Nanoscale Thermal Transport (ME 495)

Spring Quarter 2020

Thermal energy storage and transport at the nanoscale occurs through the interaction of electrons, phonons, and photons. The objective of this course to address five fundamental questions namely, (1) how is thermal energy distributed among electrons and phonons? (2) how fast do the carriers move through a material? (3) how much thermal energy do each carrier hold? (4) how do the carriers scatter as they move through a material?, and (5) how do the carriers interact with material boundaries and interfaces? The answers to these questions will provide a basis for understanding the conduction of thermal energy in solid-state nanomaterials, and the design and control of thermal processes in heat-transfer, thermoelectric, thermionic, thermophotovoltaic devices and solar cells. In the classroom, I will introduce the Landauer transport formalism and use it to elucidate the fundamental limits of heat conduction between two contacts/reservoirs by electrons and phonons, and to explain the dependence of thermal conductance on energy, frequency, wavelength, and material size. Homework problem sets will be assigned to facilitate deep learning of the course material and journal article reviews will be used to highlight new thermophysical insights on heat conduction in 1D and 2D nanomaterials including carbon nanotubes, nanowires, graphene, molecular junctions, etc. Prerequisites: - ME 377 (Heat transfer) and ME 222 (Thermodynamics).

- **Professor**: Oluwaseyi Balogun
- **Email**: o-balogun@northwestern.edu
- **Phone number**: 847-491-3054
- **Office**: Catalysis Building, Room 325
- **Class Hours**: TBD
- **Classroom**: TBD
- **Office Hours**: TBD
- **Course website**: Canvas will be used to distribute homework assignments, lecture notes, and homework solutions

Grading

- Homework assignments: TBD
- Take Home Exam: TBD
- Paper review and presentations: TBD

Supplemental References:

- Nanoscale Energy Transport and Conversion: A Parallel. Treatment of Electrons, Molecules, Phonons, and Photons, G. Chen, (Oxford, 2005)
- Microscale Energy Transport, C.L. Tien, A. Majumdar, and F.M. Gerner, (Taylor & Francis, 1998)
- Introduction to Solid State Physics, Charles Kittel (Wiley, 2004)

Tentative Week by Week Schedule (Subject to change)

Week	Tuesday	Thursday
4/1	Introduction to electrons, phonons, and photons	Lattice Vibrations and Phonons
4/8	Free Electrons (Relevant concepts from quantum mechanics)	Carrier Statistics- Statistical Ensembles
4/15	Phonon Density of States, Electron Density of States	Application of Carrier Statistics: Examples
4/22	Basic Thermal Properties: Phonon Specific Heat	Basic Thermal Properties: Electron Specific Heat
4/29	Thermal Conductivity (Kinetic Theory)	Thermal Conductivity (Kinetic Theory)
5/6	Landauer Transport Formalism:	Landauer Transport Formalism: Thermal Conductance
5/13	Landauer Transport Formalism: Quantum of Thermal Conductance	Carrier scattering and transmission: Thermal Conductivity
5/20	Carrier scattering and transmission (Boundary and Defect Scattering)	Carrier scattering and transmission (Phonon-Phonon Scattering)
5/27	Carrier scattering and transmission (Interfacial transmission)	Measurement techniques for thermal transport
6/3	Presentations	Presentations