EECS 170A Section B
Homework Solution #2

1) Pure, bulk copper (Cu) has a resistivity (ρ) of 1.7 $\mu\Omega$-cm. Imagine you wanted to jump start you car. The battery of your friends car is 12 V, and so is your battery when connected. When the car is off, no current is flowing anywhere. When you first start the car, your friend's battery will (briefly) source about 10 A in order to get the (your) motor to start up. This will cause an I R voltage drop along the wires between his car and your car. How thick must the wires be so that the IR voltage drop is much less than the 12 V of his battery? The wires are made of copper, and assume they are 10 feet long.

(20 pts)

Voltage $<< 12\ V$
Current, $I = 10\ A$
Resistivity, $\rho = 1.7\ \mu\Omega\text{-cm} = 1.7 \times 10^{-6}\ \Omega\text{-cm}$
Length, $L = 10\ \text{feet} = 304.8\text{cm}$

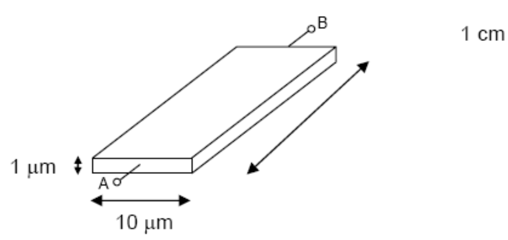
Resistance, $R << V / I = 12V / 10A = 1.2\ \Omega = (\rho L) / A$

Cross-sectional area of wire:

$$A >> (\rho L) / R = (1.7 \times 10^{-6}\ \Omega\text{-cm} \times 304.8\text{cm}) / 1.2\ \Omega$$
$$= 4.318 \times 10^{-4}\ \text{cm}^2$$
$$= \pi D^2 / 4$$

Diameter of the wire, $D >> 2.34 \times 10^{-2}\ \text{cm}$

2) A thin metal wire as shown in the figure below is made of copper. It is 1 cm long, 10 μm wide, and 1 μm thick. Calculate the resistance.



(20 pts)

Resistivity, $\rho = 1.7\ \mu\Omega\text{-cm} = 1.7 \times 10^{-6}\ \Omega\text{-cm}$
Length, $L = 1\text{cm}$
Width, $W = 10\ \mu m = 10 \times 10^{-6}\ m = 10^{-3}\ \text{cm}$
Thickness, $H = 1\ \mu m = 1 \times 10^{-6}\ m = 10^{-4}\ \text{cm}$
Resistance, $R = (\rho L)/(WH)$

$$= (1.7 \times 10^{-6}\ \Omega\text{-cm} \times 1\ \text{cm}) / (10^{-3}\ \text{cm} \times 10^{-4}\ \text{cm})$$
$$= 17\ \Omega$$

3) For Si at 300 K, do the following: (Use cm^{-3} as your units.)

a. $N_D = 10^{18}$ cm^{-3}; $N_A = 10^{12}$ cm^{-3}.
Calculate the equilibrium electron concentration (n) and hole concentration (p).

(5 pts) *Since $N_A << N_D$ and $n_i << N_D$, the concentration of electrons:*

$$n \approx N_D = 10^{18} \text{ cm}^{-3}$$

(5 pts) *And hole concentration:*

$$p = \frac{n_i^2}{N_D} = \frac{\left(10^{10}\right)^2}{10^{18}} = 10^2 \, cm^{-3}$$

b. $N_A = 10^{18}$ cm^{-3}; $N_D = 10^{12}$ cm^{-3}.
Calculate the equilibrium electron concentration (n) and hole concentration (p).

(5 pts) *Since $N_D << N_A$ and $n_i << N_A$, the concentration of holes:*

$$p \approx N_A = 10^{18} \text{ cm}^{-3}$$

(5 pts) *And electron concentration:*

$$n = \frac{n_i^2}{N_A} = \frac{\left(10^{10}\right)^2}{10^{18}} = 10^2 \, cm^{-3}$$

c. $N_A = 10^{18}$ cm^{-3}; $N_D = 10^{18}$ cm^{-3}.
Calculate the equilibrium electron concentration (n) and hole concentration (p).

(5 pts) *Since $N_A = N_D$, the concentration of electrons:*

$$n = n_i = 10^{10} \, cm^{-3}$$

(5 pts) *And hole concentration:*

$$p = n_i = 10^{10} \, cm^{-3}$$

d. $N_A = 10^{12}$ cm^{-3}; $N_D = 10^{12}$ cm^{-3}.
Calculate the equilibrium electron concentration (n) and hole concentration (p).

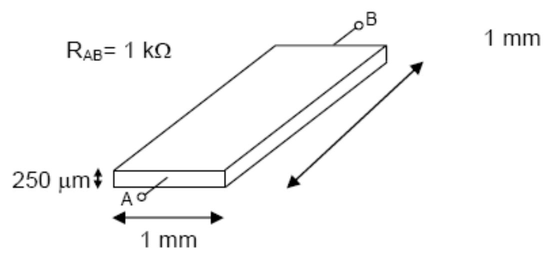
(5 pts) *Since $N_A = N_D$, the concentration of electrons:*

$$n = n_i = 10^{10} \, cm^{-3}$$

(5 pts) *And hole concentration:*

$$p = n_i = 10^{10}\ cm^{-3}$$

4) For the silicon sample at T= 300 K shown below, it is desired to have a resistance of 1 kΩ.



a. If it is n-doped, find the required doping concentration.

(5 pts) *Resistance, R = 1 kΩ = 1000 Ω*
Length, L = 1mm = 0.1 cm
Width, W = 1mm = 0.1 cm
Thickness, $H = 250\ \mu m = 2.5 \times 10^{-2}$ *cm*
Resistivity, $\rho = (RA)/L$
$= (1000\ \Omega \times 0.1cm \times 2.5 \times 10^{-2} cm) / (0.1cm)$
$= 25\ \Omega\text{-}cm$

(5 pts) *From Figure 3.8 in the text book,*
Required doping concentration, $N_D \approx 1.6 \times 10^{14}\ cm^{-3}$

b. If it is p-doped, find the required doping concentration.

(5 pts) *Resistivity,* $\rho = (RA)/L$
$= (1000\ \Omega \times 0.1cm \times 2.5 \times 10^{-2} cm) / (0.1cm)$
$= 25\ \Omega\text{-}cm$

(5 pts) *From Figure 3.8 in the text book,*
Required doping concentration, $N_A \approx 6 \times 10^{14}\ cm^{-3}$