Name____

Physics 111 Quiz #4, October 15, 2021

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

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

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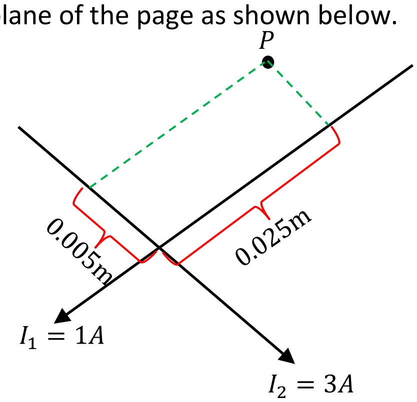
1. Suppose that you have two long straight wires that lie in the plane of the page as shown below. What is the net magnetic field at point P?



Let into the page be the positive direction.

$$B_{net} = B_1 - B_2$$

$$B_{net} = \frac{\mu_0 I_1}{2\pi r_1} - \frac{\mu_0 I_2}{2\pi r_2} = \frac{\mu_0}{2\pi}\left(\frac{I_1}{r_1} - \frac{I_2}{r_2}\right)$$

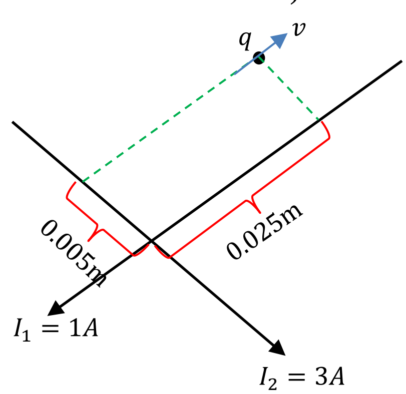
$$B_{net} = 2 \times 10^{-7}\frac{Tm}{A}\left(\frac{1A}{0.005m} - \frac{3A}{0.025m}\right) = 1.6 \times 10^{-5}T$$

Thus, the net magnetic field is into the page with magnitude $1.6 \times 10^{-5}T$.

2. Suppose that you accelerate an iodine ion ${}^{127}_{53}I^{-1}$ from rest through a potential difference of $\Delta V = 1000V$. What is the speed of the iodine ion after it has been accelerated through this potential difference?

$$W = -q\Delta V = \Delta K = \tfrac{1}{2}mv_f^2 \rightarrow v_f = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2\times\left(1000eV\times\frac{1.6\times10^{-19}J}{1eV}\right)}{127u\times\frac{1.66\times10^{-27}kg}{1u}}} = 3.9 \times 10^4\frac{m}{s}$$

3. Suppose that the iodine ion was directed as shown below. Assuming that the net magnetic field was uniform in the vicinity of point P, what would be the direction (clockwise or counterclockwise) and radius of the iodine ion's orbit? Hint: Assume $\vec{v} \perp \vec{B}$.

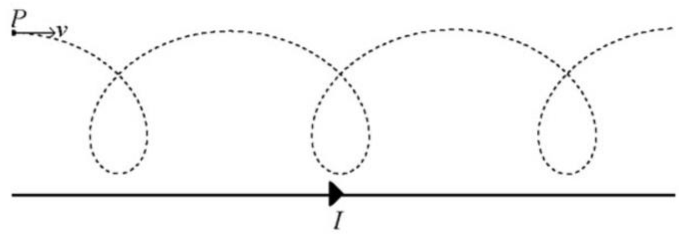


By the right-hand rule, since the net magnetic field is into the page, the force on q is directed down and the motion is clockwise. The magnitude of the force is given by:

$$F_B = ma_c \rightarrow qv_\perp B = \frac{mv_\perp^2}{R} \rightarrow R = \frac{mv_\perp}{qB}$$

$$R = \frac{\left(127u\times\frac{1.66\times10^{-27}kg}{1u}\right)\times3.9\times10^4\frac{m}{s}}{1.6\times10^{-19}C\times1.6\times10^{-5}T} = 3212m$$

4. Suppose instead you had the following situation. An unknown charge is moving horizontally above a wire with no current initially flowing. At some point, a current is turned on and the unknown charge moves in the plane of the page along the dotted line as shown below. Explain fully, what the sign (positive or negative) of the unknown charge must be to produce the motion shown above?



The magnetic field from the wire points out of the page at point P. Since the charge moves down, the net force must be down. By the right-had rule, the charge must be positive to produce the motion.

5. Explain fully the motion of the unknown charge through the magnetic field shown above. This question involves no calculations but does involve your use of formulas to explain the motion. Be sure to explain in complete detail the motion of the charge and why it moves as it does.

The magnetic force is always perpendicular to the velocity and thus the speed of the charge never changes. Since this is true, the motion should be a circle of radius R. However, the magnetic field ($B = \frac{\mu_0 I}{2\pi r}$) is not uniform and varies with r, the distance between the charge and the wire. As r gets smaller, the magnetic field gets larger, and the magnetic force ($F_B = qvB$) gets larger. The magnetic force causes the charge to undergo a centripetal acceleration and this acceleration ($\frac{v^2}{r}$) varies with the force. Since the acceleration also depends on F, as the force gets larger (due to the increasing magnetic field) the orbital radius of the charge gets smaller and we produce the teardrop shape. The upward motion of the charge close to the wire is due to the changing direction of the velocity vector. Since the direction of the velocity vector changes direction, by the right-hand rule, so to does the force (assuming here that the magnetic field does not.)