Midterm 1 Review Sheet

Fundamental Constants:

- Boltzmann constant
- Planck's constant
- Free electron mass
- Electron-volt/Joule Conversion
- Speed of light
- Stefan-Boltzmann constant
- Avogadro's number
- Ideal gas constant
- Vacuum permittivity/permeability
- Mass of proton

Chapter 1: Introduction

- Gases
    a. Mean free path
    b. Ideal gas law
    c. Maxwell distribution
- Kinetic theory
    a. Thermal conductivity/dynamic viscosity/mass diffusivity
    b. Methodology in derivation
- Quantum effects
    a. Relaxation time
    b. de Broglie relation

Chapter 2: Material Waves and Energy Quantization

- Waves
    a. Wave vector
    b. Units: wavenumber, wavelength, frequency relations
    c. Particle-wave duality
        i. Energy
        ii. Momentum
- Quantum Mechanics
    a. Schrodinger's equation
    b. Solutions to Schrodinger's equation
        i. Free particle
        ii. 1D infinite well – Energy levels
        iii. Harmonic oscillator
        iv. Rigid rotor
        v. Electronic energy levels (Hydrogen)

Chapter 3: Energy States in Solids

- Crystal Structure
    a. Common crystal lattice structures (FCC, BCC, etc.) – Number of atoms per unit cell

    b. Miller indices
    c. Reciprocal lattice/Brillouin zone
    d. Lennard-Jones potential
- Energy Quantization
    a. Kronig-Penney model (electrons)
    b. 1D chain of atoms – monatomic, diatomic, etc. (phonons)
- Density of States
    a. Electrons (3D,2D,1D)
    b. Phonons
        i. Polarization (3)
        ii. Debye model
        iii. Einstein model
    c. Photons

Chapter 4: Statistical Thermodynamics and Thermal Energy Storage

- Ensembles
    a. Microcanonical
        i. Entropy
    b. Canonical
        i. Helmholtz free energy
        ii. Partition functions
        iii. Thermal de Broglie wavelength
    c. Grand canonical
- Probability Distribution
    a. Boltzmann
    b. Fermi-Dirac
    c. Bose-Einstein
- Internal Energy and Specific Heat
    a. Gases
        i. Translation, rotation, vibration, electronic
        ii. Equipartition theorem
    b. Electrons
        i. Fermi energy/chemical potential
        ii. Carrier concentration
        iii. Boltzmann approximation
    c. Phonons
        i. Debye model
        ii. Einstein model
    d. Photons
        i. Emissive power

Chapter 5: Energy Transfer by Waves

- Wave properties
    a. Electrons
        i. Wavefunction
        ii. Wavevector k

        iii. Particle flux
    b. Photons
        i. Intensity profile for normal incidence (Poynting vector)
        ii. Absorption coefficient/skin depth
        iii. Refractive index/permittivity
    c. Phonons
        i. Atom displacement
- Interface reflection and refraction
    a. Electrons
        i. Reflection/transmission coefficients
        ii. Reflectivity/transmissivity
        iii. Evanescent waves
    b. Photons
        i. Fresnel coefficients
        ii. Reflectivity/transmissivity for TE/TM polarization
        iii. Snell's law of reflection/refraction
        iv. Critical angle
        v. Brewster angle
    c. Phonons
        i. SH wave
        ii. Reflectivity/Transmissivity
- Multiple interface systems
    a. Transfer matrix method
    b. Reflection/transmission coefficients for single film
    c. Reflectivity/transmissivity for single film
- Evanescent waves/tunneling

2.57 / 2.570 Nano-to-Macro Transport Processes

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