Name____

Physics 111 Quiz #5, February 14, 2025

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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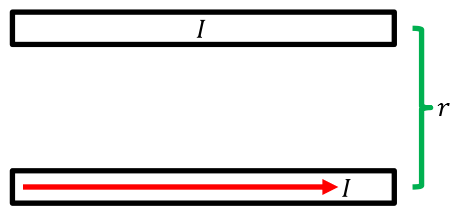
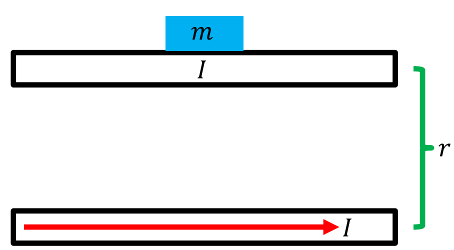
Two horizontal parallel wires of negligible mass and length $L = 30cm$ are separated by a distance $r = 1cm$ as shown below. Both wires have the same magnitude of current (I) flowing through them where the lower wire's current is flowing left-to-right, and the upper wire's current direction is unknown. The lower wire is fixed in position and cannot move while the upper wire is free to move.

1. A s a result of the currents flowing in the two wires, the upper wire experiences an upward magnetic force. Explain the direction of the current flow in the upper wire.



The lower wire's current creates a magnetic field at the upper wire's location that points out of the page by the second right-hand-rule. With the magnetic force on the upper wire up and the magnetic field out of the page, the current by the first right-hand-rule flows right-to-left.

2. The magnetic force on the upper wire causes this wire to move away from the lower wire. Masses are added to the upper wire to return the system to an equilibrium separation of $r = 1cm$. If a mass of $m = 150mg$ is added to the upper wire, what current I flows in the system?



$$F_B - F_W = ma_y = 0 \rightarrow F_B = F_W$$

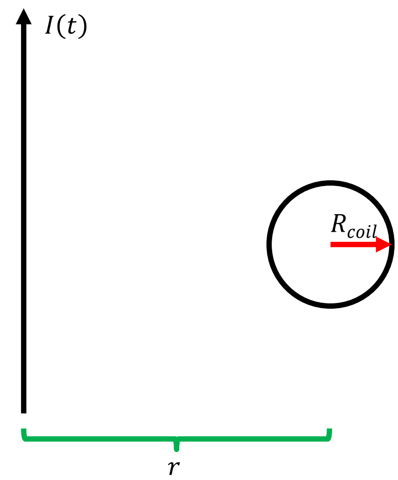
$$ILB = IL\left[\frac{\mu_0 I}{2\pi r}\right] = mg \rightarrow I = \rightarrow \sqrt{\frac{2\pi rmg}{\mu_0 L}}$$

$$I = \sqrt{\frac{2\pi \times 0.01m \times (150 \times 10^{-6}kg) \times 9.8\frac{m}{s^2}}{4\pi \times 10^{-7}\frac{Tm}{A} \times 0.3}}$$

$$I = 15.7A$$

3. Consider a $N = 200$ turn coil of wire with radius $R_{coil} = 0.5cm$ lying in the plane of the page. A long straight wire lies $r = 60cm$ to the left of the center of the coil of wire and the current (in amps) in the long straight wire varies in time according to $I(t) = 4.7 - 0.2t$, for a time t in seconds over the range $0 \leq t \leq 10$. Explain the direction of the current induced in the coil of wire.

Since the current is decreasing in time, the magnetic field everywhere in space due to the long straight wire is decreasing in time. At the coil of wire's location, the magnetic field is pointing into the page. Thus, the magnetic flux through the coil of wire pointing into the page is decreasing. To undo the decrease, we need the coil of wire to produce a magnetic field that also points into the page. To achieve this, we need a clockwise current to flow in the coil of wire.



4. What magnitude of voltage is induced across the coil of wire?

$$\epsilon = \left|-N\frac{\Delta\phi_B}{\Delta t}\right| = \left|200\pi r_{coil}^2 \cos\theta \frac{\Delta B}{\Delta t}\right|$$

$$\epsilon = \left|200\pi(0.005m)^2 \cos 0 \left(\frac{9 \times 10^{-7}T - 1.6 \times 10^{-6}T}{10s}\right)\right| = 1.1 \times 10^{-9}V$$

$$B_f = \frac{\mu_0 I_f}{2\pi r} = \frac{4\pi\times10^{-7}\frac{Tm}{A}\times\left(4.7A - 0.2\frac{A}{s}\times10s\right)}{2\pi\times0.6m} = 9 \times 10^{-7}T$$

$$B_i = \frac{\mu_0 I_i}{2\pi r} = \frac{4\pi \times 10^{-7}\frac{Tm}{A} \times \left(4.7A - 0.2\frac{A}{s} \times 0s\right)}{2\pi \times 0.6m} = 1.6 \times 10^{-6}T$$

5. If the coil of wire has a resistance $R = 3m\Omega$, what magnitude of current flows in the coil of wire?

$$I = \frac{\epsilon}{R} = \frac{1.1 \times 10^{-9}V}{3 \times 10^{-3}\Omega} = 3.7 \times 10^{-7}A = 0.37\mu A$$