	ANSWERS
1	We use $\vec{\mathbf{F}}_B = q\vec{\mathbf{v}} \times \vec{\mathbf{B}}$. Consider a three-dimensional coordinate system with the xy plane in the plane of this page, the $+x$ direction toward the right edge of the page and the $+y$ direction toward the top of the page. Then, the z axis is perpendicular to the page with the $+z$ direction being upward, out of the page. The magnetic field is directed in the $+x$ direction, toward the right. Note: For this assignment, values of certain parameters may vary. (a) When a proton (positively charged) moves in the $+y$ direction, the right-hand rule gives the direction of the magnetic force as into the page or in the $\boxed{-z \text{ direction}}$. (b) With velocity in the $-y$ direction, the right-hand rule gives the direction of the force on the proton as out of the page, in $\boxed{\text{the } +z \text{ direction}}$. (c) When the proton moves in the $+x$ direction, parallel to the magnetic field, the magnitude of the magnetic force it experiences is $F = qvB\sin(0°) = 0$. $\boxed{\text{The magnetic force is zero in this case.}}$
2	We first find the speed of the electron from the isolated system model: $(\Delta K + \Delta U)_i = (\Delta K + \Delta U)_f \rightarrow \frac{1}{2}mv^2 = e\Delta V:$ $v = \sqrt{\frac{2e\Delta V}{m}} = \sqrt{\frac{2(1.60 \times 10^{-19}\ \text{C})(2\,400\ \text{J/C})}{9.11 \times 10^{-31}\ \text{kg}}} = 2.90 \times 10^{7}\ \text{m/s}$ (a) $F_{B,\max} = qvB = (1.60 \times 10^{-19}\ \text{C})(2.90 \times 10^{7}\ \text{m/s})(1.70\ \text{T}) = \boxed{7.90 \times 10^{-12}\ \text{N}}$ (b) $F_{B,\min} = \boxed{0}$ occurs when $\vec{\mathbf{v}}$ is either parallel to or anti-parallel to $\vec{\mathbf{B}}$.
3	The force on a charged particle is proportional to the vector product of the velocity and the magnetic field: $\vec{\mathbf{F}}_B = q\vec{\mathbf{v}} \times \vec{\mathbf{B}} = (1.60 \times 10^{-19}\ \text{C})\left[(2\hat{\mathbf{i}} - 4\hat{\mathbf{j}} + \hat{\mathbf{k}})(\text{m/s}) \times (\hat{\mathbf{i}} + 2\hat{\mathbf{j}} - \hat{\mathbf{k}})\ \text{T}\right]$ Since 1 C · m · T/s = 1 N, we can write this in determinant form as: $\vec{\mathbf{F}}_B = (1.60 \times 10^{-19}\ \text{N}) \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 2 & -4 & 1 \\ 1 & 2 & -1 \end{vmatrix}$ Expanding the determinant as described in Equation 11.8, we have $\vec{\mathbf{F}}_{B,x} = (1.60 \times 10^{-19}\ \text{N})\left[(-4)(-1) - (1)(2)\right]\hat{\mathbf{i}}$ $\vec{\mathbf{F}}_{B,y} = (1.60 \times 10^{-19}\ \text{N})\left[(1)(1) - (2)(-1)\right]\hat{\mathbf{j}}$ $\vec{\mathbf{F}}_{B,z} = (1.60 \times 10^{-19}\ \text{N})\left[(2)(2) - (1)(-4)\right]\hat{\mathbf{k}}$ Again in unit-vector notation, $\vec{\mathbf{F}}_B = (1.60 \times 10^{-19}\ \text{N})(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 8\hat{\mathbf{k}}) = (3.20\hat{\mathbf{i}} + 4.80\hat{\mathbf{j}} + 12.8\hat{\mathbf{k}}) \times 10^{-19}\ \text{N}$ $\lvert\vec{\mathbf{F}}_B\rvert = \left(\sqrt{3.20^2 + 4.80^2 + 12.8^2}\right) \times 10^{-19}\ \text{N} = \boxed{13.2 \times 10^{-19}\ \text{N}}$

4	(a) The magnetic force acting on the electron provides the centripetal acceleration, holding the electron in the circular path. Therefore, $F = \|q\| vB \sin 90° = m_e v^2/r$, or $$r = \frac{m_e v}{eB} = \frac{(9.11\times10^{-31}\ \text{kg})(1.50\times10^{7}\ \text{m/s})}{(1.60\times10^{-19}\ \text{C})(2.00\times10^{-3}\ \text{T})}$$ $$= 0.042\,7\ \text{m} = \boxed{4.27\ \text{cm}}$$ (b) The time to complete one revolution around the orbit (i.e., the period) is $$T = \frac{\text{distance traveled}}{\text{constant speed}} = \frac{2\pi r}{v} = \frac{2\pi(0.042\,7\ \text{m})}{1.50\times10^{7}\ \text{m/s}} = \boxed{1.79\times10^{-8}\ \text{s}}$$
5	(a) The magnetic force provides the centripetal force to keep the particle moving on a circle: $$\sum F = ma \quad \rightarrow \quad qvB\sin 90.0° = \frac{mv^2}{R} \qquad [1]$$ and the kinetic energy of the particle is $$K = \frac{1}{2}mv^2 \qquad [2]$$ Both equations have the same term mv^2 in common: From [1], $mv^2 = qvBR$, and from [2], $mv^2 = 2K$. Setting these equal to each other gives $$mv^2 = qvBR = 2K \quad \rightarrow \quad \boxed{v = \frac{2K}{qBR}}$$ (b) From [1], we have $m = \frac{qBR}{v}$. Using our result from (a), we get $$m = \frac{qBR}{v} = qBR\left(\frac{qBR}{2K}\right) = \boxed{\frac{q^2B^2R^2}{2K}}$$
6	(a) The boundary between a region of strong magnetic field and a region of zero field cannot be perfectly sharp, but we ignore the thickness of the transition zone. In the field the electron moves on an arc of a circle: $$\sum F = ma: \quad \|q\| vB\sin 90° = \frac{mv^2}{r}$$ $$\frac{v}{r} = \omega = \frac{\|q\|B}{m} = \frac{(1.60\times10^{-19}\ \text{C})(10^{-3}\ \text{N}\cdot\text{s/C}\cdot\text{m})}{9.11\times10^{-31}\ \text{kg}}$$ $$= 1.76\times10^{8}\ \text{rad/s}$$ The time for one half revolution is, from $\Delta\theta = \omega\Delta t$, $$\Delta t = \frac{\Delta\theta}{\omega} = \frac{\pi\ \text{rad}}{1.76\times10^{8}\ \text{rad/s}} = \boxed{1.79\times10^{-8}\ \text{s}}$$

(b) The maximum depth of penetration is the radius of the path. The magnetic force cannot alter the kinetic energy of the electron.

Then,

$$v = \omega r = (1.76 \times 10^{8}\ \mathrm{s}^{-1})(0.020\ 0\ \mathrm{m}) = 3.51 \times 10^{6}\ \mathrm{m/s}$$

and

$$K = \frac{1}{2}mv^2 = \frac{1}{2}(9.11 \times 10^{-31}\ \mathrm{kg})(3.51 \times 10^{6}\ \mathrm{m/s})^2$$

$$= 5.62 \times 10^{-18}\ \mathrm{J} = \frac{5.62 \times 10^{-18}\ \mathrm{J}}{1.60 \times 10^{-19}\ \mathrm{J/eV}} = \boxed{35.1\ \mathrm{eV}}$$

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7 (a) The name "cyclotron frequency" refers to the angular frequency or angular speed

$$\omega = \frac{qB}{m}$$

For protons,

$$\omega = \frac{(1.60 \times 10^{-19}\ \mathrm{C})(0.450\ \mathrm{T})}{1.67 \times 10^{-27}\ \mathrm{kg}} = \boxed{4.31 \times 10^{7}\ \mathrm{rad/s}}$$

(b) The path radius is $R = \frac{mv}{Bq}$.

Just before the protons escape, their speed is

$$v = \frac{BqR}{m} = \frac{(0.450\ \mathrm{T})(1.60 \times 10^{-19}\ \mathrm{C})(1.20\ \mathrm{m})}{1.67 \times 10^{-27}\ \mathrm{kg}} = \boxed{5.17 \times 10^{7}\ \mathrm{m/s}}$$

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8 Fro the electron to travel undeflected, we require $F_B = F_e$, so

$$qvB = qE$$

where $v = \sqrt{\frac{2K}{m}}$ and K is kinetic energy of the electron. Then,

$$E = vB = \sqrt{\frac{2K}{m}}B = \sqrt{\frac{2(750\ \mathrm{eV})(1.60 \times 10^{-19}\ \mathrm{J/eV})}{9.11 \times 10^{-31}\ \mathrm{kg}}}(0.015\ 0\ \mathrm{T})$$

$$= \boxed{244\ \mathrm{kV/m}}$$

(b) Solution to **What If?**

For a proton to be undeflected, its speed must be given by

$$v = \frac{E}{B}$$

The kinetic energy of the proton would then be

$$K = \frac{1}{2}mv^2 = \frac{mE^2}{2B^2}$$

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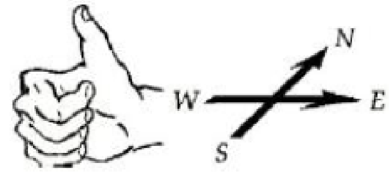
9 (a) From $F = BIL\sin\theta$, the magnetic field is

$$B = \frac{F/L}{I\sin\theta} = \frac{0.120\ \mathrm{N/m}}{(15.0\ \mathrm{A})\sin 90^\circ} = \boxed{8.00 \times 10^{-3}\ \mathrm{T}}$$

(b) The magnetic field must be in **the $+z$ direction** to produce a force in the $-y$ direction when the current is in the $+x$ direction.

10 (a) The magnetic force must be upward to lift the wire. For current in the south direction, the magnetic field must be **east** to produce an upward force, as shown by the right-hand rule in the figure.



(b) $F_B = ILB\sin\theta$ with $F_B = F_g = mg$

$$mg = ILB\sin\theta \quad \text{so} \quad \frac{m}{L}g = IB\sin\theta \quad \rightarrow \quad B = \frac{m}{L}\frac{g}{I\sin\theta}$$

$$B = \frac{m}{L}\frac{g}{I\sin\theta} = \left(\frac{0.500\times10^{-3}\ \text{kg}}{1.00\times10^{-2}\ \text{m}}\right)\left(\frac{9.80\ \text{m/s}^2}{(2.00\ \text{A})\sin 90.0^\circ}\right) = \boxed{0.245\ \text{T}}$$

11 (a) From the circumference of the loop, $2\pi r = 2.00$ m, we find its radius to be $r = 0.318$ m. The magnitude of the magnetic moment is then

$$\mu = IA = \left(17.0\times10^{-3}\ \text{A}\right)\left[\pi(0.318)^2\ \text{m}^2\right] = \boxed{5.41\ \text{mA}\cdot\text{m}^2}$$

(b) The torque on the loop is given by Equation 29.17, $\vec{\boldsymbol{\tau}} = \vec{\boldsymbol{\mu}}\times\vec{\mathbf{B}}$, and its magnitude is

$$\tau = \left(5.41\times10^{-3}\ \text{A}\cdot\text{m}^2\right)(0.800\ \text{T}) = \boxed{4.33\ \text{mN}\cdot\text{m}}$$

12 (a) $\tau = NBAI\sin\phi$

$$\tau = 100(0.800\ \text{T})\left(0.400\times0.300\ \text{m}^2\right)\times(1.20\ \text{A})\sin 60^\circ$$

$$\tau = \boxed{9.98\ \text{N}\cdot\text{m}}$$

(b) Note that ϕ is the angle between the magnetic moment and the $\vec{\mathbf{B}}$ field. The loop will rotate so as to align the magnetic moment with the $\vec{\mathbf{B}}$ field, **clockwise as seen looking down from a position on the positive y axis.**