|
| Foundations | Derivation of heat equation.<br>Isotropic / Anisotropic. Neumann's Principle.<br>Boundary conditions.<br>Elrod's Theorem. Bounds.<br>Linear / Nonlinear. Homogeneous / Inhomogeneous. |
| Separation of Variables | Sturm-Liouville Problem. SOV.<br>Steady vs. transient.<br>1D vs. multi-dimensional.<br>Superposition; Dealing with inhomogeneities.<br>Cylindrical Problems |
| Additional Analytical Methods | Semi-infinite domains. (Solve several ways)<br>Dimensional analysis.<br>Scaling.<br>Moving Heat Sources. The welding problem. |
| Other Topics (time permitting) | Approximate solutions (integral, perturbation formulations). |
| Omitted from ME250A but sometimes seen in ME251 | Spherical coordinate problems<br>Steady-periodic heating. Transfer matrix method.<br>Green's functions.<br>Integral Transform method.<br>Phase Change. Melting & solidification.<br>Numerical methods (See ME250B). Finite differences in space and time; Explicit vs. implicit methods. Stability and convergence; Incorporating nonlinearities.<br>Physics of thermal properties; Micro and nanoscale effects. (See ME259) |

## PART 2: RADIATION

Fundamentals: The nature of thermal radiation

Radiative properties of surfaces

Radiative exchange between surfaces

Radiation in participating media