ME 539 *Heat Transfer Physics*, Tu & Th, 11:30-1:00, Winter 2009, 1363 G.G. Brown

Department of Mechanical Engineering, University of Michigan

Week Of	Subject	Readings (Chapter. Section)	Homework: Problems and Computer Codes
January 5	**Introduction and Preliminaries**: Macroscopic Energy Equation and Role of Microscale (Atomic-Level) Heat Carriers: Electron, Phonon, Fluid Particle, and Photon; Atomic-level Energy Kinetics: Length, Time, and Energy Scales; Scope of Heat Transfer Physics	1.1 - 1.8 Appendix F	**HW # 1**:
January 12	**Molecular Orbitals-Potentials-Dynamics, and Quantum Energy States**: Interatomic Forces, Potentials and Models; *Ab Initio* Interatomic Potential Calculations and Models; Statistical Ensembles, Energies, Temperature, and Partition Function; Hamiltonian Mechanics	2.1 - 2.4	**HW # 2**: Interatomic Potential From Gaussian Code
January 19	Computational Classical Molecular Dynamics (MD) Simulation and Scales; Schrödinger Equation; Quantum Simple Harmonic Oscillator and for Free Electron Gas, Electronic Energy in Hydrogen-Like Atoms	2.5 - 2.6	**HW # 3**: 2-D MD Gas Particle Code
January 26	**Carrier Energy Transport and Transition Theories**: Boltzmann Transport Equation (BTE); In- and Out-Scattering; Relaxation Time Approximation; Evaluation of Scattering and Energy Interaction Rates, Fermi Golden Rule	3.1 - 3.2 Appendix E	**HW # 4**:
February 2	Maxwell Equations; Onsager Transport Coefficients; Stochastic Transport Processes (Langevin Equation); Green-Kubo (G-K) Autocorrelation Decay and Lattice Thermal Conductivity	3.3 - 3.6 Appendix B	**HW # 5**: 3-D MD-GK Code for Ar FCC Phonon k
February 9	**Phonon**: Dispersion in Harmonic Lattice Vibration (Acoustic and Optical Phonons); Phonon Density of States; Reciprocal Lattice Space and Brillouin Zones; Lattice Specific Heat Capacity **SELECTION OF PROJECT TOPIC DUE**	4.1 - 4.3, 4.6 – 4.7	**HW # 6**: 3-D Ar FCC Phonon Dispersion Code
February 16	Phonon BTE and Callaway Lattice Conductivity Model (Single-Mode Relaxation Time); Cahill-Pohl Minimum Lattice Conductivity; MD-GK (Heat Current Autocorrelation) Lattice Conductivity Decomposition, Phonon Boundary Resistance; Ultrasound Heating; Size Effects	4.9 - 4.10, 4.12 - 4.13, 4.17 - 4.19 Appendix C Appendix D	**HW # 7**: 4.17, 4.22, 4.23, 4.29 Case Study I: Phonon Transport in Nanoporous Crystals
February 23	**SPRING RECESS**		
March 2	**Electron**: Schrödinger Equation for Electron Band Structure in Crystals; Electron Band Structure in One-Dimensional Ionic Lattice; Tight-Binding Approximation; Full and Model Band Structures and Effective Electron Mass in Semiconductors; Periodic Electron Gas Model for Metals; *Ab Initio* Calculation of Band Structure; Electron Density of States for Semiconductors; Electron Specific Heat Capacity **ABSTRACT OF PROJECT DUE**	5.1 - 5.8	**HW # 8**: Tight-Binding Method Fermi Surface Graphing Code Materials Studio Code for Electronic Band Structure
March 9	Electron BTE for Semiconductors; Energy-Dependent and Average Relaxation Time; Semiconductor and Metal Electro-Thermal Transport Coefficients (Electrical Conductivity, Seebeck Coefficient, Peltier Coefficient, and Electronic Thermal Conductivity); Electron Scattering by Phonon; Electron-Lattice Thermal Non-Equilibrium and Cooling Length; Size Effects	5.9 - 5.13 5.15 5.18 - 5.19 5.22	**HW # 9**: BoltzTraP Code for Thermoelectric Properties (Electron BTE) Case Study II: Micro TE Cooler
March 16	**Fluid Particle**: Quantum Fluid Particle Electronic, Translational, Vibrational, and Rotational Energy States and Partition Functions; Fluid Particle Specific Heat Capacity (Ideal Gas and Dense Fluid); Fluid Particle BTE; Equilibrium Energy Distribution Function; Binary Collision Rate; Relaxation Time and Mean-Free Path; Theoretical Maximum Evaporation/Condensation Heat Transfer Rate	6.1 - 6.7	**HW # 10**:

March 23	Ideal Gas Thermal Conductivity from BTE; Liquid Thermal Conductivity; Brownian Motion of Solid Particles and Effective Conductivity; Fluid Particle-Surface Interactions and Flow Regimes; Thermophoresis; Adsorption and Desorption; Turbulent-Flow Structure and Boundary-Layer Transport; Thermal Plasmas; Size Effects	6.8 - 6.14	**HW # 11**: 3-D Liquid MD Code for Fluid Particle Trajectory and f_f^o 1-D Surface Accommodation Coefficient MD Code
March 30	**Photon**: Planck Distribution for Photon Gas (Blackbody Radiation); Lasers and Narrow Band Emission; Quantum and Semi-classical Treatment of Photon-Matter Interaction; Photon Absorption and Stimulated and Spontaneous Emissions in Two-Level Electronic Transition System; Electronic Population Rage Equation **DRAFT REPORT ON PROJECT DUE**	7.1 - 7.2, 7.4	**HW # 12**:
April 6	Photon Particle Treatment and BTE, Equation of Radiative Transfer Absorption, Emission, and Scattering Cross Sections; Radiant Thermal Conductivity; Wave (Coherent) Treatment of Photon (Photon Localization); Continuous and Band Absorption; Continuous and Band Emission	7.5 - 7.10	**HW # 13**:
April 13	Radiative and Non-Radiative (Involving Phonon Emission) Decays and Quantum Efficiency; Anti-Stokes Fluorescence and Photon-Electron-Phonon Couplings (Laser Cooling of Solids); Gas Lasers and Laser Cooling of Gases; Photovoltaic Solar Cell; Size Effects	7.11 - 7.15	Case Study III: Laser Cooling of Solids
April 20	Review, Course Evaluation **Last Day of Class: Tuesday, April 21**		
April 28	**TUESDAY APRIL 28: FINAL REPORT ON PROJECT DUE**		

Instructor **Massoud Kaviany**, Office: 3108 G.G. Brown, Phone: 936-0402,
E-mail: **kaviany@umich.edu**

Class Conduct
If more than 10 minutes late, please refrain from attending.
2% of total points is deducted for each unexcused absence.
5% extra points are given for strong class participation.

Office Hours Mondays and Wednesdays, 12:30 - 1:30, and by Appointment

Grade Policy
Homework: 70%
Project: 30% (Projects will be graded based on heat transfer physics content)

Homework Problems are assigned every Thursday and are due the following Thursday

Projects
Choose from (a) provided list of possible project topics, or (b) personal research interest.
Dates for selection, preliminary and final reports, are marked above.

Textbook *Heat Transfer Physic*s, M. Kaviany, Cambridge University Press, 2008