Physics 212-01. Fall 2008. Midterm # III. Version 1

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1. Consider a particle, of charge \(Q\), that undergoes a circular orbit due to a magnetic field \(B\) (\(B\) pointing into the papers). The speed of the orbiting charge is 0.1\% of the speed of light \(c\), and the radius of the orbit is \(5.7 \times 10^{-14}\) m. Which expression defines the mass of the particle?

(a) \((5.7 \times 10^{-11})QB\)  
(b) \((5.7 \times 10^{-11})QB/c\)  
(c) \((5.7 \times 10^{-13})QB/c\)  
(d) \((5.7 \times 10^{-13}) B/c\)  
(e) \((5.7 \times 10^{-14})QB/c\)

For condition: \(\vec{B} \perp \vec{v}\), we found that: 
\[ r = \frac{mv}{qB} \]

\[ m = \frac{r qB}{0.001c} \]

\[ \nu \approx 0.1 \% c \]

\[ r = 5.7 \times 10^{-14} \text{ m} \]

2. A positive charge found to have a constant speed \(v = 3.6 \times 10^4\) m/s in the device described in the Figure. The device consists of a parallel plate capacitor embedded in a uniform magnetic field points into the page. The magnitude of the electric field of the capacitor is \(7.2 \times 10^4\) V/m. What is the magnitude of the magnetic field?

(a) 1 T  
(b) 3 T  
(c) 2 T  
(d) 4 T  
(e) \(7.2 \times 10^{-4}\) T  
(f) \(3.6 \times 10^{-4}\) T  
(g) 0.5 T  
(h) 0.25 T

3. What is the magnitude of total force (i.e. magnetic+electric) on a moving charges in a segment of a semiconductor placed in a Hall type setup? (Consider equilibrium was reached).

(a) bigger than zero  
(b) depending on the speed of the charges  
(c) zero  
(d) depending on \(B\)

Read note and derivation in book.  
(same situation as in problem #2)
4. A 0.12 m long straight wire carrying a current of 7.2 A is maneuvered entirely within a region known to contain a constant magnetic field until the force on the wire has a maximum magnitude of 0.37 N. What is the magnitude of the magnetic field?

(a) 0.2 T (b) 43 T (c) 2.3 T (d) 0.43 T (e) 0.37 T (f) 12 T (g) 0.01 T

\[ \vec{F} = I \vec{\ell} \times \vec{B}, \text{ magnitude } F = I L B \sin \theta \] \[ F_{\text{max}} \text{ maximum for } \theta = 90^\circ, \sin \theta = 1 \]

\[ F_{\text{max}} = I L B \Rightarrow B = \frac{F}{I L} = \frac{0.37}{7.2 \times 0.12} = 0.43 \text{ T} \]

5. A wire carrying a current \( I \) is placed in a magnetic field \( B \). In which situation the magnetic force on the wire is zero?

(a) \( I \) is perpendicular to \( B \) \( \quad \) (b) \( I \) is parallel to \( B \) \( \quad \) (c) the angle between \( I \) and \( B \) is \( 45^\circ \)

\[ \vec{F} = I \vec{\ell} \times \vec{B}, \quad F = I L B \sin \theta \] \[ \text{for } \theta = 0^\circ, \sin \theta = 0, \quad F = 0 \]

Then \( I \) is parallel to \( B \)

6. The Figure shows a proton traveling through a region of uniform electric and magnetic fields. The direction of the field \( E \) is directed parallel to the \( y \) axis and has a magnitude of 2000 V/m. The magnetic field \( B \) is directed out of the figure (in the positive direction of the \( z \) axis) and has a magnitude of 0.50 T. At the instant the proton’s velocity vector is in the positive direction of the \( x \) axis as shown, the total force (magnetic+electric) on the proton found to be \( 4.8 \times 10^{-16} \) N in the negative \( y \)-direction.

What is the speed of the proton?

(a) 2000 m/s (b) \( 1.6 \times 10^{-19} \) m/s (c) 1000 m/s (d) 0 (e) \( 10000 \) m/s (f) 3 m/s

\[ \vec{F}_t \text{ is given by} \]

\[ \vec{F}_t = \vec{F}_e + \vec{F}_{\text{magnetic}} \]

\[ \vec{F}_e = q \vec{E} = 1.6 \times 10^{-19} (2000 \hat{j}) = 3.2 \times 10^{-16} \text{ N}(\hat{j}) \text{ and} \]

\[ \vec{F}_m = q \vec{v} \times \vec{B} = 1.6 \times 10^{-19} (\vec{v}) (0.5) = 8 \times 10^{-20} \text{ N} (\hat{\gamma}) \]

Thus, the vector equation:

\[ 4.8 \times 10^{-16} (\hat{\gamma}) = 3.2 \times 10^{-16} (\hat{j}) + 8 \times 10^{-20} \text{ N} (\hat{\gamma}) \]

Solve for \( \vec{v} \):

\[ \vec{v} = \frac{4.8 \times 10^{-16} + 3.2 \times 10^{-16}}{8 \times 10^{-20}} = 10000 \text{ m/s} \]
7. Consider the same Figure as in Problem 7. Again, The Figure shows a proton traveling through a region of uniform electric and magnetic fields. The direction of the field \( E \) is directed parallel to the \( y \) axis and has a magnitude of 2000 \( \text{V/m} \). The magnetic field \( B \) is directed out of the figure (in the positive direction of the \( z \) axis) and has a magnitude of 0.50 \( \text{T} \).

At the instant the proton’s velocity vector is in the positive direction of the \( x \) axis as shown the speed found to be 4000 \( \text{m/s} \). Find the total force (magnetic+electric) on the proton.

(a) 4.8x10\(^{16} \) N  (b) 3 N  (c) zero  (d) 3.2x10\(^{16} \) N  (e) 10000 N  (f) 500 N  (g) 10 N  (h) 6.4x10\(^{16} \) N

\[ \vec{F}_E = qE = 3.2 \times 10^{-16} \text{N} \hat{y} \]

\[ \vec{F}_m = qvB = 3.2 \times 10^{-16} \text{N} \times 4000 \left( -\hat{y} \right) \]

\[ \vec{F}_{\text{net}} = \vec{F}_m + \vec{F}_E = 3.2 \times 10^{-16} \text{N} \hat{y} + 3.2 \times 10^{-16} \text{N} \hat{y} = 0 \]

8. Draw the magnetic field lines of a bar of magnet: pattern and directions.

![Magnetic Field Lines](image)

9. What is the magnitude of \( \frac{1}{\mu_0} \oint \vec{B} \cdot d\vec{s} \) for the closed path presented in the figure (in units of amperes)?

(a) 0  (b) 3  (c) 6  (d) 7  (e) 10  (f) 8  (g) 12

**Ampère’s Law:** \( \oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enclosed}} \text{ in the path} \)

\[ \frac{1}{\mu_0} \oint \vec{B} \cdot d\vec{s} = I_{\text{enclosed}} = 1 + 4 - 2 = 3 \]
10. The magnetic field 0.4 m away from a long, straight wire carrying current 2.00 A is 1.0x10^-6 T. At what distance is it 0.2x10^-6 T?

(a) 1 m  (b) 4 m  (c) 7 m  (d) 0.5 m  (e) 2 m  (f) 0.25 m  (g) 0.2x10^-6 m  (h) 100 m

Use \( B = \frac{\mu_0 I}{2\pi r} \) for a long wire.

\[
\begin{align*}
B_1 &= 1.0 \times 10^{-6} T, & B_2 &= 0.2 \times 10^{-6} T \\
\frac{B_1}{B_2} &= \frac{1}{4} \\
\frac{1 \times 10^{-6}}{0.2 \times 10^{-6}} &= \frac{r_2}{0.4} \\
solve for r_2 &= 2 m
\end{align*}
\]

11. A proton moving at 4.0x10^6 m/s through a magnetic field of magnitude 1.70 T experiences a magnetic force of magnitude 8.2x10^{-13} N. What is the angle between the proton’s velocity and the field?

(a) 0°  (b) 12.6°  (c) 0.4°  (d) 48.9°  (e) 0.75°  (f) 90°  (g) 0°  (h) 180°

\[
\vec{F} = 9 \vec{v} \times \vec{B}, \quad \vec{F} = 9 vvBsin\theta
\]

\[
8.2 \times 10^{-13} = (1.6 \times 10^{-19})(4 \times 10^6)(1.7)sin\theta, \quad solve for sin\theta
\]

\[
sin\theta = 0.754
\]

\[
\theta = \sin^{-1}0.754 = 48.9°
\]

12. Draw the magnetic field (pattern and direction) of a wire which carries a current I.

13. Two parallel wires of equal length carry currents (see Figure). Assume \( I_1 = 2 \) A and \( I_2 = 6 \) A. What is the relationship between the magnitude \( F_1 \) (the magnetic force on wire 1) and the magnitude \( F_2 \) (the magnetic force on wire 2)?
(a) $F_1 = 6F_2$  (b) $F_1 = 3F_2$  (c) $F_1 = F_2$  (d) $F_1 = (1/3)F_2$  (e) $F_1 = (1/6)F_2$  (f) $F_1 = 4F_2$

The field $\mathbf{B}_2$ due to current $I_2$ exerts a magnetic force of magnitude
\[ \mathbf{F}_2 = I_2 l \mathbf{B}_2 = I_2 l \left( \frac{\mu_0 I_2}{2\pi r} \right) \] on wire $2$.

Similarly, the field $\mathbf{B}_1$ due to current $I_1$ exerts a magnetic force of magnitude
\[ \mathbf{F}_1 = I_1 l \mathbf{B}_1 = I_1 l \left( \frac{\mu_0 I_1}{2\pi r} \right) \] on wire $1$.

\[ \Rightarrow F_1 = F_2 \]

14. Considering a proton entering, at velocity $\mathbf{v}$, a uniform magnetic field $\mathbf{B}$. The magnetic force, $\mathbf{F}$, on the proton has a maximum when $\mathbf{v}$ is:

(a) parallel to $\mathbf{B}$  (b) perpendicular to $\mathbf{B}$  (c) zero  (d) antiparallel to $\mathbf{B}$

\[ \mathbf{F} = q\mathbf{v} \times \mathbf{B}, \quad \mathbf{F} = q\mathbf{vB} \sin \theta, \quad \mathbf{F} \text{ is maximum for } \theta = 90^\circ, \sin 90^\circ = 1 \]

\[ \mathbf{v} \perp \mathbf{B} \]

15. A current-carrying, rectangular coil of wire is placed in a uniform magnetic field $\mathbf{B}$. The magnitude of the torque on the coil is not dependent upon which one of the following quantities?

(a) the magnitude of the current in the loop  (b) the direction of the current in the loop  (c) the length of the sides of the loop  (d) the area of the loop  (e) the orientation of the loop relative to $\mathbf{B}$

\[ \mathbf{I} = \mathbf{I} \times \mathbf{B} \]

\[ \mathbf{I} \times \mathbf{B} \sin \theta \]

The magnitude of the torque depends on the magnitude of the current but not on its direction.

\[ \mathbf{B} \text{ is at an angle } \theta \text{ with respect to vector } \mathbf{a}, \text{ which is perpendicular to the plane of the loop.} \]