Physics 1BH Winter 2022 Midterm #2

Name (please print): Katherine Callahan

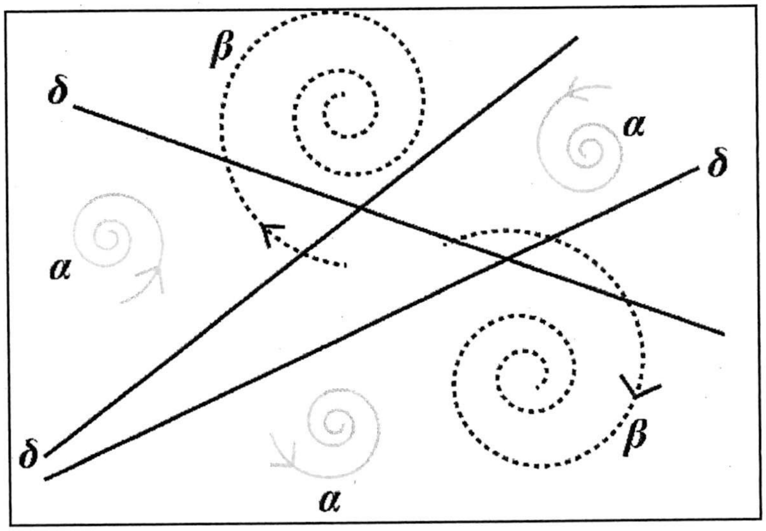
UID: 505-718-225

Instructions

- This exam is 50 minutes long.
- This exam is closed-notes, closed-book. No phones or calculators allowed.
- The standard equations sheet is allowed.
- You will independently be given points for your reasoning, your mathematical work, and for correctness of answers, so make sure to show your reasoning and work even if you're not certain you can compute the correct answer. Try to convey your solution strategy even if you can't execute it in time.
- If on a given problem you need some space to do scratch work, do that scratch work **ELSEWHERE**. Only the work that is included on this test packet **in the boxed space provided will be graded**. If you need additional sheets please ask the instructor/proctor.
- **Put boxes around any final numerical or symbolic answers.**
- **DO NOT BOX MULTIPLE "FINAL" ANSWERS. If you do not want an answer graded, cross it out COMPLETELY with an 'X.'** Providing multiple "final" answers will result in a zero for that question.

Problem 1	10 pts
Problem 2	30 pts
Problem 3	30 pts
Problem 4	30 pts

1. (**10 points**) Imagine a device for measuring cosmic ray particles. A chamber containing a strong **out-of-page** magnetic field is filled with a medium (say a liquid) that can **visualize** the paths of fast-moving particles. The paths in the presence of the magnetic can tell us the sign of the charge and the momentum, $p = mv$. To the right is an image from such a chamber where three particles are identified: **α, β, δ.** (*Note: A similar apparatus is called a "bubble chamber" and a similar image is found on the cover of The Strokes' album "Is This It."*)



a. For each particle (**α, β, δ**) state whether the charge is negative/positive or neutral. Briefly explain.
b. For the charged particles above, which has the larger magnitude momentum? Why?
[***Hint:*** *Think about the connection between the Lorentz force and centripetal motion.*]

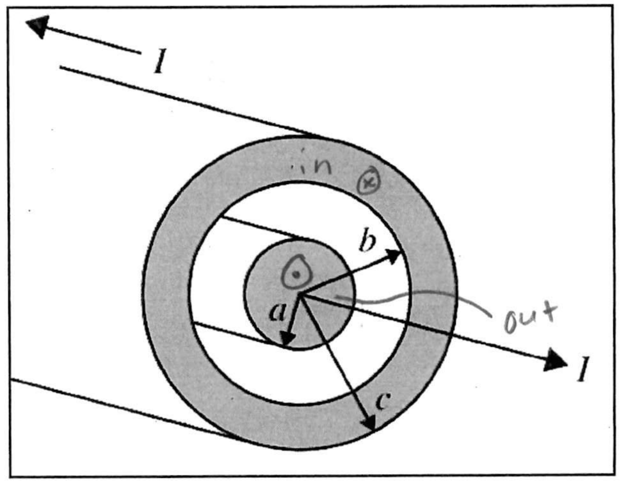
$F_B = Q\vec{v} \times \vec{B}$

a) Particle α is positive because its velocity and the magnetic field indicate a force pointing to the center of its circular path, which is in line with its movement. Particle β is negative because its circular path does not line up with where the force on it points, according to the right hand rule, so it must be negative. Particle δ has a neutral charge because it does not have circular motion, indicating it does not experience any force.

b) $Q\vec{v} \times \vec{B} = mv^2/r \rightarrow r = \frac{mv}{QB} = \frac{p}{QB}$

Particle β has a larger momentum magnitude because the initial radius of its circular path is larger, indicating more momentum. When using the Lorentz force and centripetal motion, the radius of the circular path is proportional to momentum, so a higher radius means a higher momentum magnitude.

2. (**30 points**) Equal but anti-parallel **uniformly distributed** currents I exist in two conductors that comprise a coaxial cable of radii a, b, c (refer to figure).



Derive expressions for the magnetic field at radial distances r:

(a) $r < a$
(b) $a < r < b$
(c) $b < r < c$
(d) $c < r$

a)

Ampere's Law:

$$B(2\pi r) = \mu_0 I_{enc}$$

$$I_{enc} = \frac{\pi r^2}{\pi a^2} I = \frac{r^2}{a^2} I$$

$$B = \frac{\mu_0}{2\pi r} \cdot \frac{r^2}{a^2} I = \frac{\mu_0 r I}{2\pi a^2}$$

$$B_1 = \frac{\mu_0 r I}{2\pi a^2}$$ counterclockwise

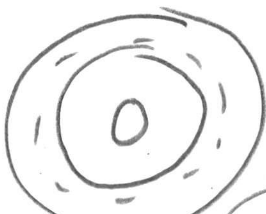
b) $a < r < b$

$$B(2\pi r) = \mu_0 I_{enc}$$

$I_{enc} = I$ (out of page)

$$B_2 = \frac{\mu_0 I}{2\pi r}$$ counterclockwise

c) $b < r < c$



$$B(2\pi r) = \mu_0 I_{enc}$$

$$I_{enc} = I - \frac{c^2}{b^2} I = I\left(1 - \frac{r^2}{c^2}\right)$$

$$I_2 = \frac{\pi r^2}{\pi c^2}$$

$$B = \frac{\mu_0}{2\pi r} I\left(1 - \frac{r^2}{c^2}\right)$$

$$B = \frac{\mu_0 I}{2\pi r} - \frac{\mu_0 I r}{2\pi c^2}$$ counterclockwise

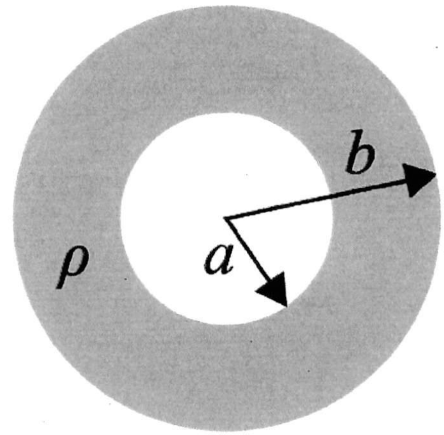
d) $c < r$

$B(2\pi r) = \mu_0 I_{enc}$

$I_{enc} = 0$

$\boxed{\vec{B} = 0}$

3. (**30 points**) The region between two thin concentric spherical shells of a conductor is filled with material with resistivity $\rho = 24{,}000\ \Omega\text{–m}$. The inner conductor has a radius $a = 2.0$ m and the outer conductor radius $b = 4.0$ m. What is the resistance between the inner and outer conductor?



$R = \rho \frac{L}{A}$

$L = 2\pi r$

$A = \pi b^2 - \pi a^2 = \pi(b^2 - a^2) = 12\pi$

$a < r < b \; = 2 < r < 4$

$R = \rho \frac{2\pi r}{6 \cdot 12\pi}$

$dR = \frac{\rho}{6} dr$

$R = \int_2^4 \frac{\rho}{6} dr = \frac{\rho}{6}\left[r\right]_2^4$

$= \frac{\rho}{6}[4-2]$

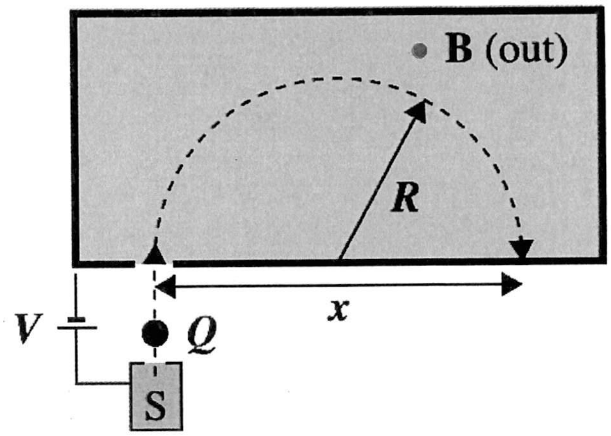
$= \frac{\rho}{6}(2) = \frac{\rho}{3}$

$24{,}000/3 = 8{,}000$

$\boxed{R = 8{,}000\ \Omega}$

4. (**30 points**) Pictured here is an arrangement to measure the charge-to-mass ratio of a mystery ion of mass m and charge Q that is produced at rest from a source S. It is accelerated by a potential difference $V = 1000$ V and allowed to enter a (gray) region of constant magnetic field $\mathbf{B} = 10$ T (pointing out of the page). If it travels along a semi-circular path of diameter $2R = x = 1$ m, what is the charge-to-mass ratio, Q/m, in C/kg? It may be helpful to recall that 1 Tesla $= \dfrac{\text{kg}}{\text{C} \cdot \text{s}}$ and 1 Volt $= \dfrac{\text{kg} \cdot \text{m}^2}{\text{C} \cdot \text{s}^2}$.

Hint: As always, solve for Q/m **before** filling in numerical values.



$F_c = m\dfrac{v^2}{R}$, charge is negative

$F_B = Q\, v \times B$

$\dfrac{mv^2}{R} = Q\, v \times B$

$\dfrac{mv}{R} = QB$

$\dfrac{Q}{m} = \dfrac{v}{BR}$, where v is the velocity

$\Delta\phi = 1000\text{ V}$

$\dfrac{m}{s} \cdot \dfrac{10\text{ C}\cdot s}{kg} \cdot \dfrac{1}{m}$

$\dfrac{Q}{m} = \dfrac{v}{BR}$ (units: $10\text{ C}/\text{kg}$)

Problem	Score	Max pts
Problem 1		10 pts
Problem 2		30 pts
Problem 3		30 pts
Problem 4		30 pts
Total		100 pts