HW #11: The Interconnectedness of All Things

Here, we consider ***connections*** between:

- light and sound, and
- electrical and thermal conductivity, and
- electrical resistivity and temperature

1. – ***The Optical Branch in the phonon dispersion curve***:

Optical phonons are called "optical" because they can in some cases couple to electromagnetic radiation. This can, for example, happen in a one-dimensional chain with *two ions of opposite charge* per unit cell. A vibration of these two ions "against" each other would correspond to a changing electric dipole and could be excited by the changing electric field of an electromagnetic wave. Using conservation of energy and momentum, show that such an excitation can only work for the optical phonon branch, and not for the acoustic phonon branch.

2. – ***Classical vs. Quantum description of metal***:

Hofmann Ch 5 reviews the *classical* description of a metal. Calculate the classical mean kinetic energy for the electrons in metallic sodium (Na) at room temperature. From this, determine their de Broglie wave length λ. For a classical description to be valid, we have to require that λ is much smaller than the mean separation d of the particles. Show that this is not the case.

3. – ***Wiedemann-Franz Law***:

Page 79 of Hofmann introduces the Wiedemann-Franz Law. You should show that the Wiedemann-Franz coefficient, L, in the (classical) Drude model is indeed given by Hofmann's Equation 5.31, that is:

$$L \equiv \frac{\kappa}{\sigma T} = \frac{3}{2}\frac{k_B^2}{e^2}$$

4. – ***Resistivity of a metal is linear in Temperature****:*

We have seen that the (classical) Drude model does at least give the correct order of magnitude for the resistivity of many metals near room temperature, …but what about the temperature dependence of the resistivity? In class, we noted that, experimentally, the resistivity of (a clean) metal is, in fact, linear in Temperature, over a wide range, and back when you did a lab, in Modern Physics, on Thermal Radiation and the Stefan-Boltzmann Law, the thermometer you needed to use was, in fact, based upon the resistivity of the filament in the lamp:

$$\rho\left(T\right)=\rho_0\left[1+\alpha\left(T-T_0\right)\right]$$

Here, ρ_0 is the resistivity at room temperature, T_0, and α is the so-called thermal coefficient of resistance. — You should show that the Drude model does NOT give rise to a linear temperature dependence.