Chapter 22: Magnetism

11. A charged particle moves in a region in which a magnetic field exists.
Solve the magnetic force equation (equation 22-1) for the angle θ that would produce the specified force.

1. (a) Solve equation 22-1 for θ: $\theta = \sin^{-1}\left(\frac{F}{qvB}\right)$

2. Insert the numerical values for $F = 4.8\ \mu\text{N}$: $\theta = \sin^{-1}\left[\frac{4.8\times10^{-6}\ \text{N}}{(0.32\times10^{-6}\ \text{C})(16\ \text{m/s})(0.95\ \text{T})}\right] = \boxed{81^\circ}$

3. (b) Insert the numerical values for $F = 3.0\ \mu\text{N}$: $\theta = \sin^{-1}\left[\frac{3.0\times10^{-6}\ \text{N}}{(0.32\times10^{-6}\ \text{C})(16\ \text{m/s})(0.95\ \text{T})}\right] = \boxed{38^\circ}$

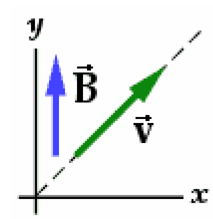
4. (c) Insert the numerical values for $F = 0.10\ \mu\text{N}$: $\theta = \sin^{-1}\left[\frac{1.0\times10^{-7}\ \text{N}}{(0.32\times10^{-6}\ \text{C})(16\ \text{m/s})(0.95\ \text{T})}\right] = \boxed{1.2^\circ}$

12. A charged particle moves in a region in which a magnetic field exists.
Use a ratio together with equation 22-1 to determine the force the particle experiences after changing its speed and the angle its velocity makes with the magnetic field.

1. Use equation 22-1 to make a ratio: $\frac{F_{\text{new}}}{F_{\text{old}}} = \frac{qv_{\text{new}}B\sin\theta_{\text{new}}}{qv_{\text{old}}B\sin\theta_{\text{old}}} = \frac{v_{\text{new}}\sin\theta_{\text{new}}}{v_{\text{old}}\sin\theta_{\text{old}}} = \frac{(6.3\ \text{m/s})\sin 25^\circ}{(27\ \text{m/s})\sin 90^\circ} = 0.099$

2. Now solve for F_{new}: $F_{\text{new}} = 0.099\,F_{\text{old}} = (0.099)(2.2\times10^{-4}\ \text{N}) = \boxed{2.2\times10^{-5}\ \text{N}}$

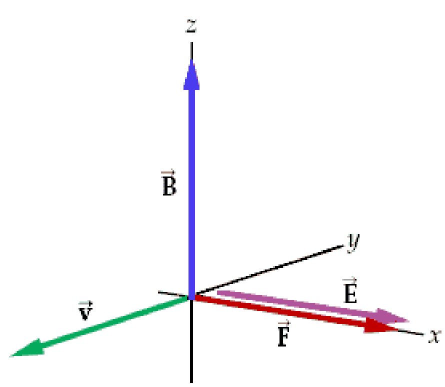
13. An ion moves with constant speed in a magnetic field.



The ion experiences no magnetic force when it is moving in the $\hat{\mathbf{y}}$ direction, so we conclude that the magnetic field also points in the $\hat{\mathbf{y}}$ direction. When the ion travels in the xy plane and along the line $y = x$, it moves at an angle of 45° with respect to $\vec{\mathbf{B}}$. When it moves in the $\hat{\mathbf{x}}$ direction, it experiences the maximum magnetic force.

Apply equation 22-2, letting $F_{\text{max}} = |q|vB$: $F = F_{\text{max}}\sin 45^\circ = (6.2\times10^{-16}\ \text{N})\sin 45^\circ = \boxed{4.4\times10^{-16}\ \text{N}}$

16. The directions of the electric field, magnetic field, velocity, and force vectors involved in this problem are depicted in the diagram at the right.



The particle is positively charged, so the electric field $\vec{\mathbf{E}}$ exerts a force in the $+\hat{\mathbf{x}}$ direction. Because the net force acting on the particle is in the $+\hat{\mathbf{x}}$ direction, the magnetic force must also be along the $\hat{\mathbf{x}}$ direction, but it could be in either the $+\hat{\mathbf{x}}$ direction or the $-\hat{\mathbf{x}}$ direction. We can compare the relative magnitudes of the net force and the electric force to decide in which of these two directions the magnetic force must point. Once the direction of $\vec{\mathbf{F}}_{\text{B}}$ is known, the Right-Hand Rule can be used to discern the direction of the particle's velocity $\vec{\mathbf{v}}$.

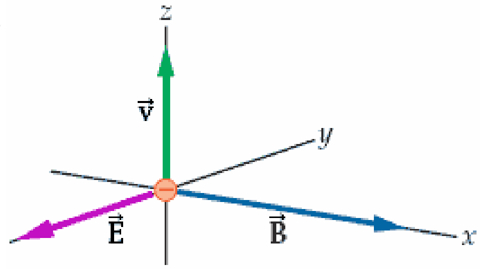
1. Find $\vec{\mathbf{F}}_{\text{E}}$ using equation 19-9: $\vec{\mathbf{F}}_{\text{E}} = qE\,\hat{\mathbf{x}} = (6.60\times10^{-6}\ \text{C})(1250\ \text{N/C})\,\hat{\mathbf{x}} = (8.25\times10^{-3}\ \text{N})\,\hat{\mathbf{x}}$

2. Because $F_{\text{net}} < F_E$, the force due to the magnetic field opposes the force due to the electric field and must point in the $-\hat{\mathbf{x}}$ direction. According to the RHR, $\vec{\mathbf{v}}$ is in the $\boxed{\text{negative } y\text{-direction}}$.

3. Write Newton's Second Law in the x direction and solve the expression for v:

$$\sum F_x = qE - qvB$$
$$qvB = qE - F_{\text{net}}$$
$$v = \frac{1}{B}\left(E - \frac{F_{\text{net}}}{q}\right) = \frac{1}{1.02\ \text{T}}\left(1250\ \frac{\text{N}}{\text{C}} - \frac{6.23\times10^{-3}\ \text{N}}{6.60\times10^{-6}\ \text{C}}\right)$$
$$= 300\ \text{m/s} = \boxed{0.30\ \text{km/s}}$$

22. A velocity selector is constructed by forming perpendicular $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ fields as indicated in the diagram at the right.

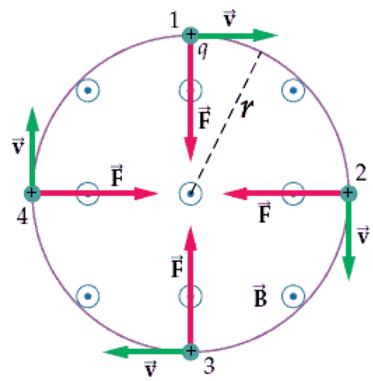


According to the Left-Hand Rule (or to the opposite of the Right-Hand Rule), the magnetic force on the negatively charged particle is in the $-\hat{\mathbf{y}}$ direction. The force due to the electric field must therefore point in the $+\hat{\mathbf{y}}$ direction in order to oppose the magnetic force, and $\vec{\mathbf{E}}$ must point in the $-\hat{\mathbf{y}}$ direction because the charge is negative. The magnitude of $\vec{\mathbf{E}}$ must satisfy the relation $v = E/B$, as discussed in the text.

Solve $v = E/B$ for E and incorporate the direction of $\vec{\mathbf{E}}$ as discussed in the Strategy:

$$\vec{\mathbf{E}} = vB(-\hat{\mathbf{y}}) = \left(4.5\times10^{3}\ \text{m/s}\right)(0.96\ \text{T})(-\hat{\mathbf{y}})$$
$$= \boxed{\left(-4.3\times10^{3}\ \text{N/C}\right)\hat{\mathbf{y}}}$$

25. The magnetic force on a charged particle traveling at constant speed causes it to move in a circle.



The magnetic force provides the centripetal force required to keep the particle moving in a circle. The radius of the circle in terms of m, v, q, and B is given by equation 22-3. We must first solve equation 22-3 for the speed v of the particle, then find the time it takes the particle to complete one orbit by dividing the circumference by the speed.

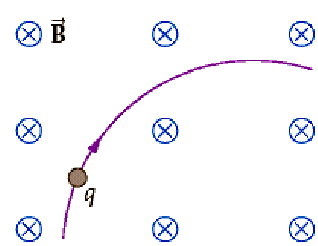
1. (a) Solve equation 22-3 for v:

$$v = \frac{qrB}{m} = \frac{\left(12.5\times10^{-6}\ \text{C}\right)(21.8\ \text{m})(1.01\ \text{T})}{2.80\times10^{-5}\ \text{kg}}$$
$$= \boxed{9.83\ \text{m/s}}$$

2. (b) Divide the circumference by the speed:

$$t = \frac{2\pi r}{v} = \frac{2\pi m}{qB} = \frac{2\pi(21.8\ \text{m})}{(9.83\ \text{m/s})} = \boxed{13.9\ \text{s}}$$

26. The magnetic force on a charged particle traveling at constant speed causes it to move in a circle.



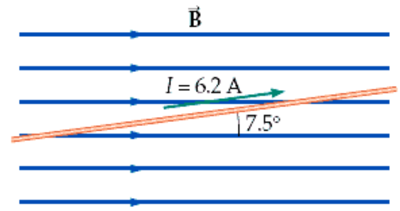
Apply the Right-Hand Rule to the diagram at the right in order to determine whether the particle is positively or negatively charged. Then use equation 22-3, which gives the radius of the circle in terms of m, v, q, and B, in order to find the mass m of the particle.

1. (a) According to the RHR, a positively charged particle would experience a force to the left. Because the particle is experiencing a force to the right, it must be negatively charged.

2. (b) Solve equation 22-3 for m:

$$m = \frac{erB}{v} = \frac{\left(1.60\times10^{-19}\ \text{C}\right)(0.520\ \text{m})(0.180\ \text{T})}{\left(6.0\times10^{6}\ \text{m/s}\right)} \times \frac{1.0\ \text{u}}{1.67\times10^{-27}\ \text{kg}} = \boxed{1.5\ \text{u}}$$

34. A current-carrying wire experiences a force due to the presence of a magnetic field.



Solve equation 22-4 for B to answer the question of part (a), and solve the same equation for θ to answer the question of part (b).

1. (a) Write equation 22-4 in terms of force per unit length:

$$\frac{F}{L} = I B \sin\theta$$

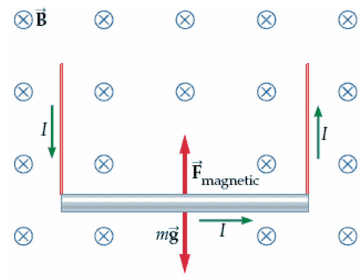
2. Solve for B:

$$B = \frac{F/L}{I\sin\theta} = \frac{0.033 \text{ N/m}}{(6.2 \text{ A})\sin 7.5°} = 0.041 \text{ T} = \boxed{41 \text{ mT}}$$

2. (b) Solve equation 22-4 for θ:

$$\theta = \sin^{-1}\frac{F/L}{I\,B} = \sin^{-1}\frac{0.015 \text{ N/m}}{(6.2 \text{ A})(0.041 \text{ T})} = \boxed{3.4°}$$

35. A wire carries a current in a region where the magnetic field exerts an upward force on the wire.



Set the magnitude of the magnetic force (equation 22-4) equal to the weight of the wire to find the current required to levitate the wire. The force is maximum when the current is perpendicular to the field. Therefore, the minimum required current occurs in the perpendicular configuration.

1. Set the magnetic force equal to the weight:

$$F = mg = I\,L\,B\sin 90° = I\,L\,B$$

2. Solve for I:

$$I = \frac{mg}{LB} = \frac{(0.75 \text{ kg})(9.81 \text{ m/s}^2)}{(3.6 \text{ m})(0.84 \text{ T})} = \boxed{2.4 \text{ A}}$$

43. Two wire loops have the same perimeter length, but one has the shape of a circle and the other a square. Each loop carries the same current and is immersed in the same magnetic field.

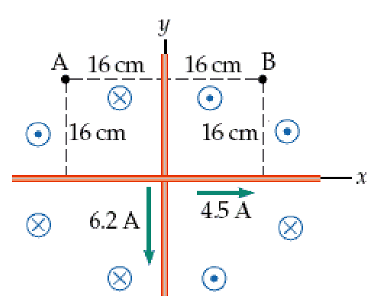
The two loops each experience a torque due to the magnetic field. The maximum torque is proportional to the area of the loop (equation 22-5). Use a ratio to determine which loop will experience the larger torque.

1. (a) A circle has a larger area than a square when the perimeters of each are equal. Therefore, the maximum torque of the square loop is $\boxed{\text{less than}}$ the maximum torque of the circular loop.

2. (b) Use equation 22-5 to calculate the ratio of the torques:

$$\frac{\tau_{\text{square}}}{\tau_{\text{circle}}} = \frac{IA_sB}{IA_cB} = \frac{A_s}{A_c} = \frac{\left(\frac{1}{4}L\right)^2}{\pi\left(\frac{1}{2\pi}L\right)^2} = \left(\frac{L^2}{16}\right)\left(\frac{4\pi}{L^2}\right) = \boxed{\frac{\pi}{4}} = 0.785$$

51. Two current-carrying wires cross at right angles and each produce a magnetic field.



The magnetic field produced by each wire is given by equation 22-9 and points in a direction given by the Right-Hand Rule (see figure 22-20). The field directions produced by the 4.5-A current are shown at the left and right of the diagram, and the field directions produced by the 6.2-A current are shown at the top and bottom. The net magnetic field is the vector sum of the magnetic field contributions from each wire.

1. (a) The field directions indicated in the diagram indicate that the field contributions subtract at point A and add at point B. We conclude that the magnitude of the net magnetic field is greatest at $\boxed{\text{point B}}$.

2. (b) Use equation 22-9 to find B_A:

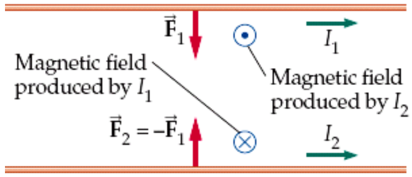
$$B_A = \frac{\mu_0 I_1}{2\pi r} + \frac{\mu_0 I_2}{2\pi r} = \frac{\mu_0}{2\pi r}(I_1 + I_2)$$

$$= \frac{(4\pi\times 10^{-7} \text{ T}\cdot\text{m/A})}{2\pi(0.16 \text{ m})}(6.2 - 4.5 \text{ A}) = 2.1\times 10^{-6} \text{ T} = \boxed{2.1\ \mu\text{T}}$$

3. Repeat to find B_B:

$$B_B = \frac{\mu_0}{2\pi r}(I_1 - I_2) = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})}{2\pi(0.16\ \text{m})}(6.2 - 4.5\ \text{A}) = 1.3\times10^{-5}\ \text{T} = \boxed{13\ \mu\text{T}}$$

53. Two wires carry parallel currents and are separated by a short distance.



Equation 22-10 gives the force exerted by two parallel wires of length L and separation d that are carrying currents I_1 and I_2.

1. (a) Use eq. 22-10 to find F/L:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d} = \frac{(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(2.75\ \text{A})(4.33\ \text{A})}{2\pi(0.0925\ \text{m})} = \boxed{2.57\times10^{-5}\ \text{N/m}}$$

2. (b) The force exerted on a meter of the 4.33-A wire is the same as the force exerted on a meter of the 2.75-A wire because these forces form an action-reaction pair (Newton's Third Law).