14. For a free charge q inside the metal strip with velocity $\vec{v}$ we have $\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$. We set this force equal to zero and use the relation between (uniform) electric field and potential difference. Thus,

$$v = \frac{E}{B} = \frac{\left|V_x - V_y\right|/d_{xy}}{B} = \frac{\left(3.90 \times 10^{-9}\,\text{V}\right)}{\left(1.20 \times 10^{-3}\,\text{T}\right)\left(0.850 \times 10^{-2}\,\text{m}\right)} = 0.382\,\text{m/s}.$$

15. (a) We seek the electrostatic field established by the separation of charges (brought on by the magnetic force). With Eq. 28-10, we define the magnitude of the electric field as

$$|\vec{E}| = v|\vec{B}| = \left(20.0\text{ m/s}\right)\left(0.030\text{ T}\right) = 0.600\text{ V/m}.$$

Its direction may be inferred from Figure 28-8; its direction is opposite to that defined by $\vec{v} \times \vec{B}$. In summary,

$$\vec{E} = -(0.600\,\text{V/m})\hat{\text{k}}$$

which insures that $\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$ vanishes.

(b) Equation 28-9 yields $V = Ed = (0.600\text{ V/m})(2.00\text{ m}) = 1.20\text{ V}$.

31. Each of the two particles will move in the same circular path, initially going in the opposite direction. After traveling half of the circular path they will collide. Therefore, using Eq. 28-17, the time is given by

$$t = \frac{T}{2} = \frac{\pi m}{Bq} = \frac{\pi\left(9.11\times10^{-31}\,\text{kg}\right)}{(3.53\times10^{-3}\,\text{T})\left(1.60\times10^{-19}\,\text{C}\right)} = 5.07\times10^{-9}\,\text{s}.$$

35. (a) By conservation of energy (using qV for the potential energy, which is converted into kinetic form) the kinetic energy gained in each pass is 200 eV.

(b) Multiplying the part (a) result by n = 100 gives $\Delta K = n(200\text{ eV}) = 20.0$ keV.

(c) Combining Eq. 28-16 with the kinetic energy relation ($n(200\text{ eV}) = m_p v^2/2$ in this particular application) leads to the expression

$$r = \frac{m_p}{e\,B}\sqrt{\frac{2n(200\text{ eV})}{m_p}}$$

which shows that r is proportional to $\sqrt{n}$. Thus, the percent increase defined in the problem in going from n = 100 to n = 101 is $\sqrt{101/100}$ – 1 = 0.00499 or 0.499%.

36. (a) The magnitude of the field required to achieve resonance is

$$B = \frac{2\pi f m_p}{q} = \frac{2\pi(12.0\times10^6\ \text{Hz})\left(1.67\times10^{-27}\,\text{kg}\right)}{1.60\times10^{-19}\,\text{C}} = 0.787\,\text{T}.$$

(b) The kinetic energy is given by

$$K = \tfrac{1}{2}mv^2 = \frac{1}{2}m\left(2\pi Rf\right)^2 = \frac{1}{2}\left(1.67\times10^{-27}\,\text{kg}\right)4\pi^2(0.530\ \text{m})^2(12.0\times10^6\ \text{Hz})^2$$
$$= 1.33\times10^{-12}\,\text{J} = 8.34\times10^6\,\text{eV}.$$

(c) The required frequency is

$$f = \frac{qB}{2\pi m_p} = \frac{\left(1.60\times10^{-19}\,\text{C}\right)\left(1.57\,\text{T}\right)}{2\pi\left(1.67\times10^{-27}\,\text{kg}\right)} = 2.39\times10^7\,\text{Hz}.$$

(d) The kinetic energy is given by

$$K = \tfrac{1}{2}mv^2 = \frac{1}{2}m\left(2\pi Rf\right)^2 = \frac{1}{2}\left(1.67\times10^{-27}\,\text{kg}\right)4\pi^2(0.530\ \text{m})^2(2.39\times10^7\ \text{Hz})^2$$
$$= 5.3069\times10^{-12}\,\text{J} = 3.32\times10^7\,\text{eV}.$$

45. The magnetic force on the wire is

$$\vec{F}_B = i\vec{L}\times\vec{B} = iL\hat{\text{i}}\times\left(B_y\hat{\text{j}} + B_z\hat{\text{k}}\right) = iL\left(-B_z\hat{\text{j}} + B_y\hat{\text{k}}\right)$$
$$= \left(0.500\text{A}\right)\left(0.500\text{m}\right)\left[-\left(0.0100\text{T}\right)\hat{\text{j}} + \left(0.00300\text{T}\right)\hat{\text{k}}\right]$$
$$= \left(-2.50\times10^{-3}\hat{\text{j}} + 0.750\times10^{-3}\hat{\text{k}}\right)\text{N}.$$

49. The applied field has two components: $B_x > 0$ and $B_z > 0$. Considering each straight segment of the rectangular coil, we note that Eq. 28-26 produces a nonzero force only for the component of $\vec{B}$ that is perpendicular to that segment; we also note that the equation is effectively multiplied by N = 20 due to the fact that this is a 20-turn coil. Since we wish to compute the torque about the hinge line, we can ignore the force acting on the straight segment of the coil that lies along the y axis (forces acting at the axis of rotation produce no torque about that axis). The top and bottom straight segments experience forces due to Eq. 28-26 (caused by the B_z component), but these forces are (by the right-hand rule) in

the ±y directions and are thus unable to produce a torque about the y axis. Consequently, the torque derives completely from the force exerted on the straight segment located at x = 0.050 m, which has length L = 0.10 m and is shown in Figure 28-44 carrying current in the –y direction. Now, the B_z component will produce a force on this straight segment which points in the –x direction (back towards the hinge) and thus will exert no torque about the hinge. However, the B_x component (which is equal to $B\cos\theta$ where B = 0.50 T and θ = 30°) produces a force equal to $NiLB_x$ that points (by the right-hand rule) in the +z direction. Since the action of this force is perpendicular to the plane of the coil, and is located a distance x away from the hinge, then the torque has magnitude

$$\tau = (NiLB_x)(x) = NiLxB\cos\theta = (20)(0.10\text{ A})(0.10\text{ m})(0.050\text{ m})(0.50\text{ T})\cos 30^\circ$$
$$= 0.0043\text{ N}\cdot\text{m}.$$

Since $\vec{\tau} = \vec{r} \times \vec{F}$, the direction of the torque is –y. In unit-vector notation, the torque is $\vec{\tau} = (-4.3\times10^{-3}\text{ N}\cdot\text{m})\hat{\text{j}}$.

An alternative way to do this problem is through the use of Eq. 28-37. We do not show those details here, but note that the magnetic moment vector (a necessary part of Eq. 28-37) has magnitude

$$|\vec{\mu}| = NiA = (20)(0.10\text{ A})(0.0050\text{ m}^2)$$

and points in the –z direction. At this point, Eq. 3-30 may be used to obtain the result for the torque vector.