Name______________________________________

Physics 111 Quiz #4, October 7, 2024

Please show all work, thoughts and/or reasoning to receive partial credit. The quiz is worth 10 points total, and all parts may not be of equal weight.

I affirm that I have carried out my academic endeavors with full academic honesty.

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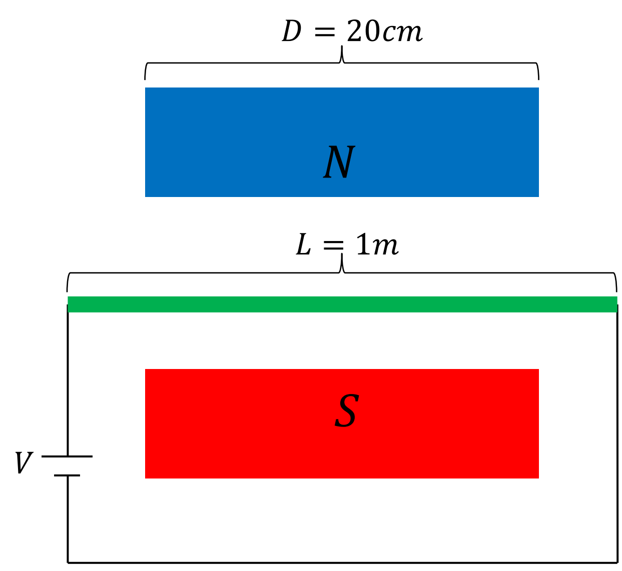
1. Suppose that you have a wire of radius $r = 50\mu m$ and length $L = 1m$ that will be used in a circuit as a resistor. The wire is made out of tungsten ($\rho_{M,W} = 19300\frac{kg}{m^3}, M_W = 0.1833\frac{kg}{mol}, \rho = 5.6 \times 10^{-8}\Omega m$), which donates two charges carriers to the current, and is connected to a $V = 20V$ battery. How much current is produced by the battery?

$$R = \frac{\rho L}{A} = \frac{= 5.6 \times 10^{-8}\Omega m \times 1m}{\pi(50 \times 10^{-6}m)^2} = 7.1\Omega$$

$$V = IR \rightarrow I = \frac{V}{R} = \frac{20V}{7.1\Omega} = 2.8A$$

2. Suppose that this wire was placed between the poles of a square magnet, shown below, with side length $D = 20cm$. The magnetic field has a strength $|\vec{B}| = B = 3mT$. When placed between the poles of the magnet, what force would the wire segment feel? Assume that $\vec{I} \perp \vec{B}$.



The magnetic field points down the plane of the page and the current points to the right, then, by the right-hand rule, the magnetic force on the wire would point into the page away from you with a magnitude

$$F = IDB = 2.8A \times 0.2m \times 3 \times 10^{-3}T$$

$$F = 0.0017N = 1.7mN$$

3. What is the drift velocity of charge carriers in tungsten wire if the current in part 1 flows?

$$I = neAv_d \rightarrow v_d = \frac{I}{neA}$$

$$n = \left(\frac{\rho_{m,W} N_A}{m_W}\right) \times \frac{\text{charge carriers donated}}{\text{atom}} = \frac{19300\frac{kg}{m^3} \times 6.022 \times 10^{23}\frac{W\ atoms}{mol\ W}}{0.1833\frac{kg}{mol\, W}} \times \frac{2}{W\ atom}$$

$$n = 1.27 \times 10^{29} m^{-3}$$

$$v_d = \frac{I}{neA} = \frac{2.8A}{1.27 \times 10^{29} m^{-3} \times 1.6 \times 10^{-19} C \times \pi(50 \times 10^{-6} m)^2} = 0.0175\frac{m}{s}$$

4. What is the Hall voltage induced across the diameter of the wire?

$$V_{Hall} = v_d dB = 0.0175 \times (2 \times 50 \times 10^{-6} m) \times 3 \times 10^{-3} T = 5.3 \times 10^{-9} V = 5.3 nV$$

5. Although they cannot physically do this, assume that the charge carriers could make a circular orbit about the magnetic field in the wire. If the charge carriers have charge $q = +e$ and mass $m = m_e = 9.11 \times 10^{-31} kg$, what would be the radius of their circular orbit? Assume that $\vec{v}_d \propto \vec{I} \perp \vec{B}$.

$$F = qv_\perp B = \frac{mv_\perp^2}{R} \rightarrow R = \frac{mv_\perp}{qB} = \frac{9.11 \times 10^{-31} kg \times 0.0175\frac{m}{s} \sin 90}{1.6 \times 10^{-19} C \times 3 \times 10^{-3} T} = 3.3 \times 10^{-11} m$$