Answer on Question 69084, Physics, Electromagnetism

Question:

A copper wire of diameter $1\,mm$ and length $30\,m$ is connected across a battery of $2\,V$. Calculate the current density in the wire and drift velocity of the electrons. The resistivity of copper is $1.72 \cdot 10^{-8}\ \Omega \cdot m$ and $n = 8.0 \cdot 10^{28}\ electrons/m^3$.

Solution:

a) Let's first find the resistance of the copper wire from the formula:

$$R = \rho \frac{l}{A},$$

here, ρ is the resistivity of the copper wire, l is the length of the wire, $A = \frac{\pi d^2}{4}$ is the cross-sectional area of the wire and d is the diameter of the wire.

Then, we get:

$$R = \rho \frac{l}{A} = \rho \frac{4l}{\pi d^2} = 1.72 \cdot 10^{-8}\ \Omega \cdot m \cdot \frac{4 \cdot 30\ m}{\pi \cdot (1.0 \cdot 10^{-3}\ m)^2} = 0.65\ \Omega.$$

Then, from the Ohm's law we can find the current flowing through the copper wire:

$$I = \frac{V}{R} = \frac{2.0\ V}{0.65\ \Omega} = 3.1\ A.$$

Finally, we can find the current density in the wire:

$$J = \frac{I}{A} = \frac{4I}{\pi d^2} = \frac{4 \cdot 3.1\ A}{\pi \cdot (1.0 \cdot 10^{-3}\ m)^2} = 3.95 \cdot 10^6\ \frac{A}{m^2}.$$

b) We can find the drift velocity of the electrons from the formula:

$$v = \frac{I}{nAq},$$

here, I is the current flowing through the wire, n is the number of free electrons per unit volume of the copper wire, A is the cross-sectional area of the wire and q is the charge on each electron.

Then, we get:

$$v = \frac{I}{nAq} = \frac{4I}{n\pi d^2 q} = \frac{4 \cdot 3.1\ A}{8.0 \cdot 10^{28}\ \frac{electrons}{m^3} \cdot \pi \cdot (1.0 \cdot 10^{-3}\ m)^2 \cdot 1.6 \cdot 10^{-19}\ C} =$$

$$= 3.08 \cdot 10^{-4}\ \frac{m}{s}.$$

Answer:

a) $J = 3.95 \cdot 10^{6}\ \frac{A}{m^2}$.

b) $v = 3.08 \cdot 10^{-4}\ \frac{m}{s}$.