Condensed Matter Physics I
(M. Peressi)
Exercises - Drude Model

Hint: normally the Ashcroft-Mermin book uses CGS units; however, it can be convenient to use MKS(SI) units in presence of eqs. containing the resistivity (use ρ in Ω-meters, m in Kg, n in electrons/m^3, e in Coulomb.

Exercise 1

1. Consider typical values of the magnetic field (H(Earth)≈0.5 Gauss; H(lab)≈ 1-10 T). Evaluate the product $\omega_c \tau$, where ω_c is the cyclotron frequency and τ the electron relaxation time. On average, can an electron in a metal make many revolutions between collisions or not?

Exercise 2

1. Give a numerical estimate of the mean electronic velocity in case of a current density of 0.1 A/mm^2 flowing in a copper wire (n_{el}= 8.47 10^{22} cm^{-3}). [v=0.007 cm/s]

Exercise 3

Consider Al at room temperature. Its electron density is $n = 18.1 \cdot 10^{22}/cm^3$ and its electrical resistivity is $\rho = 2.45\ \mu\Omega \cdot cm$.

1. Find its electron relaxation time τ and electron mean free path ℓ in the Drude model. [τ=8.01 10^{-15} s; ℓ = 13 Å]
2. Consider AC conductivity. At which frequency w the real part of the conductivity $\sigma(\omega)$ will be 1/10 of its zero-frequency value? [$\nu = \omega/2\pi$ =59.7 10^{12} THz]

Exercise 4

Sodium (Na) in standard temperature and pressure conditions is a metal with BCC structure, density of about 0.97 g cm^{-3} and mass number = 23.

1. Calculate the atomic density (number of atoms per unit volume) of solid sodium. [n_{at}=2.54 10^{22} cm^{-3}]
2. Calculate the electron density. [n_{el}=n_{at}]
3. Calculate the plasma frequency. [ω_p=8.99 10^{15} s^{-1}]
4. If the electron gas is treated as a classical one, which is the kinetic energy at T=0^o K? and at room temperature?
5. Given the resistivity in DC at room temperature, ρ= 4.2 $\mu\Omega$ cm, calculate the relaxation time τ. [τ=3.3 10^{-14} s]

Other exercises

Ex. 2 and 3 of Chapter 1 of A&M