Magnetic Fields and Forces  
Physics 106

Concepts:
1. Magnets
2. Earth’s Magnetic Field
3. Magnetic Fields
4. Magnetic Force on a Current-Carrying Conductor
5. Motion of a Charged Particle in a Magnetic Field

Units

\[ F_{\text{mag}} \text{ Force, Newtons (N)} \]
\[ B \text{ Magnetic Field, Tesla (T)} \]
\[ |B| = T = \frac{Wb}{m^2} = \frac{N}{C \cdot m / s} = \frac{N}{A \cdot m} \]

Equations:

**Vector equation** for magnetic (Lorentz) force: \( \vec{F} = q \vec{v} \times \vec{B} \)

- \( \vec{B} \) is the magnetic field, \( \vec{v} \) is the velocity of the particle and \( q \) is the charge of the particle.
- The \( \times \) symbol means “cross product”—use right hand rule.

**Magnitude equation** for magnetic force: \( F = qvB\sin \theta \)

- To get just the magnitude, use just the numerical values for \( q, v \) and \( B \), and then multiply by the sin of the angle between \( v \) and \( B \).

Current carrying wire: \( F = BIl \sin \theta \), where \( B \) is magnetic field, \( I \) is current, \( l \) is the length of the wire and \( \sin \theta \) is the angle between \( B \) and \( I \).

Radius of a particle’s motion when it enters a magnetic field: \( r = \frac{mv}{qB} \), where \( m, v \) and \( q \) are the mass, velocity and charge of the particle, and \( B \) is the magnetic field.

**Sample Problem**
A singly charged positive ion has a mass of 2.5E-26 kg. After being accelerated through a potential difference of 250 V, the ion enters a magnetic field of 0.500 T, in a direction perpendicular to the field. Calculate the radius of the ion’s path in the field.
A proton moves perpendicularly to a uniform magnetic field $B$ at $1.0 \times 10^7$ m/s and experiences an acceleration of $2.0 \times 10^{13}$ m/s$^2$ in the $+x$ direction when its velocity is in the $+z$ direction. Determine the magnitude and direction of the field.

A 15-cm length of conductor that is free to move is held in place between two thin conductors. When a 5.0 A current is directed as shown in the figure, the wire segment moves upward at a constant velocity. If the mass of the wire is 15 g, find the magnitude and direction of the minimum magnetic field that is required to move the wire. (The wire slides without friction).

Sample Exam Question
A proton moving at a speed of $3.8 \times 10^6$ m/s cuts across the lines of a magnetic field at an angle of 70°. The strength of the field is $0.25 \times 10^{-4}$ T. What is the magnitude of the force acting on the proton?

- a. $5.1 \times 10^{-18}$ N
- b. $9.0 \times 10^{-18}$ N
- c. $1.4 \times 10^{-17}$ N
- d. $2.3 \times 10^{-17}$ N

Sample Conceptual Exam Question
The right-hand rule allows one to find a property of the interaction of a magnetic field with a charged particle. The right-hand rule applied to moving charges:

- a. results in positive charges moving clockwise.
- b. results in negative charges moving clockwise.
- c. can be used for positive charges only.
- d. gives the direction of the force on a charge moving in a magnetic field.

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