Answer on Question 59042, Physics, Electric Circuits

Question:

The average velocity of the electrons in a piece of wire of cross-sectional area $2.0 \cdot 10^{-6}\ m^2$ is $2.5 \cdot 10^{-4}\ ms^{-1}$ when a steady current of $4.0\ A$ is flowing. Calculate the number of free electrons per unit volume of the material:

a) $3.0 \cdot 10^{19}\ \ electrons/m^3$

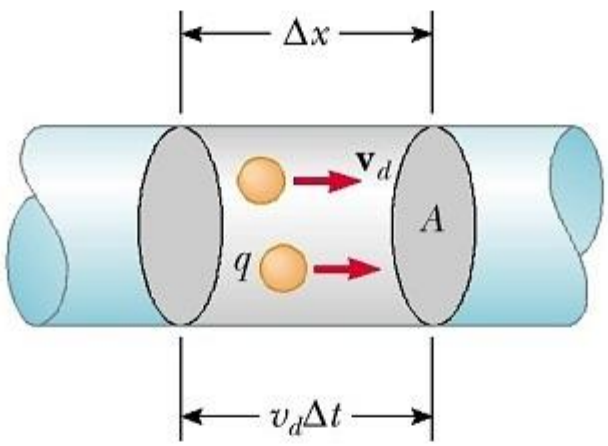
b) $5.0 \cdot 10^{20}\ \ electrons/m^3$

c) $2.0 \cdot 10^{23}\ \ electrons/m^3$

d) $5.0 \cdot 10^{28}\ \ electrons/m^3$

Solution:

Let's consider the current in a piece of wire of cross-sectional area A:



The volume of a section of the wire of length Δx (the gray region in the picture above) is $A\Delta x$. If n is the number of free electrons per unit volume, then the number of free electrons in the gray section is $nA\Delta x$. Then, we can write the charge ΔQ in this section:

$$\Delta Q = nA\Delta xq,$$

here, q is the charge on each electron.

If the electrons move with an average speed (drift speed) v_d, then we can find the distance they move in a time Δt:

$$\Delta x = v_d \Delta t.$$

Therefore, we can rearrange our formula for ΔQ as follows:

$$\Delta Q = nAv_d \Delta t q.$$

Dividing both sides of this equation by Δt we get:

$$\frac{\Delta Q}{\Delta t} = I = nAv_d q,$$

here, I is the current in the wire.

From the last formula we can calculate the number of free electrons per unit volume of the material:

$$n = \frac{I}{Av_d q} = \frac{4.0\ A}{2.0 \cdot 10^{-6}\ m^2 \cdot 2.5 \cdot 10^{-4}\ ms^{-1} \cdot 1.6 \cdot 10^{-19}\ C} = 5.0 \cdot 10^{28}\ \frac{electrons}{m^3}.$$

Answer:

d) $5.0 \cdot 10^{28}\ electrons/m^3$.