



ME 539 (AP 639) Heat Transfer Physics, M & W, 3:00-4:30, Winter 2018, 2150 Dow
Department of Mechanical Engineering, University of Michigan

Week Of	Subjects	Readings (Chapter, Section)	Homework, Computer Codes, and Case Studies
January 7	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: 1.3, 1.4, 1.5, 1.7
January 14	Molecular Orbitals-Potentials-Dynamics, and Quantum Energy States: Interatomic Forces, Potentials and Models; <i>Ab Initio</i> Interatomic Potential Calculations and Models; Statistical Ensembles, Energies, Temperature, and Partition Function; Hamiltonian Mechanics	2.1 - 2.4	HW # 2 Interatomic Potential Using Gaussian Code
January 21	Monday: Martin Luther King Day 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 28	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 4	Maxwell Equations; Onsager Transport Coefficients; Stochastic Transport Processes (Langevin Equation); Green-Kubo (G-K) Autocorrelation Decay and Thermal Conductivity, Elastic Solid and Newtonian Fluid Conservation and Wave Equations and Scales	3.3 - 3.9 Appendix B	HW # 5
February 11	Phonon: Dispersion in Harmonic Lattice Vibration (Acoustic and Optical Phonons); Phonon Density of States; Reciprocal Lattice Space and Brillouin Zones; Lattice Specific Heat Capacity	4.1 - 4.3, 4.6 - 4.7	HW # 6: 3-D Ar FCC Phonon Dispersion Code
February 18	Phonon BTE and Callaway Lattice Conductivity Model (Single-Mode Relaxation Time); Phonon Scattering Relaxation Times; Cahill-Pohl Minimum Lattice Conductivity; Material Metrics of Lattice Conductivity (Slack Relation); Lattice Conductivity Decomposition, Phonon Boundary Resistance; Ultrasound Heating; Size Effects	4.9 - 4.12, 4.17 - 4.19 Appendix C Appendix D	HW # 7 Case Study I: Phonon Conductivity of Cage-Bridge, Layered, and Filled-Cage Crystals
February 25	Electron: Schrödinger Equation for Electron Band Structure in Crystals; Electron Band Structure in One-Dimensional Ionic Lattice; Tight-Binding Approximation; <i>Ab Initio</i> Calculation of Band Structure; Full and Model Band Structures and Effective Electron Mass in Semiconductors; Periodic Electron Gas Model for Metals; Electron Density of States for Semiconductors and Fermi Level; Electron Specific Heat Capacity	5.2 - 5.8	HW # 8 Tight-Binding Method Fermi Surface Graphing Code Materials Studio Code for Electronic Band Structure
March 4	Spring Recess		
March 11	Electron BTE for Semiconductors; Energy-Dependent and Average Relaxation Time; Semiconductor and Metal TE Transport Coefficients (Electrical Conductivity, Seebeck Coefficient, Peltier Coefficient, Electric Thermal Conductivity, and Wiedemann-Franz law); Electron Scattering by Phonons; Electron-Phonon Thermal Nonequilibrium and Cooling Length; Size Effects	5.9 - 5.13, 5.15, 5.17 - 5.19, 5.22	HW # 9 Case Study II: Single- and Multistage Micro TE Cooler

March 18	Fluid Particle: <i>Ab Initio</i> Calculations of Quantum States, 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 Gaussian Code for CO ₂ Rotational and Vibrational Quantum States
March 25	Ideal Gas Thermal Conductivity from BTE; Liquid Thermal Conductivity; Brownian Motion of Dispersed Solid Particles and Effective Liquid 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 Case Study III: Effective Thermal Conductivity of Nanogap; Extreme boiling heat transfer
April 1	Photon: Planck Distribution for Photon Gas (Blackbody Radiation); Lasers and Narrow Band Emission; Population Rate Equation for Photon Absorption and Stimulated and Spontaneous Emissions in Two-Level Electronic Systems; Einstein Coefficients, Absorption Coefficient and Cross-Section Area	7.1 - 7.2, 7.4	HW # 12
April 8	Photon Particle Treatment and BTE with Absorption, Emission, and Scattering Cross-Section Areas; Radiation Intensity and Equation of Radiative Transfer (ERT) and its Relation with Macroscopic Energy Equation; Optically Thick Limit of ERT and Radiant Thermal Conductivity; Wave (Coherent) Treatment of Photon (Photon Localization); Continuous and Band Absorption from FGR; Continuous and Band Emission and Surface Emissivity	7.5 - 7.10	HW # 13
April 15	Radiative and Nonradiative (Involving Phonon Emission) Decays and Quantum Efficiency; Anti-Stokes Fluorescence (Phonon Absorption) and Photon-Electron-Phonon Couplings (Laser Cooling of Solids); Gas Lasers and Laser Cooling of Atomic and Molecular Gases; Photovoltaic Solar Cell; Size Effects Course Evaluation (Online)	7.11 - 7.15	Case Study IV: Phonon-assisted photon absorption (laser cooling and solar cell)
April 22	Last Day of Class: Tuesday, April 23 No class Monday		
Instructor	Massoud Kaviani , Office: 3444 G.G. Brown, Phone: 936-0402, E-mail: kaviany@umich.edu		
Office Hours	Mondays and Wednesdays, 12:30 - 1:30, and/or by Appointment		
Grade Policy	Homework: 100%		
Class Participation	5% extra points are given for strong class participation		
Homework	Problems are assigned every Thursday and are due the following Thursday		
Textbook	<i>Heat Transfer Physics</i> , M. Kaviani, Second Edition , Cambridge University Press, 2014		
Wikipedia article	Heat Transfer Physics <i>Wikipedia</i> article is at URL (with useful links) http://en.wikipedia.org/wiki/Heat_transfer_physics		