Assign. #7 | MAT E 201 | Dr. S. Djokić

Q1 $I = 20A$, $d = 3\,mm$, $\ell = 1000\,m$

Power Loss: $P = VI = I^2R$, $R = \ell \frac{1}{A\sigma}$, $A = \frac{d^2\pi}{4}$

$$P = I^2 \frac{\ell}{\sigma} \frac{4}{d^2\pi} = (20A)^2 \cdot \frac{1000\,m}{\sigma} \cdot \frac{4}{(3\cdot 10^{-3}m)^2\pi}$$

$$P = 5.6588 \cdot 10^{10} \cdot \frac{1}{\sigma}\,[A^2/m] = 5.6588 \cdot 10^{8} \cdot \frac{1}{\sigma}\,[A^2/cm]$$

a) Aluminum $\sigma = 3.77 \cdot 10^5\,\Omega^{-1}cm^{-1}$

$P = 1501\,W$

b) Nickel $\sigma = 1.46 \cdot 10^5\,\Omega^{-1}cm^{-1}$

$P = 3876\,W$

c) SiC $\sigma = 10^{-10}\,\Omega^{-1}cm^{-1}$

$P = 5.6588 \cdot 10^{18}\,W$

Q2 AlAs fibre, $d = 0.5\,mm = 0.05\,cm$, $\ell = 0.7\,cm$

$\sigma_{AlAs} = 0.1\,\Omega^{-1}cm^{-1}$, $V = 110\,V$

a) $V = IR = I\frac{\ell}{A\sigma}$, $A = \frac{d^2\pi}{4} \Rightarrow I = \frac{Vd^2\pi}{4\ell}\sigma$

$I = \frac{110V \cdot (0.05cm)^2\pi}{4 \cdot 0.7cm} \cdot 0.1\,\Omega^{-1}cm^{-1} = 0.003085A$

b) $J = \frac{I}{A} = nq\bar{v}$

$\frac{I}{A} = nq\frac{\ell}{t} \Rightarrow \frac{n}{t} = \frac{4I}{d^2\pi q\ell}$

$\left(\frac{n}{t}\right)$ - number of electrons per second

$\frac{n}{t} = \frac{4 \cdot 0.003085\,A}{(0.05cm)^2\pi \cdot 1.6 \cdot 10^{-19}C \cdot 0.7cm} = 1.4028 \cdot 10^{20}\frac{1}{cm^3 s}$

Q3 $d = 0.3\,mm$ Cu wire, $P < 300W$, $I = 5A$

$A = \frac{d^2\pi}{4}$, $l = ?$ $\sigma_{Cu} = 5.598 \cdot 10^5\,\Omega^{-1}cm^{-1}$

$R = \frac{l}{\sigma A}$, $V = IR = I\frac{4l}{\sigma d^2\pi}$, $P = VI = \frac{I^2 4l}{\sigma d^2\pi}$

$$l = \frac{P\sigma d^2\pi}{4I^2} = \frac{300 \cdot 5.598 \cdot 10^5\,\Omega^{-1}cm^{-1} \cdot (0.03cm)^2\pi}{4 \cdot (5A)^2}$$

$l = 4748.39\,cm = 47.48\,m$

Q4 $V = 5000V$, Cu wire, $\sigma_{Cu} = 5.598 \cdot 10^5\,\Omega^{-1}cm^{-1}$

$l = 1000\,m$ $R = 5\Omega$

$$R = \frac{1}{\sigma}\cdot\frac{l}{A} = \frac{1}{\sigma}\cdot\frac{4l}{d^2\pi} \Rightarrow d = \sqrt{\frac{4l}{R\sigma\pi}}$$

$$d = \sqrt{\frac{4 \cdot 1000 \cdot 100\,cm}{5\Omega \cdot 5.598 \cdot 10^5\,\Omega^{-1}cm^{-1}\pi}} = 0.213\,cm$$

$V = IR = I \cdot \frac{1}{\sigma}\frac{l}{A} = J \cdot \frac{1}{\sigma} \cdot l$

$$J = \frac{V\sigma}{l} = \frac{5000 \cdot 5.598 \cdot 10^5}{1000 \cdot 100} = 29900\,A/cm^2$$

Q5 Ag, $\mu = 85\ cm^2/Vs$

From Appendix A, $Ag \Rightarrow a_0 = 4.0862 \cdot 10^{-8}\ cm$

FCC structure $\Rightarrow$ 4 at/u.c.

Total number of electrons per cm^3

$$n_T = \frac{4\ at/u.c. \cdot 1\ electron/at}{(4.0862 \cdot 10^{-8}\ cm)^3} = 5.8627 \cdot 10^{22} \frac{electr.}{cm^3}$$

Since $\mu = \frac{\sigma}{nq}$, $\sigma_{Ag} = 6.80 \cdot 10^5\ \Omega^{-1} cm^{-1}$

Number of charge carriers:

$$n = \frac{\sigma}{\mu q} = \frac{6.80 \cdot 10^5\ \Omega^{-1} cm^{-1}}{85\ cm^2/Vs \cdot 1.6 \cdot 10^{-19}\ C} = 5 \cdot 10^{22}\ electr.$$

Fraction of electrons that carry charge (F)

$$F = \frac{n}{n_T} = \frac{5 \cdot 10^{22}}{5.8627 \cdot 10^{22}} = 0.8525$$