

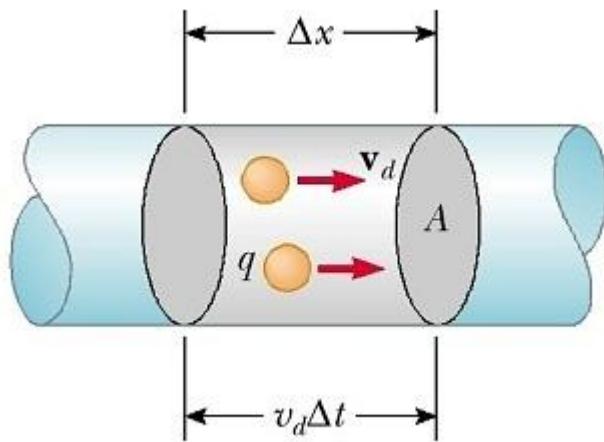
Answer on Question 58646, Physics, Electromagnetism

Question:

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

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:

$$\Delta Q = nA\Delta x q,$$

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:

$$\Delta Q = nA v_d \Delta t q.$$

Dividing both sides of this equation by Δt we get:

$$\frac{\Delta Q}{\Delta t} = I = nAv_dq,$$

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:

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

Answer:

$$n = 5.0 \cdot 10^{28} \frac{\text{electrons}}{\text{m}^3}.$$