# 06 – Magnetic Fields (Ch. 28)

$e = 1.60 \cdot 10^{-19}$ C; $m_p = 1.673 \cdot 10^{-27}$ Kg;  $m_e = 9.109 \cdot 10^{-31}$ Kg

1) A proton traveling at 23.0° with respect to the direction of a magnetic field of strength 2.60 mT experiences a magnetic force of $6.50 \cdot 10^{-17}$ N. Calculate (a) the proton's speed and (b) its kinetic energy in electron-volts.

1. **THINK** The magnetic force on a charged parti014cle is given by $\vec{F}_B = q\vec{v} \times \vec{B}$, where $\vec{v}$ is the velocity of the charged particle and $\vec{B}$ is the magnetic field.

**EXPRESS** The magnitude of the magnetic force on the proton (of charge $+e$) is $F_B = evB\sin\phi$, where $\phi$ is the angle between $\vec{v}$ and $\vec{B}$.

**ANALYZE** (a) The speed of the proton is

$$v = \frac{F_B}{eB\sin\phi} = \frac{6.50\times10^{-17}\,\text{N}}{\left(1.60\times10^{-19}\,\text{C}\right)\left(2.60\times10^{-3}\,\text{T}\right)\sin 23.0°} = 4.00\times10^{5}\,\text{m/s}.$$

(b) The kinetic energy of the proton is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}\left(1.67\times10^{-27}\,\text{kg}\right)\left(4.00\times10^{5}\,\text{m/s}\right)^2 = 1.34\times10^{-16}\,\text{J},$$

which is equivalent to

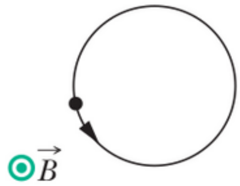
$$K = (1.34\times10^{-16}\,\text{J}) / (1.60\times10^{-19}\,\text{J/eV}) = 835\,\text{eV}.$$

2) A particle of mass 10 g and charge 80 μC moves through a uniform magnetic field, in a region where the free-fall acceleration is $-9.8\hat{j}$ m/s$^2$. The velocity of the particle is a constant $20\hat{i}$ km/s , which is perpendicular to the magnetic field. What, then, is the magnetic field?

2. The force associated with the magnetic field must point in the $\hat{j}$ direction in order to cancel the force of gravity in the $-\hat{j}$ direction. By the right-hand rule, $\vec{B}$ points in the $-\hat{k}$ direction (since $\hat{i}\times\left(-\hat{k}\right) = \hat{j}$). Note that the charge is positive; also note that we need to assume $B_y = 0$. The magnitude $|B_z|$ is given by Eq. 28-3 (with $\phi = 90°$). Therefore, with $m = 1.0\times10^{-2}$ kg, $v = 2.0\times10^{4}$ m/s, and $q = 8.0\times10^{-5}$ C, we find

$$\vec{B} = B_z\hat{k} = -\left(\frac{mg}{qv}\right)\hat{k} = (-0.061\ \text{T})\hat{k}\,.$$

18) In the figure, a particle moves along a circle in a region of uniform magnetic field of magnitude B = 4.00 mT. The particle is either a proton or an electron (you must decide which). It experiences a magnetic force of magnitude $3.20 \cdot 10^{-15}$ N. What are (a) the particle's speed, (b) the radius of the circle, and (c) the period of the motion?




18. With the $\vec{B}$ pointing "out of the page," we evaluate the force (using the right-hand rule) at, say, the dot shown on the left edge of the particle's path, where its velocity is down. If the particle were positively charged, then the force at the dot would be toward the left, which is at odds with the figure (showing it being bent toward the right). Therefore, the particle is negatively charged; it is an electron.

(a) Using Eq. 28-3 (with angle $\phi$ equal to 90°), we obtain

$$v = \frac{|\vec{F}|}{e|\vec{B}|} = 4.99 \times 10^{6} \text{ m/s}.$$

(b) Using either Eq. 28-14 or Eq. 28-16, we find $r = 0.00710$ m.

(c) Using Eq. 28-17 (in either its first or last form) readily yields $T = 8.93 \times 10^{-9}$ s.

39) A horizontal power line carries a current of 5000 A from south to north. Earth's magnetic field (60.0 μT) is directed toward the north and inclined downward at 70.0° to the horizontal. Find the (a) magnitude and (b) direction of the magnetic force on 100 m of the line due to Earth's field.

39. **THINK** The magnetic force on a wire that carries a current $i$ is given by $\vec{F}_B = i\vec{L} \times \vec{B}$, where $\vec{L}$ is the length vector of the wire and $\vec{B}$ is the magnetic field.

**EXPRESS** The magnitude of the magnetic force on the wire is given by $F_B = iLB \sin \phi$, where $\phi$ is the angle between the current and the field.

**ANALYZE** (a) With $\phi = 70°$, we have

$$F_B = (5000 \text{ A})(100 \text{ m})(60.0 \times 10^{-6} \text{ T}) \sin 70° = 28.2 \text{ N}.$$

(b) We apply the right-hand rule to the vector product $\vec{F}_B = i\vec{L} \times \vec{B}$ to show that the force is to the west.

**LEARN** From the expression $\vec{F}_B = i\vec{L} \times \vec{B}$, we see that the magnetic force acting on a current-carrying wire is a maximum when $\vec{L}$ is perpendicular to $\vec{B}$ ($\phi = 90°$), and is zero when $\vec{L}$ is parallel to $\vec{B}$ ($\phi = 0°$).