9. (a) The magnetic force produces an acceleration perpendicular to the original motion:
\[ F = qv \times B = m\ddot{a}, \text{ or } a_\perp = evB/m. \]
For a small change in direction, we can take the force to be constant, so the perpendicular component of the velocity is
\[ v_\perp = a_\perp \Delta t = (evB \Delta t)/m. \]
If \( D \) is the diameter of the region of the magnetic field, the time the particle spends in the field is
\[ t = D/v. \]
The direction of motion is given by
\[ \tan \theta = v_\perp / v = (eB \Delta t)/m. \]
If the angle of deflection is small, we have
\[ \tan \theta = (eB \Delta t)/m. \]
(b) If \( D \) is the diameter of the region of the magnetic field, the time the particle spends in the field is
\[ \Delta t = D/v. \]
The angle of deflection is
\[ \theta = (eB \Delta t)/m = eBD/mv; \]
\( 0.1 \text{ rad} = (1.60 \times 10^{-19} \text{ C})B(0.1 \text{ m})/(1.7 \times 10^{-27} \text{ kg})(1.4 \times 10^7 \text{ m/s}), \) which gives \( B = 0.15 \text{ T}. \)

21. (a) The speed of the electron is given by
\[ v = (2K/m)^{1/2} = [2(10 \times 10^3 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})/(9.1 \times 10^{-31} \text{ kg})]^{1/2} = 5.9 \times 10^7 \text{ m/s}. \]
If we assume that the deflection is small, the time the electron takes to reach the screen is
\[ \Delta t = L/v = (0.40 \text{ m})/(5.9 \times 10^7 \text{ m/s}) = 6.8 \times 10^{-9} \text{ s}. \]
The magnetic force produces an acceleration perpendicular to the original motion:
\[ a_\perp = evB/m. \]
For a small deflection (THIS IS AN ASSUMPTION), we can take the force to be constant, so the perpendicular component of the velocity is
\[ v_\perp = a_\perp \Delta t = (evB \Delta t)/m \]
\[ = (1.60 \times 10^{-19} \text{ C})(5.9 \times 10^7 \text{ m/s})(5 \times 10^{-5} \text{ T})(6.8 \times 10^{-9} \text{ s})/(9.1 \times 10^{-31} \text{ kg}) = 0.35 \times 10^7 \text{ m/s}. \]
Because this is small compared to the original speed, the speed is essentially constant. We find the angle of the velocity from the original direction from
\[ \sin \theta = v_\perp / v = (0.35 \times 10^7 \text{ m/s})/(5.9 \times 10^7 \text{ m/s}) = 0.059, \text{ which gives } \theta = 3.4^\circ. \]
The final velocity is \( 5.9 \times 10^7 \text{ m/s}, 3.4^\circ \text{ from the original direction}. \)
(b) Because we have assumed constant acceleration, we find the deflection of the electron from
\[ d = \frac{1}{2} (0 + v_\perp) \Delta t = \frac{1}{2} (0.35 \times 10^7 \text{ m/s})(6.8 \times 10^{-9} \text{ s}) = 1.2 \times 10^{-2} \text{ m} = 1.2 \text{ cm}. \]
This justifies our assumption of small deflection.

24. The two forces are in opposite directions. For their magnitudes to be equal, we have
\[ F_s = F_B, \text{ or } mg = qvB; \]
\[ (1.67 \times 10^{-27} \text{ kg})(9.8 \text{ m/s}^2) = (1.60 \times 10^{-19} \text{ C})v(0.7 \times 10^{-2} \text{ T}), \text{ which gives } v = 1.5 \times 10^3 \text{ m/s}. \]
31. (a) The cyclotron frequency is
\[ f = \frac{qB}{2\pi m} \]
\[ = \frac{(1.60 \times 10^{-19} \text{ C})(1.0 \text{ T})}{[2\pi(1.7 \times 10^{-27} \text{ kg})]} = 1.5 \times 10^7 \text{ Hz}. \]

(b) We find the maximum velocity from
\[ R_{\text{max}} = \frac{mv_{\text{max}}}{qB} = v_{\text{max}} \frac{2}{2\pi f}; \]
\[ 0.50 \text{ m} = v_{\text{max}} \frac{2}{2\pi(1.5 \times 10^7 \text{ Hz})}, \] which gives \( v_{\text{max}} = 4.8 \times 10^7 \text{ m/s} \) tangential.

(c) The maximum kinetic energy is
\[ K_{\text{max}} = \frac{1}{2} mv_{\text{max}}^2 = \frac{1}{2} \left(1.7 \times 10^{-27} \text{ kg}\right)(4.8 \times 10^7 \text{ m/s})^2 = 1.9 \times 10^{-12} \text{ J} = 1.2 \times 10^7 \text{ eV}. \]

(d) In a full circle, the proton crosses the gap twice, so the energy gain in one cycle is \( \Delta E = 2e \Delta V \).
The number of circles is
\[ n = \frac{K_{\text{max}}}{\Delta E} = \frac{1.2 \times 10^7 \text{ eV}}{[2(1 \text{ e})(50 \times 10^3 \text{ V})]} = 120. \]

(e) The time the proton spends in the accelerator is
\[ t = \frac{nT}{f} = \frac{120}{(1.5 \times 10^7 \text{ Hz})} = 8.0 \times 10^{-6} \text{ s}. \]

39. (a) \( \vec{F}_E = q \vec{E} \), in the direction of \( \vec{E} \), i.e., from left to right on the page.

\( \vec{F}_B = q \vec{v} \times \vec{B} \), so the direction of \( \vec{F}_B \) is “out of page” \( \times “up” \) = from right to left on the page.

\( \vec{F} = \vec{F}_E + \vec{F}_B = q\vec{E} + q\vec{v} \times \vec{B} \), where \( \vec{F}_E \) and \( \vec{F}_B \) are opposite to each other so
\[ F = |F_E - F_B| = \frac{1}{2} \left| \vec{E} - \vec{v} \vec{B} \right|. \]

(c) \( F = 0 \) if \( E - vB = 0 \), or \( E = vB \).

49. From \( \vec{F} = ILB \times \vec{B} \), we see that the force on the wire produced by the magnetic field will be down, so the wire will move down. At the new equilibrium position, the magnetic force will be balanced by the increased elastic forces of the springs:
\[ F_B = F_{\text{elastic}}, \]
\[ ILB = 2k \Delta y, \] which gives \( \Delta y = \frac{ILB}{2k} \).

59. (a) We find the current from the maximum torque:
\[ \tau_{\text{max}} = \mu B = INAB; \]
\[ 3 \times 10^{-5} \text{ N} \cdot \text{m} = I(50)(6 \times 10^{-4} \text{ m}^2)(0.2 \text{ T}), \] which gives \( I = 5.0 \times 10^{-3} \text{ A} = 5.0 \text{ mA} \).

(b) We find the work required to rotate the coil from
\[ W = \Delta U = (- \mu \cdot \vec{B}) (\vec{B} i - \mu \cdot \vec{B}) = \mu B (- \cos \theta_{\text{f}} + \cos \theta_{\text{i}}). \]

For a rotation of 180°, we have
\[ W = \mu B [- \cos (180 + \theta_{\text{i}}) + \cos \theta_{\text{i}}] = 2\mu B \cos \theta_{\text{i}} = 2\tau_{\text{max}} \cos \theta_{\text{i}} = 6 \times 10^{-5} \text{ cos \theta_{\text{i}}}. \]
80. The magnetic dipole moment of the loop is
\[ \mu = I \ell A = Iab \text{ perpendicular to the loop.} \]
The diagram shows the loop as viewed along the pivot axis.
At equilibrium, the net torque is zero:
\[ \tau_{\text{net}} = \mu \times B + b \times (2mg) = 0, \quad \text{or} \]
\[ IabB \sin(90^\circ - \theta) - 2mgb \sin \theta = 0, \quad \text{which gives} \]
\[ \theta = \tan^{-1}\left(\frac{IaB}{2mg}\right). \]
We choose the horizontal plane through the pivot as the reference level for the gravitational potential energy. The total potential energy is
\[ U = -\mu \cdot B + 2mgh = -IabB \sin \theta - 2mgb \cos \theta. \]
To find the angle which minimizes the potential energy, we set \( dU/d\theta = 0 \):
\[ dU/d\theta = -IabB \cos \theta + 2mgb \sin \theta = 0, \quad \text{which gives} \]
\[ \tan \theta = IaB/2mg. \]
If the current is reversed, the magnetic dipole moment reverses.
[The loop will rise to the same angle on the other side of the vertical.]