Condensed matter physics - 2017

Indian Institute of Science Education and Research Bhopal

Assignment 2

Drude model

1. Estimate the collision time τ for an electron in copper. Resistivity and atomic density of copper are given by 1.7×10^{-6} ohm-cm and 8.5×10^{22} atoms/cm^3.

2. Assuming Drude model show that probability for an electron, picked at random at any time, not to have made a collision during the preceding t is given by e^{-t}/τ. Show that at any moment, the time between the last and the next collision averaged over all electrons is 2τ.

3. A piece of metal is placed in a static uniform magnetic field $\vec{B} = B_0\hat{z}$. Treat conduction electrons as free gas with scattering time (mean free time) τ and number density n. Derive and expression for *resistivity tensor* ρ_{ij}. The resistivity tensor is defined as

$$E_i = \rho_{ij}\mathcal{J}_j$$

where E_i is the i^{th} component of electric field and $\mathcal{J}_i$ is the i^{th} component of DC current density.

4. When we apply a temperature gradient in a metallic sample, initially average velocity of electron from high temperature side to low temperature side is greater than that of from low temperature side to high temperature side. As a result there will be a net electric current in the sample. Since thermal conductivity is measured in open circuit condition, the current will keep flowing until enough charges are accumulated at the surface of the material to build up a retarded electric field to oppose the current. In equilibrium, there will be no net current and average velocity of electrons at any point is zero (what we considered in class during derivation of thermal conductivity). Thus an electric field developed in the sample, at equilibrium, is given by

$$\vec{E} = Q\ \vec{\nabla}T, \quad \text{where } Q \text{ is called thermopower.}$$

Show that in Drude model

$$Q = -\frac{C_v}{3ne}.$$

Justify the sign.