Modern physics Chapter 9-10. Solutions to exercises.

9.1.1 The resistivity is given by $\rho = \rho_0(1+\alpha\Delta T)$. For copper ρ_0 = 1.7x10^{-8} Ωm and the constant α = 4.0x10^{-3} T^{-1}. The temperature T_0 = 273 K. Equation:

$$\rho_{373} = 1{,}7\times10^{-8}(1+4.0\times10^{-3}(373-273)) = 2.38\times10^{-8}\Omega m \approx 2.4\times10^{-8}\Omega m$$

9.1.2 The relative resistivity ρ/ρ_0 where α = -7.0x10^{-2} T^{-1}. ΔT = (25 – 20) K

Equation $\frac{\rho}{\rho_0} = 1-7.0\times10^{-2}(25-20) = 1-0.35$, i.e. a reduction by 35%.

9.2.1 Bragg's formula $2d\sin\theta = m\lambda$ where θ = 30^o is the angle for grazing incidence. First order with m = 1 gives

$$d = \frac{m\lambda}{2\sin\theta} = \frac{1\times1.2}{2\sin 30^o}\mathring{A} = 1.2\mathring{A}$$

9.3.1 The potential energy is given by $V = -6\frac{e^2}{4\pi\varepsilon_0 a}$ where a = 0.281 nm. Equation:

$$V = -6\frac{e^2}{4\pi\varepsilon_0 a} = -9.00\times10^9\,\frac{6\times1.602\times10^{-19}}{0.281\times10^{-9}}eV = 30.74eV \approx 31eV$$

9.3.2 A linear crystal model gives $V = \alpha\times\frac{e^2}{4\pi\varepsilon_0 a}$ where V = 7.2 eV and a = 0.281 nm.

We determine α : $7.2e = \alpha\times\frac{9.00\times10^9\times1.6\times10^{-19}e}{0.281\times10^{-9}}$ giving a = 1,4 (no unit)

9.6.1 The energies can be written using the quantum numbers: $E_{n1n2n3} = \frac{h^2}{8ma^2}\left(n_1^2+n_2^2+n_3^2\right)$

With $n_1 = n_2 = n_3 = 1$ and a = 1,0 mm we have:

$$E_{111} = \frac{\left(6.63\times10^{-34}\right)^2}{8\times9.1\times10^{-31}\times\left(1.0\times10^{-3}\right)^2}\times\frac{1}{1.6\times10^{-19}}eV = 1.3\text{x}10^{-13}\text{eV}$$

9.7.1 The Fermi energy $u_F = \frac{h^2}{2m}\left(\frac{3}{8\pi}\times\frac{N}{V}\right)^{2/3}$ where N/V is searched for. We get:

$$\left(u_F\right)^{3/2} = \left(\frac{h^2}{2m}\right)^{3/2}\frac{3}{8\pi}\times\frac{N}{V}\quad \text{Ekvation:}\quad \frac{N}{V} = \frac{8\pi}{3}\frac{\left(u_F\times2m\right)^{3/2}}{h^3}$$

$$\frac{N}{V} = \frac{8\pi\left(1.5\times1.6\times10^{-19}\times2\times9.1\times10^{-31}\right)^{3/2}}{3\times\left(6.63\times10^{-34}\right)^3}\text{electrons/m}^3$$

$$\approx 3.3\times10^{26}\ \text{electrons/m}^3$$

9.7.2 The Fermi function $f(u) = \frac{1}{e^{(u-u_F)/kT}}$ At T = 500 K and $u = u_F$ – 0.1 eV, we get

$$f(u) = \frac{1}{e^{(u-u_F)/kT}} = \frac{1}{e^{-0.1\times1.6\times10^{-19}/1.38\times10^{-23}\times500}} = 0.09838 \approx 0.0984$$

9.9.1 The probability is $P = N/N_0$ where $N = N_0 e^{E_g / kT}$ and $E_g = 1.5$ eV.
$- E_g/kT = - 1.5 \text{x} 1,6 \text{x} 10^{-19}/(1.38 \text{x} 10^{-23} \text{x} 293) = - 59.356$

The probability is $P = e^{-59.356} \approx 1.66 \times 10^{-26}$ vanishingly small.

9.10.1 At equilibrium the magnetic and electric forces are equal $F_E = F_{B.}$,
i.e. $eE = evB$, why $B = E/v = 10 \text{x} 10^{-3}/0.42$ T = 24 mT