Physics 375 **Fall (12) 2003**

Solid State Physics: Problem Set #7

Thermal and Electronic Properties of Solids: Phonon Interactions and the Free Electron Model

Due: Friday Feb. 28 by 6 pm

Note: Write-up for experiment #3 (Bragg X-ray) is due Friday Feb. 28.

Reading assignment:	for Monday,	6.1-6.3	(the free electron ideal gas model)
	for Wednesday,	6.4, 6.7	(electrical and thermal conductivity in metals)
	for Friday,	6.5	(optical properties of metals)

Problem assignment:

Chapter 6 Problems:

*6.3 Variation in Fermi energy due to thermal expansion or applied pressure **[Robert]**

6.5 Electron vs phonon contributions to heat capacity

6.10 Size effects on electronic energy level spacing in a metal

A1. *Phonon mean free path*. Estimate the mean free of phonons in germanium and diamond at room temperature (300 K). The thermal conductivities of these materials are 80 W/m•K and 2000 W/m•K respectively. Consult your periodic table handout for other required physical constants. [Result for Ge: $\ell \approx 40$ nm if you estimate v_s from θ_D]

*A2. *Phonon-phonon interaction*. Consider the following phonon collision in Manganese: A phonon traveling in the [100] direction with wave-vector k interacts and combines with another phonon of the same magnitude k which is traveling in the [110] direction. Draw a diagram to show the magnitude and direction of the resultant phonon and determine the maximum value of k for which this collision proceeds as an n-process. (Consult your periodic table handout for Mn properties). **[Brian]**

A3. *Electronic properties of copper*. The electrical conductivity of copper at room temperature is $\sigma = 5.62 \times 10^7\ \Omega^{-1}\text{m}^{-1}$. Using this value along with other physical properties of copper given in the periodic table handout determine the following:

a) concentration n of conduction electrons ; b) relaxation time τ; c) Fermi energy E_F

d) Fermi velocity v_F ; e) mean free path ℓ of conduction electrons

A4. *Fermi-Dirac function*. Plot the Fermi-Dirac function $f(E)$ (Eq. 6.21) versus the energy ratio E/E_F for copper at T=0 K, room temperature, and the melting temperature for Cu. Use Eq. 6.22 for the temperature dependence of the chemical potential E'. Comment on the validity of ignoring the temperature dependence of E' when dealing with metals.

*To be presented in class on Friday.