Háskóli Íslands
Raunvísindadeild
Eðlisfræði

Haust 2014

Eðlisfræði þéttefnis I

Dæmablað 11

Skilafrestur 25. November 2014 kl. 15:00

1. **Bloch oscillations** (15)

   Consider whether it should be possible to observe Bloch oscillations.

   (a) Take the relaxation time τ in copper to be approximately 2×10^{-13} s. How strong an electric field would be needed in order to have one Bloch oscillation in less than a relaxation time?

   (b) Assuming a characteristic band gap of 2 eV, how large is this field compared to one that could induce Zener tunneling?

   (c) Consider next GaAs where the low-temperature relaxation times can rise to 3×10^{-10} s, and where it is possible to build artificial structures for which the lattice constant is on the order of $a = 10$ nm. How large an electric field would be needed to see Bloch oscillations in this case ?

2. **Hall hrif** (10)

   A sample of $n-$type GaAs whose carrier concentration is 10^{16} cm^{-3} is in the shape of a slab whose length is 5 cm, width 0.5 cm,and thickness of 1 mm. When this slab is palced in a magnetic field of 0.6 Wb/m^{2}normal to the slab, with a current of 10 mA. Calculate

   (a) The Hall constant in this sample

   (b) The Hall voltage developed across the slab.

3. **Microscopic Drude theory** (25)

A microscopic picture of the Drude theory can be built from the following assumptions: (i) While moving through the metal, the electrons suffer random collisions with the ions, between the collisions, there are no interactions between the electrons and ions or among the electrons. (ii) Collisions are instantaneous events that abruptly change the velocity of the electrons. (iii) Collisions occur with a rate (probability per time) of $1/\tau$. (iv) The collisions maintain local thermal equilibrium, i.e., after a collision the electron emerges in a random direction with a speed appropriate to the local temperature at the place of the collision.

(a) Show that an electron picked at random had no collision during the preceding time interval t with probability $\exp(-t/\tau)$. Show that it will have no collisions during the following time interval t with the same probability.

(b) Show that the probability that the time interval between two successive collisions is in the range $[t, t+dt]$ is $(dt/\tau)\exp(-t/\tau)$

(c) Show (as a consequence of (a)) that at any moment the mean time back to the last collision or up to the next collision is τ.

(d) Show (as a consequence of (b)) that the mean time between successive collisions is τ.

(e) Part (c) implies that at any moment the time T between the last and next collision averaged over all electrons is 2τ. Why is this not inconsistent with the result of (b) ? To explain, you may want to derive a probability distribution of T. This factor of 2 problem is responsible for Drude's mistake in the Wiedeman-Franz law.