2. **IDENTIFY** and **SET UP:** Apply Eq. (27.2) to calculate $\vec{F}$. Use the cross products of unit vectors from Section 1.10.

EXECUTE: $\vec{v} = (+4.19\times10^4 \text{ m/s})\hat{i} + (-3.85\times10^4 \text{ m/s})\hat{j}$

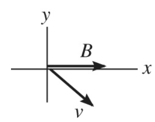
(a) $\vec{B} = (1.40 \text{ T})\hat{i}$

$\vec{F} = q\vec{v}\times\vec{B} = (-1.24\times10^{-8} \text{ C})(1.40 \text{ T})[(4.19\times10^4 \text{ m/s})\hat{i}\times\hat{i} - (3.85\times10^4 \text{ m/s})\hat{j}\times\hat{i}]$

$\hat{i}\times\hat{i} = 0,\ \hat{j}\times\hat{i} = -\hat{k}$

$\vec{F} = (-1.24\times10^{-8} \text{ C})(1.40 \text{ T})(-3.85\times10^4 \text{ m/s})(-\hat{k}) = (-6.68\times10^{-4} \text{ N})\hat{k}$

EVALUATE: The directions of $\vec{v}$ and $\vec{B}$ are shown in Figure.



The right-hand rule gives that $\vec{v}\times\vec{B}$ is directed out of the paper $(+z\text{-direction})$.

The charge is negative so $\vec{F}$ is opposite to $\vec{v}\times\vec{B}$.

$\vec{F}$ is in the $-z$-direction. This agrees with the direction calculated with unit vectors.

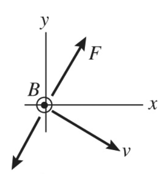
(b) EXECUTE: $\vec{B} = (1.40 \text{ T})\hat{k}$

$\vec{F} = q\vec{v}\times\vec{B} = (-1.24\times10^{-8} \text{ C})(1.40 \text{ T})[(+4.19\times10^4 \text{ m/s})\hat{i}\times\hat{k} - (3.85\times10^4 \text{ m/s})\hat{j}\times\hat{k}]$

$\hat{i}\times\hat{k} = -\hat{j},\ \hat{j}\times\hat{k} = \hat{i}$

$\vec{F} = (-7.27\times10^{-4} \text{ N})(-\hat{j}) + (6.68\times10^{-4} \text{ N})\hat{i} = [(6.68\times10^{-4} \text{ N})\hat{i} + (7.27\times10^{-4} \text{ N})\hat{j}]$

EVALUATE: The directions of $\vec{v}$ and $\vec{B}$ are shown in Figure.



The direction of $\vec{F}$ is opposite to $\vec{v}\times\vec{B}$ since q is negative. The direction of $\vec{F}$ computed from the right-hand rule agrees qualitatively with the direction calculated with unit vectors.

3. **IDENTIFY:** Apply $\vec{F} = q\vec{v}\times\vec{B}$.

SET UP: $\vec{v} = v_y\hat{j}$, with $v_y = -3.80\times10^3$ m/s. $F_x = +7.60\times10^{-3}$ N, $F_y = 0$, and $F_z = -5.20\times10^{-3}$ N.

EXECUTE: **(a)** $F_x = q(v_yB_z - v_zB_y) = qv_yB_z$.

$B_z = F_x/qv_y = (7.60\times10^{-3} \text{ N})/[(7.80\times10^{-6} \text{ C})(-3.80\times10^3 \text{ m/s})] = -0.256 \text{ T}$

$F_y = q(v_zB_x - v_xB_z) = 0$, which is consistent with $\vec{F}$ as given in the problem. There is no force component along the direction of the velocity.

$F_z = q(v_xB_y - v_yB_x) = -qv_yB_x$. $B_x = -F_z/qv_y = -0.175 \text{ T}$.

(b) B_y is not determined. No force due to this component of $\vec{B}$ along $\vec{v}$; measurement of the force tells us nothing about B_y.

(c) $\vec{B}\cdot\vec{F} = B_xF_x + B_yF_y + B_zF_z = (-0.175 \text{ T})(+7.60\times10^{-3} \text{ N}) + (-0.256 \text{ T})(-5.20\times10^{-3} \text{ N})$

$\vec{B}\cdot\vec{F} = 0$. $\vec{B}$ and $\vec{F}$ are perpendicular (angle is 90°).

Evaluate: The force is perpendicular to both $\vec{v}$ and $\vec{B}$, so $\vec{v}\cdot\vec{F}$ is also zero.

4. **IDENTIFY:** When a particle of charge $-e$ is accelerated through a potential difference of magnitude V, it gains kinetic energy eV. When it moves in a circular path of radius R, its acceleration is $\dfrac{v^2}{R}$.

SET UP: An electron has charge $q = -e = -1.60\times10^{-19}$ C and mass 9.11×10^{-31} kg.

EXECUTE: $\frac{1}{2}mv^2 = eV$ and $v = \sqrt{\dfrac{2eV}{m}} = \sqrt{\dfrac{2(1.60\times10^{-19}\text{ C})(2.00\times10^{3}\text{ V})}{9.11\times10^{-31}\text{ kg}}} = 2.65\times10^{7}$ m/s. $\vec{F} = m\vec{a}$ gives $|q|vB\sin\phi = m\dfrac{v^2}{R}$. $\phi = 90°$ and $B = \dfrac{mv}{|q|R} = \dfrac{(9.11\times10^{-31}\text{ kg})(2.65\times10^{7}\text{ m/s})}{(1.60\times10^{-19}\text{ C})(0.180\text{ m})} = 8.38\times10^{-4}$ T.

EVALUATE: The smaller the radius of the circular path, the larger the magnitude of the magnetic field that is required.

5. **IDENTIFY:** After being accelerated through a potential difference V the ion has kinetic energy qV. The acceleration in the circular path is v^2/R.

SET UP: The ion has charge $q = +e$.

EXECUTE: $K = qV = +eV$. $\frac{1}{2}mv^2 = eV$ and $v = \sqrt{\dfrac{2eV}{m}} = \sqrt{\dfrac{2(1.60\times10^{-19}\text{ C})(220\text{ V})}{1.16\times10^{-26}\text{ kg}}} = 7.79\times10^{4}$ m/s.

$F_B = |q|vB\sin\phi$. $\phi = 90°$. $\vec{F} = m\vec{a}$ gives $|q|vB = m\dfrac{v^2}{R}$.

$$R = \frac{mv}{|q|B} = \frac{(1.16\times10^{-26}\text{ kg})(7.79\times10^{4}\text{ m/s})}{(1.60\times10^{-19}\text{ C})(0.723\text{ T})} = 7.81\times10^{-3}\text{ m} = 7.81\text{ mm}.$$

EVALUATE: The larger the accelerating voltage, the larger the speed of the particle and the larger the radius of its path in the magnetic field.

6. **IDENTIFY:** For no deflection the magnetic and electric forces must be equal in magnitude and opposite in direction.

SET UP: $v = E/B$ for no deflection. With only the magnetic force, $|q|vB = mv^2/R$.

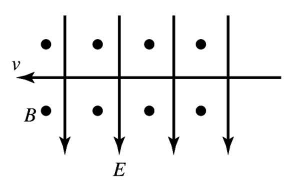
EXECUTE: **(a)** $v = E/B = (1.56\times10^{4}\text{ V/m})/(4.62\times10^{-3}\text{ T}) = 3.38\times10^{6}$ m/s.

(b) The directions of the three vectors $\vec{v}$, $\vec{E}$ and $\vec{B}$ are sketched in Figure.

(c) $R = \dfrac{mv}{|q|B} = \dfrac{(9.11\times10^{-31}\text{ kg})(3.38\times10^{6}\text{ m/s})}{(1.60\times10^{-19}\text{ C})(4.62\times10^{-3}\text{ T})} = 4.17\times10^{-3}$ m.

$$T = \frac{2\pi m}{|q|B} = \frac{2\pi R}{v} = \frac{2\pi(4.17\times10^{-3}\text{ m})}{(3.38\times10^{6}\text{ m/s})} = 7.74\times10^{-9}\text{ s}.$$

EVALUATE: For the field directions shown in Figure, the electric force is toward the top of the page and the magnetic force is toward the bottom of the page.



7. **IDENTIFY:** The velocity selector eliminates all ions not having the desired velocity. Then the magnetic field bends the ions in a circular arc.
SET UP: In a velocity selector, $E = vB$. For motion in a circular arc in a magnetic field of magnitude B, $R = \dfrac{mv}{|q|B}$. The ion has charge $+e$.

EXECUTE: **(a)** $v = \dfrac{E}{B} = \dfrac{155\text{ V/m}}{0.0315\text{ T}} = 4.92\times 10^3\text{ m/s}.$

(b) $m = \dfrac{R|q|B}{v} = \dfrac{(0.175\text{ m})(1.60\times 10^{-19}\text{ C})(0.0175\text{ T})}{4.92\times 10^3\text{ m/s}} = 9.96\times 10^{-26}\text{ kg}.$

EVALUATE: Ions with larger ratio $\dfrac{m}{|q|}$ will move in a path of larger radius.

10. **IDENTIFY** and **SET UP:** The magnetic force is given by Eq. (27.19). $F_I = mg$ when the bar is just ready to levitate. When I becomes larger, $F_I > mg$ and $F_I - mg$ is the net force that accelerates the bar upward. Use Newton's second law to find the acceleration.

(a) EXECUTE: $IlB = mg$, $I = \dfrac{mg}{lB} = \dfrac{(0.750\text{ kg})(9.80\text{ m/s}^2)}{(0.500\text{ m})(0.450\text{ T})} = 32.67\text{ A}$

$\mathcal{E} = IR = (32.67\text{ A})(25.0\ \Omega) = 817\text{ V}$

(b) $R = 2.0\ \Omega$, $I = \mathcal{E}/R = (816.7\text{ V})/(2.0\ \Omega) = 408\text{ A}$

$F_I = IlB = 92\text{ N}$

$a = (F_I - mg)/m = 113\text{ m/s}^2$

EVALUATE: I increases by over an order of magnitude when R changes to $F_I >> mg$ and a is an order of magnitude larger than g.

Answers

8. a) 3.96×10^{-2} N b)7.87 N
9. 0.210 m