

Eðlisfræði þéttefnis I

Dæmablað 11

Skilafrestur 15. November 2018 kl. 15:00

1. Snertimætti p-n-skeyta – Built-in potential for a p-n-junction (10)

Finna skal snertimætti fyrir kísil p-n skeyti við stofuhita ef boleðlisviðnám kísils er $1 \Omega \text{ cm}$. Hreyfanleiki rafeinda í kísili er $1400 \text{ cm}^2/\text{Vs}$; $\mu_n/\mu_p = 3.1$; og $n_i = 1.05 \times 10^{10} \text{ cm}^{-3}$.

Find the built-in potential for a p-n Si junction at room temperature if the bulk resistivity of Si is $1 \Omega \text{ cm}$. Electron mobility in Si at RT is $1400 \text{ cm}^2/\text{Vs}$; $\mu_n/\mu_p = 3.1$; and $n_i = 1.05 \times 10^{10} \text{ cm}^{-3}$.

(Próf desember 2016)

2. Fermi surfaces in two dimensions (10)

Consider a two-dimensional system of nearly free electrons (weak periodic potential) with a square unit cell (lattice constant a). Determine the Fermi surfaces for the cases of 1, 2, 3, and 5 electrons per unit cell. To this end, first project the free electron Fermi surface into the 1st Brillouin zone and then think about at what points gaps open. Plot the Fermi surfaces in the Brillouin zone. It might be useful to make separate plots for the different bands. (Note: Semi-quantitative plots are OK, i.e., you need to get the topology right, the exact positions are not so important.)

3. Hall effect (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 placed 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.

4. 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.

5. Empty lattice or free electron model (10)

(a) Construct the first, second and third Brillouin zones for a two dimensional square lattice crystal of lattice constant a . In the free electron approximation, what is the

number of electrons per unit cell needed for the third Brillouin zone to start being filled

(b) Consider a monovalent simple cubic crystal and calculate the fraction of substitutions with bivalent atoms required for the Fermi surface to touch the boundary of the first Brillouin zone.

(c) In a FCC crystal with conventional lattice constant $a = 0.4$ nm, what is the energy difference between the lowest and next lowest bands at the center of the first Brillouin zone.

(d) Determine if the Fermi surface of a monovalent BCC crystal lies within the first Brillouin zone.