ph 135

Problem set - 2

Due: Monday 29th by 5pm in TA box.

1. Scattering-time estimates. Let's get a feeling for the times and lengths involved in electron transport in metals. Look up electrical resistivity on wikipedia. You'll find a table with the resistivity (which is the inverse of the conductivity) of various metals.

   (a) What is the most conducting metal listed, nad what is the resistivity? Likewise, what is the least conducting metal listed, and what is its resistivity?

   (b) From the resistivity data, crudely estimate the scattering time τ in the metals you listed based on our jellium model.

   (c) What is the corresponding mean free path ℓ of the metals you listed? Again, base your answer on the crude jellium model.

2. The Ioffe-Regel limit. Good metals are easy to recognize. But what about bad metals? According to the Ioffe-Regel rule, a bad metal is one where the parameter $k_F\ell \geq 1$, where k_F is the Fermi wave number, and ℓ is the mean free path. In this case, scattering is comparable to the Fermi wavelength, so thinking of the electron as a quantum particle is a stretch.

   (a) For a metal with a lattice constant of $a = 3nm$ and one electron in the conduction band per site, what would be the resistivity threshold of a 'bad-metal'?

   (b) What would be the Ioffe-Regel limit in two dimensions? Note that resistivity in 2d is given in units of resistance, which is also referred to as the resistance per square.

3. Use the Boltzman equation to find the thermoelectric coefficient λ for a dilute (free) electron gas - which describe the situation in a semiconductor. Assume that μ is constant while whie temperature has a finite gradient for your calculation. For your final answer, recall that for a dilute gas the chemical potential is $\mu = T\ln(n\lambda_T^3)$, where $\lambda_T = \frac{\sqrt{2\pi mT}}{h}$, and $n\lambda_T^3 \ll 1$. Note that this applies to each of the spin components separately. Assume that the density n as well as temperature T, mass m, and scattering time τ are given.