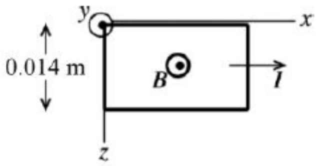
HW6 CH27 Solutions

**27.45. IDENTIFY:** The drift velocity is related to the current density by $J_x = n|q|v_d$. The electric field is determined by the requirement that the electric and magnetic forces on the current-carrying charges are equal in magnitude and opposite in direction.

**SET UP and EXECUTE:** **(a)** The section of the silver ribbon is sketched in Figure 27.45a.




$J_x = n|q|v_d$.

so $v_d = \dfrac{J_x}{n|q|}$.

**Figure 27.45a**

**EXECUTE:** $J_x = \dfrac{I}{A} = \dfrac{I}{y_1 z_1} = \dfrac{140\ \text{A}}{(0.24\times10^{-3}\ \text{m})(0.0140\ \text{m})} = 4.17\times10^{7}\ \text{A/m}^2.$

$$v_d = \frac{J_x}{n|q|} = \frac{4.17\times10^{7}\ \text{A/m}^2}{(5.90\times10^{28}/\text{m}^3)(1.602\times10^{-19}\ \text{C})} = 4.4\times10^{-3}\ \text{m/s} = 4.4\ \text{mm/s}.$$

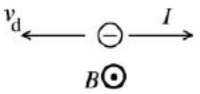
**(b)** magnitude of $\vec{E}$:

$|q|E_z = |q|v_d B_y$.

$E_z = v_d B_y = (4.4\times10^{-3}\ \text{m/s})(0.94\ \text{T}) = 4.1\times10^{-3}\ \text{V/m}.$

direction of $\vec{E}$:

The drift velocity of the electrons is in the opposite direction to the current, as shown in Figure 27.45b.

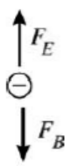



$\vec{v}\times\vec{B}\uparrow$.

$\vec{F}_B = q\vec{v}\times\vec{B} = -e\vec{v}\times\vec{B}\downarrow$.

**Figure 27.45b**

The directions of the electric and magnetic forces on an electron in the ribbon are shown in Figure 27.45c.




$\vec{F}_E$ must oppose $\vec{F}_B$ so $\vec{F}_E$ is in the $-z$-direction.

**Figure 27.45c**

$\vec{F}_E = q\vec{E} = -e\vec{E}$ so $\vec{E}$ is opposite to the direction of $\vec{F}_E$ and thus $\vec{E}$ is in the $+z$-direction.

**(c)** The Hall emf is the potential difference between the two edges of the strip (at $z = 0$ and $z = z_1$) that results from the electric field calculated in part (b). $\varepsilon_{\text{Hall}} = Ez_1 = (4.1\times10^{-3}\ \text{V/m})(0.0140\ \text{m}) = 57.4\ \mu\text{V}.$

**27.55. IDENTIFY:** The force exerted by the magnetic field is given by $F = IlB\sin\phi$. The net force on the wire must be zero.

**SET UP:** For the wire to remain at rest the force exerted on it by the magnetic field must have a component directed up the incline. To produce a force in this direction, the current in the wire must be directed from right to left in the figure with the problem in the textbook. Or, viewing the wire from its left-hand end the directions are shown in Figure 27.55a.

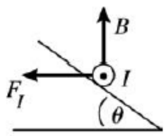



**Figure 27.55a**

The free-body diagram for the wire is given in Figure 27.55b.

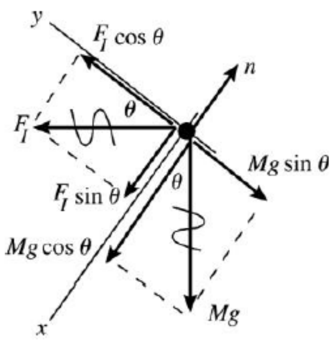



**Figure 27.55b**

**EXECUTE:** $\Sigma F_y = 0.$

$F_I \cos\theta - Mg\sin\theta = 0.$

$F_I = ILB\sin\phi.$

$\phi = 90°$ since $\vec{B}$ is perpendicular to the current direction.

Thus $(ILB)\cos\theta - Mg\sin\theta = 0$ and $I = \dfrac{Mg\tan\theta}{LB}.$

**EVALUATE:** The magnetic and gravitational forces are in perpendicular directions so their components parallel to the incline involve different trig functions. As the tilt angle $\theta$ increases there is a larger component of $Mg$ down the incline and the component of $F_I$ up the incline is smaller; $I$ must increase with $\theta$ to compensate. As $\theta \to 0$, $I \to 0$ and as $\theta \to 90°$, $I \to \infty$.

**27.58.** **IDENTIFY:** Turning the charged loop creates a current, and the external magnetic field exerts a torque on that current.

**SET UP:** The current is $I = q/T = q/(1/f) = qf = q(\omega/2\pi) = q\omega/2\pi$. The torque is $\tau = \mu B\sin\phi$.

**EXECUTE:** In this case, $\phi = 90°$ and $\mu = IA$, giving $\tau = IAB$. Combining the results for the torque and current and using $A = \pi r^2$ gives $\tau = \left(\dfrac{q\omega}{2\pi}\right)\pi r^2 B = \tfrac{1}{2}q\omega r^2 B.$

**27.59.** **IDENTIFY:** The force exerted by the magnetic field is $F = ILB\sin\phi$. $a = F/m$ and is constant. Apply a constant acceleration equation to relate $v$ and $d$.

**SET UP:** $\phi = 90°$. The direction of $\vec{F}$ is given by the right-hand rule.

**EXECUTE:** **(a)** $F = ILB$, to the right.

**(b)** $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ gives $v^2 = 2ad$ and $d = \dfrac{v^2}{2a} = \dfrac{v^2 m}{2ILB}.$

**(c)** $d = \dfrac{(1.12\times10^4\ \text{m/s})^2(30\ \text{kg})}{2(2400\ \text{A})(0.51\ \text{m})(0.82\ \text{T})} = 1.67\times10^6\ \text{m} = 1670\ \text{km}.$

**27.61.** **IDENTIFY:** We are dealing with the magnetic force on a curved current-carrying wire.

**SET UP and EXECUTE:** **(a)** Use Example 27.8 as a guide except integrate from $\theta = 0$ to $\pi/2$. This gives $F_x = F_y = IRB$, so $F = \sqrt{(IRB)^2 + (IRB)^2} = IRB\sqrt{2}$ = (5.00 A)(0.200 m)(0.800 T) $\sqrt{2}$ = 1.13 N. Using the right-hand rule for the magnetic force on a current-carrying wire, we see that the direction of the force is toward the origin.

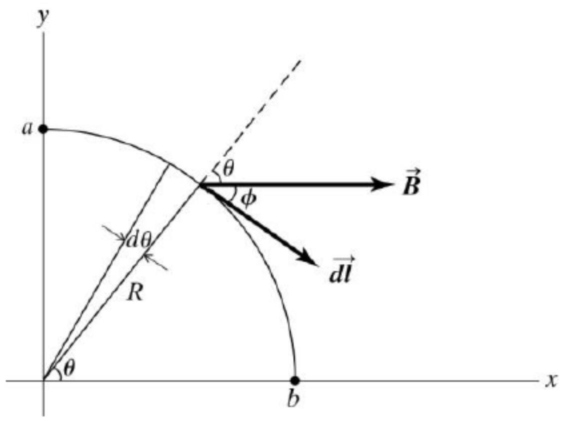



**Figure 27.61**

**(b)** Refer to Fig. 27.61. $dF = IBdl\sin\phi = IBdl\cos\theta$. $dl = Rd\theta$. $F = \int_0^{\pi/2} IB\cos\theta Rd\theta = IBR$. Using the numbers gives $F$ = (5.00 A)(0.800 T)(0.200 m) = 0.800 N. By the right-hand rule, the force is in the $+z$-direction.

**27.66. IDENTIFY and SET UP:** The force on a current-carrying bar of length $l$ is $F = IlB$ if the field is perpendicular to the bar. The torque is $\tau_z = \mu B\sin\phi$.

**EXECUTE: (a)** The force on the infinitesimal segment is $dF = IBdl = IBdx$. The torque about point $a$ is $d\tau_z = xdF\sin\phi = xIBdx$. In this case, $\sin\phi = 1$ because the force is perpendicular to the bar.

**(b)** We integrate to get the total torque: $\tau_z = \int_0^L xIBdx = \frac{1}{2}IBL^2$.

**(c)** For $F = ILB$ at the center of the bar, the torque is $\tau_z = F\left(\frac{L}{2}\right) = ILB\left(\frac{L}{2}\right) = \frac{1}{2}IBL^2$, which is the same result we got by integrating.

**27.71. IDENTIFY:** Apply $d\vec{F} = Id\vec{l} \times \vec{B}$ to each side of the loop.

**SET UP:** For each side of the loop, $d\vec{l}$ is parallel to that side of the loop and is in the direction of $I$. Since the loop is in the $xy$-plane, $z = 0$ at the loop and $B_y = 0$ at the loop.

**EXECUTE: (a)** The magnetic field lines in the $yz$-plane are sketched in Figure 27.71.

**(b)** Side 1, that runs from (0,0) to (0,$L$): $\vec{F} = \int_0^L Id\vec{l} \times \vec{B} = I\int_0^L \frac{B_0 y\, dy}{L}\hat{i} = \frac{1}{2}B_0 LI\hat{i}$.

Side 2, that runs from (0,$L$) to ($L$,$L$): $\vec{F} = \int_{0,y=L}^{L} Id\vec{l} \times \vec{B} = I\int_{0,y=L}^{L} \frac{B_0 y\, dx}{L}\hat{j} = -IB_0 L\hat{j}$.

Side 3, that runs from ($L$,$L$) to ($L$,0): $\vec{F} = \int_{L,x=L}^{0} Id\vec{l} \times \vec{B} = I\int_{L,x=L}^{0} \frac{B_0 y\, dy}{L}(-\hat{i}) = -\frac{1}{2}IB_0 L\hat{i}$.

Side 4, that runs from ($L$,0) to (0,0): $\vec{F} = \int_{L,y=0}^{0} Id\vec{l} \times \vec{B} = I\int_{L,y=0}^{0} \frac{B_0 y\, dx}{L}\hat{j} = 0$.

**(c)** The sum of all forces is $\vec{F}_{\text{total}} = -IB_0 L\hat{j}$.