489 Spring 2004 Homework 2

Due Wednesday, Feb. 4, 2004

1. Ashcroft and Mermin , problem 1.2. The purpose of this problem is to show that on the microscopic scale electron scattering leads to energy dissipation which agrees with the usual form of Ohm's law. (You may need to work parts of problem 1.1 to solve this problem, but you do not need to turn in work on problem 1.1)

2. Derive the form of the Wiedemann-Franz law (Ashcroft and Mermin, Eq. (13.58) in Chapter 13) from the form of the thermal conductivity in Eq. (1.51) and the quantum expression for the specific heat of a 3-D electron gas. (You do NOT need to use or understand the material in Ashcroft and Mermin that leads up to Eq. (13.58). You can derive this result very simply.)

3. (a) From information in tables (Ashcroft and Mermin or elsewhere) find the density of valence electrons, plasma frequency, conductivity σ and the relaxation time τ at room T for Na and Al.

   (b) Find the density of valence electrons for diamond carbon and silicon, assuming 4 valence electrons per atom and information on the crystal structure and lattice constants given in the text. Also find the plasma frequency assuming the free electron model. (Plasma oscillations are observed at frequencies near these free electron values even in insulators like diamond. Think of a plausible explanation for why the electrons seem to act free for this purpose; this will be discussed later in the course and you do not need to turn in your answers.)

   (c) Sketch the form of the real and imaginary parts of the dielectric function $\epsilon(\omega)$ for Al in the free electron model. Use a log scale for ω and show ranges from well below $1/\tau$ to well above ω_P. Indicate limiting forms for ϵ.

   (d) Sketch the form of the real and imaginary parts of the index of refraction for the same range. Where is the absorption greatest? For what ω is the wave velocity v greater than the speed of light c? What would happen if you tried to transmit a message in the range where $v > c$?

4. Aschroft and Mermin , problem 4.1.

5. Aschroft and Mermin , problem 4.5.

You do not need to turn them in, but I also recommend Problems 1.1, 4.2, 4.3, and 4.4(a) of Aschroft and Mermin.