I. PROBLEM SESSION 8

A. Problem 8.1 (2.3 and 3.3 from the midterm)

8.1.1 What is the density of states Einstein used in his analysis of heat capacity? Correlate, qualitatively, the characteristic frequency used by Einstein (ω_E) with the sketch of $D(\omega)$ produced when solving problem 2.2. Further, Einstein temperature can be determined as $\Theta_E = \frac{\hbar\omega_E}{k_B}$, where k_B is a Boltzmann constant. Make a rough estimate of Θ_E (order-of-magnitude accuracy is acceptable). The velocity of sound ($5000m/s$) and a lattice parameter typical for common crystals, say $a = 3 * 10^{-8}cm$, may be applied when estimating Θ_E. Analyze the trends for Θ_E provided by changes in the mass of atoms and the strength of the elastic constant. It is known that at sufficiently low temperatures almost all phonons are in their ground states. What difference in phonon occupation a small rise in temperature going to make in terms of Einstein formalism? When answering the last question the magnitudes of $\hbar\omega_E$ and k_BT may be compared and considering the occupation probabilities may provide a basis for conclusions.

8.1.2 Classical statistical mechanics predicts that a free particle should have a heat capacity of $3k_B/2$ where k_B is a Boltzmann constant. If N atoms each give one valence electron to the electron gas, as considered in problems 3.1 and 3.2, then the electronic contribution to the heat capacity should be $3k_BN/2$, just as for atoms in a monoatomic gas. Calculate $3k_BN/2$ for a mole to use as a reference. On the other hand experiments usually tell that the actual electronic contribution to the heat capacity is in the order of 0.01 of the classical $3k_BN/2$ value. Use the graph obtained when solving problem 3.2 and make an estimate of total electronic thermal kinetic energy and the corresponding heat capacity accessible for FEFG. Importantly, avoid the complicated integration of the $D(\epsilon)f(\epsilon, \mu, T)$ product ? make a motivated estimate! Using this estimate, calculate, at room temperature $T = 300K$, the electronic heat capacity in potassium characterized with an electron concentration of $1.44 * 10^{22}cm^{-3}$. Note, it is convenient to introduce the quantity $T_F = \frac{\epsilon_F}{k_B}$ called Fermi temperature.

B. Problem 8.2

Drude modell for electrical/thermal conductivity:

a) Show that the Wiedemann-Franz coefficient in the Drude model is given by $\frac{3k_b^2}{2e^2}$. How is the coefficient modified when considering the FEFG model? b) Show (calculate) that the Drude model provides reasonable values of electrical resistivity at room temperature, ρ_0 at T_0. Further, it is know experimentally that the temperature dependence of the resistivity is given by $\rho(T) = \rho_0(1 + \alpha(T - T_0))$ where α is so called thermal resistance coefficient. Show that the Drude model is in qualitative disagreement with the observation. Please discuss if the application of FEFG model improves the situation.

C. Problem 8.3

Hall effect:

How does magnetic field modify dynamics of electrons? Explain the mechanism behind the Hall effect. Can you think of any other ways the introduction of a magnetic field alter the properties of the electron gas? Can the Hall effect be explained in terms of Drude/FEFG models? What is the core problem?