5. SSM WWW ***REASONING AND SOLUTION*** For the three rods in the drawing in the text, we have the following:

Rod A: The motional emf is $\boxed{\text{zero}}$, because the velocity of the rod is parallel to the direction of the magnetic field, and the charges do not experience a magnetic force.

Rod B: The motional emf ξ is, according to Equation 22.1,

$$\xi = vBL = (2.7 \text{ m/s})(0.45 \text{ T})(1.3 \text{ m}) = \boxed{1.6 \text{ V}}$$

The positive end of Rod B is $\boxed{\text{end 2}}$.

Rod C: The motional emf is $\boxed{\text{zero}}$, because the magnetic force F on each charge is directed perpendicular to the length of the rod. For the ends of the rod to become charged, the magnetic force must be directed parallel to the length of the rod.

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6. ***REASONING*** The situation in the drawing given with the problem statement is analogous to that in Figure 22.4b in the text. The blood flowing at a speed v corresponds to the moving rod, and the diameter of the blood vessel corresponds to the length L of the rod in the figure. The magnitude of the magnetic field is B, and the measured voltage is the emf ξ induced by the motion. Thus, we can apply $\xi = BvL$ (Equation 22.1).

SOLUTION Using Equation 22.1, we find that

$$\xi = BvL = (0.60 \text{ T})(0.30 \text{ m/s})\left(5.6\times10^{-3} \text{ m}\right) = \boxed{1.0\times10^{-3} \text{ V}}$$

---

7. ***REASONING*** The average power $\overline{P}$ delivered by the hand is given by $\overline{P} = W/t$, where W is the work done by the hand and t is the time interval during which the work is done. The work done by the hand is equal to the product of the magnitude F_{hand} of the force exerted by the hand, the magnitude x of the rod's displacement, and the cosine of the angle between the force and the displacement.

Since the rod moves to the right at a constant speed, it has no acceleration and is, therefore, in equilibrium. Thus, the force exerted by the hand must be equal to the magnitude F of the magnetic force that the current exerts on the rod. The magnitude of the magnetic force is given by $F = ILB\sin\theta$ (Equation 21.3), where I is the current, L is the length of the moving rod, B is the magnitude of the magnetic field, and θ is the angle between the direction of the current and that of the magnetic field.

SOLUTION The average power $\overline{P}$ delivered by the hand is

$$\overline{P} = \frac{W}{t} \tag{6.10a}$$

The work W done by the hand in Figure 22.5 is given by $W = F_{\text{hand}}x\cos\theta'$ (Equation 6.1). In this equation F_{hand} is the magnitude of the force that the hand exerts on the rod, x is the magnitude of the rod's displacement, and θ' is the angle between the force and the displacement. The force and displacement point in the same direction, so $\theta' = 0°$. Since the magnitude of the force exerted by the hand equals the magnitude F of the magnetic force, $F_{\text{hand}} = F$. Substituting $W = F_{\text{hand}}x\cos 0°$ into Equation 6.10a and using the fact that $F_{\text{hand}} = F$, we have that

$$\overline{P} = \frac{W}{t} = \frac{F_{\text{hand}}x\cos 0°}{t} = \frac{Fx\cos 0°}{t} \tag{1}$$

The magnitude F of the magnetic force is given by $F = ILB\sin\theta$ (Equation 21.3). In this case, the current and magnetic field are perpendicular to each other, so $\theta = 90°$ (see Figure 22.5). Substituting this expression for F into Equation 1 gives

$$\overline{P} = \frac{Fx\cos 0°}{t} = \frac{(ILB\sin 90°)x\cos 0°}{t} \tag{2}$$

The term x/t in Equation 2 is the speed v of the rod. Thus, the average power delivered by the hand is

$$\overline{P} = \frac{(ILB\sin 90°)x\cos 0°}{t} = (ILB\sin 90°)v\cos 0°$$

$$= (0.040 \text{ A})(0.90 \text{ m})(1.2 \text{ T})\sin 90°(3.5 \text{ m/s})\cos 0° = \boxed{0.15 \text{ W}}$$

---

8. ***REASONING*** Once the switch is closed, there is a current in the rod. The magnetic field applies a force to this current and accelerates the rod to the right. As the rod begins to move, however, a motional emf appears between the ends of the rod. This motional emf depends on the speed of the rod and increases as the speed increases. Equally important is the fact that the motional emf opposes the emf of the battery. The net emf causing the current in the rod is the algebraic sum of the two emf contributions. Thus, as the speed of the rod increases and the motional emf increases, the net emf decreases. As the net emf decreases, the current in the rod decreases and so does the force that field applies to the current. Eventually, the speed reaches the point when the motional emf has the same magnitude as the battery emf, and the net emf becomes zero. At this point, there is no longer a net force acting on the rod and the speed remains constant from this point onward, according to Newton's second law. This maximum speed can be determined by using Equation 22.1 for the motional emf, with a value of the motional emf that equals the battery emf.

$$A = \frac{\Phi}{B\cos\phi} = \frac{8.4\times10^{-3}\text{ Wb}}{(0.47\text{ T})\cos 78^\circ} = \boxed{0.086\text{ m}^2}$$

b. From $A = \dfrac{\Phi}{B\cos\phi}$, with $\phi = 0.0°$, the minimum possible area of the second surface is

$$A = \frac{8.4\times10^{-3}\text{ Wb}}{(0.47\text{ T})\cos 0.0^\circ} = \boxed{0.018\text{ m}^2}$$

---

13. $\boxed{\text{SSM}}$ ***REASONING*** The general expression for the magnetic flux through an area A is given by Equation 22.2: $\Phi = BA\cos\phi$, where B is the magnitude of the magnetic field and ϕ is the angle of inclination of the magnetic field **B** with respect to the normal to the area.

The magnetic flux through the door is a maximum when the magnetic field lines are perpendicular to the door and $\phi_1 = 0.0°$ so that $\Phi_1 = \Phi_{max} = BA(\cos 0.0°) = BA$.

SOLUTION When the door rotates through an angle ϕ_2, the magnetic flux that passes through the door decreases from its maximum value to one-third of its maximum value. Therefore, $\Phi_2 = \frac{1}{3}\Phi_{max}$, and we have

$$\Phi_2 = BA\cos\phi_2 = \tfrac{1}{3}BA \quad \text{or} \quad \cos\phi_2 = \tfrac{1}{3} \quad \text{or} \quad \phi_2 = \cos^{-1}\left(\tfrac{1}{3}\right) = \boxed{70.5^\circ}$$

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14. ***REASONING*** At any given moment, the flux Φ that passes through the loop is given by $\Phi = BA\cos\phi$ (Equation 22.2), where B is the magnitude of the magnetic field, A is the area of the loop, and $\phi = 0°$ is the angle between the normal to the loop and the direction of the magnetic field (both directed into the page). As the handle turns, the area A of the loop changes, causing a change $\Delta\Phi$ in the flux passing through the loop. We can think of the loop as being divided into a rectangular portion and a semicircular portion. Initially, the area A_0 of the loop is equal to the rectangular area A_{rec} plus the area $A_{semi} = \frac{1}{2}\pi r^2$ of the semicircle, where r is the radius of the semicircle: $A_0 = A_{rec} + \frac{1}{2}\pi r^2$. After half a revolution, the semicircle is once again within the plane of the loop, but now as a reduction of the area of the rectangular portion. Therefore, the final area A of the loop is equal to the area of the rectangular portion minus the area of the semicircle: $A = A_{rec} - \frac{1}{2}\pi r^2$.

SOLUTION The change $\Delta\Phi$ in the flux that passes through the loop is the difference between the final flux $\Phi = BA\cos\phi$ (Equation 22.2) and the initial flux $\Phi_0 = BA_0\cos\phi$:

$$\Delta\Phi = \Phi - \Phi_0 = BA\cos\phi - BA_0\cos\phi = B\cos\phi(A - A_0) \qquad (1)$$

Substituting $A_0 = A_{rec} + \frac{1}{2}\pi r^2$ and $A = A_{rec} - \frac{1}{2}\pi r^2$ into Equation (1) yields

$$\Delta\Phi = B\cos\phi(A - A_0) = B\cos\phi\left[\left(A_{rec} - \tfrac{1}{2}\pi r^2\right) - \left(A_{rec} + \tfrac{1}{2}\pi r^2\right)\right] = -\pi r^2 B\cos\phi$$

Therefore the change in the flux passing through the loop during half a revolution of the semicircle is

$$\Delta\Phi = -\pi r^2 B\cos\phi = -\pi(0.20\text{ m})^2(0.75\text{ T})\cos 0^\circ = \boxed{-0.094\text{ Wb}}$$

---

15. ***REASONING*** The definition of magnetic flux Φ is $\Phi = BA\cos\phi$ (Equation 22.2), where B is the magnitude of the magnetic field, A is the area of the surface, and ϕ is the angle between the magnetic field vector and the normal to the surface. The values of B and A are the same for each of the surfaces, while the values for the angle ϕ are different. The z axis is the normal to the surface lying in the x, y plane, so that $\phi_{xy} = 35°$. The y axis is the normal to the surface lying in the x, z plane, so that $\phi_{xz} = 55°$. We can apply the definition of the flux to obtain the desired ratio directly.

SOLUTION Using Equation 22.2, we find that

$$\frac{\Phi_{xz}}{\Phi_{xy}} = \frac{BA\cos\phi_{xz}}{BA\cos\phi_{xy}} = \frac{\cos 55^\circ}{\cos 35^\circ} = \boxed{0.70}$$

---

16. ***REASONING AND SOLUTION*** The change in flux $\Delta\Phi$ is given by $\Delta\Phi = B\,\Delta A\cos\phi$, where ΔA is the area of the loop that leaves the region of the magnetic field in a time Δt. This area is the product of the width of the rectangle (0.080 m) and the length $v\,\Delta t$ of the side that leaves the magnetic field, $\Delta A = (0.080\text{ m})\,v\,\Delta t$.

$$\Delta\Phi = B\,\Delta A\cos\phi = (2.4\text{ T})(0.080\text{ m})(0.020\text{ m/s})(2.0\text{ s})\cos 0.0^\circ = \boxed{7.7\times10^{-3}\text{ Wb}}$$

$$|\xi| = \left|-N\left(\frac{\Phi - \Phi_0}{t - t_0}\right)\right| = \left|-N\left(\frac{BA\cos\phi - BA_0\cos\phi}{t - t_0}\right)\right|$$

$$= \left|-NB\cos\phi\left(\frac{A - A_0}{t - t_0}\right)\right| = \left|-NB\cos\phi\left(\frac{\Delta A}{\Delta t}\right)\right|$$

Solving this equation for $\left|\frac{\Delta A}{\Delta t}\right|$ and substituting in the value of 0.38 V for the magnitude of the emf, we find that

$$\left|\frac{\Delta A}{\Delta t}\right| = \frac{|\xi|}{NB\cos\phi} = \frac{0.38\text{ V}}{(1)(2.1\text{ T})\cos 65°} = \boxed{0.43\text{ m}^2/\text{s}}$$

---

24. ***REASONING*** According to Faraday's law the emf induced in either single-turn coil is given by Equation 22.3 as

$$\xi = -N\frac{\Delta\Phi}{\Delta t} = -\frac{\Delta\Phi}{\Delta t}$$

since the number of turns is $N = 1$. The flux is given by Equation 22.2 as

$$\Phi = BA\cos\phi = BA\cos 0° = BA$$

where the angle between the field and the normal to the plane of the coil is $\phi = 0°$, because the field is perpendicular to the plane of the coil and, hence, parallel to the normal. With this expression for the flux, Faraday's law becomes

$$\xi = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Delta(BA)}{\Delta t} = -A\frac{\Delta B}{\Delta t} \qquad (1)$$

In this expression we have recognized that the area A does not change in time and have separated it from the magnitude B of the magnetic field. We will apply this form of Faraday's law to each coil. The current induced in either coil depends on the resistance R of the coil, as well as the emf. According to Ohm's law, the current I induced in either coil is given by

$$I = \frac{\xi}{R} \qquad (2)$$

SOLUTION Applying Faraday's law in the form of Equation 1 to both coils, we have

$$\xi_{\text{square}} = -A_{\text{square}}\frac{\Delta B}{\Delta t} = -L^2\frac{\Delta B}{\Delta t} \quad \text{and} \quad \xi_{\text{circle}} = -A_{\text{circle}}\frac{\Delta B}{\Delta t} = -\pi r^2\frac{\Delta B}{\Delta t}$$

The area of a square of side L is L^2, and the area of a circle of radius r is pr^2. The rate of change $\Delta B/\Delta t$ of the field magnitude is the same for both coils. Dividing these two expressions gives

$$\frac{\xi_{\text{square}}}{\xi_{\text{circle}}} = \frac{-L^2\frac{\Delta B}{\Delta t}}{-\pi r^2\frac{\Delta B}{\Delta t}} = \frac{L^2}{\pi r^2} \qquad (3)$$

The same wire is used for both coils, so we know that the perimeter of the square equals the circumference of the circle

$$4L = 2\pi r \quad \text{or} \quad \frac{L}{r} = \frac{2\pi}{4} = \frac{\pi}{2}$$

Substituting this result into Equation (3) gives

$$\frac{\xi_{\text{square}}}{\xi_{\text{circle}}} = \frac{L^2}{\pi r^2} = \frac{\pi^2}{\pi 2^2} = \frac{\pi}{4} \quad \text{or} \quad \xi_{\text{square}} = \frac{\pi}{4}\xi_{\text{circle}} = \frac{\pi}{4}(0.80\text{ V}) = \boxed{0.63\text{ V}} \qquad (4)$$

Using Ohm's law as given in Equation (2), we find for the induced currents that

$$\frac{I_{\text{square}}}{I_{\text{circle}}} = \frac{\frac{\xi_{\text{square}}}{R}}{\frac{\xi_{\text{circle}}}{R}} = \frac{\xi_{\text{square}}}{\xi_{\text{circle}}}$$

Here we have used the fact that the same wire has been used for each coil, so that the resistance R is the same for each coil. Using the result in Equation (4) gives

$$\frac{I_{\text{square}}}{I_{\text{circle}}} = \frac{\xi_{\text{square}}}{\xi_{\text{circle}}} = \frac{\pi}{4} \quad \text{or} \quad I_{\text{square}} = \frac{\pi}{4}I_{\text{circle}} = \frac{\pi}{4}(3.2\text{ A}) = \boxed{2.5\text{ A}}$$

---

25. ***REASONING*** Using Equation 22.3 (Faraday's law) and recognizing that $N = 1$, we can write the magnitude of the emfs for parts a and b as follows:

$$|\xi_a| = \left|-\left(\frac{\Delta\Phi}{\Delta t}\right)_a\right| \quad (1) \qquad \text{and} \qquad |\xi_b| = \left|-\left(\frac{\Delta\Phi}{\Delta t}\right)_b\right| \quad (2)$$

To solve this problem, we need to consider the change in flux $\Delta\Phi$ and the time interval Δt for both parts of the drawing in the text.

SOLUTION The change in flux is the same for both parts of the drawing and is given by

$$(\Delta\Phi)_a = (\Delta\Phi)_b = \Phi_{\text{inside}} - \Phi_{\text{outside}} = \Phi_{\text{inside}} = BA \qquad (3)$$

In Equation (3) we have used the fact that initially the coil is outside the field region, so that $\Phi_{\text{outside}} = 0$ Wb for both cases. Moreover, the field is perpendicular to the plane of the coil and has the same magnitude B over the entire area A of the coil, once it has completely entered the field region. Thus, $\Phi_{\text{inside}} = BA$ in both cases, according to Equation 22.2.

The time interval required for the coil to enter the field region completely can be expressed as the distance the coil travels divided by the speed at which it is pushed. In part *a* of the drawing the distance traveled is W, while in part *b* it is L. Thus, we have

$$(\Delta t)_a = W/v \qquad (4) \qquad\qquad (\Delta t)_b = L/v \qquad (5)$$

Substituting Equations (3), (4), and (5) into Equations (1) and (2), we find

$$|\xi_a| = \left|-\left(\frac{\Delta\Phi}{\Delta t}\right)_a\right| = \frac{BA}{W/v} \qquad (6) \qquad\qquad |\xi_b| = \left|-\left(\frac{\Delta\Phi}{\Delta t}\right)_b\right| = \frac{BA}{L/v} \qquad (7)$$

Dividing Equation (6) by Equation (7) gives

$$\frac{|\xi_a|}{|\xi_b|} = \frac{\dfrac{BA}{W/v}}{\dfrac{BA}{L/v}} = \frac{L}{W} = 3.0 \qquad \text{or} \qquad |\xi_b| = \frac{|\xi_a|}{3.0} = \frac{0.15\text{ V}}{3.0} = \boxed{0.050\text{ V}}$$

---

26. ***REASONING*** An emf is induced in the coil because the magnetic flux through the coil is changing in time. The flux is changing because the angle ϕ between the normal to the coil and the magnetic field is changing.

The amount of induced current is equal to the induced emf divided by the resistance of the coil (see Equation 20.2).

According to Equation 20.1, the amount of charge Δq that flows is equal to the induced current I multiplied by the time interval $\Delta t = t - t_0$ during which the coil rotates, or $\Delta q = I(t - t_0)$.

SOLUTION According to Equation 20.1, the amount of charge that flows is $\Delta q = I\Delta t$. The current is related to the emf ξ in the coil and the resistance R by Equation 20.2 as $I = \xi/R$. The amount of charge that flows can, therefore, be written as

$$\Delta q = I\,\Delta t = \left(\frac{\xi}{R}\right)\Delta t$$

The emf is given by Faraday's law of electromagnetic induction as

$$\xi = -N\left(\frac{\Delta\Phi}{\Delta t}\right) = -N\left(\frac{BA\cos\phi - BA\cos\phi_0}{\Delta t}\right)$$

where we have also used Equation 22.2, which gives the definition of magnetic flux as $\Phi = BA\cos\phi$. With this emf, the expression for the amount of charge becomes

$$\Delta q = I\,\Delta t = \left[\frac{-N\left(\dfrac{BA\cos\phi - BA\cos\phi_0}{\Delta t}\right)}{R}\right]\Delta t = \frac{-NBA(\cos\phi - \cos\phi_0)}{R}$$

Solving for the magnitude of the magnetic field yields

$$B = \frac{-R\Delta q}{NA(\cos\phi - \cos\phi_0)} = \frac{-(140\ \Omega)(8.5\times10^{-5}\text{ C})}{(50)(1.5\times10^{-3}\text{ m}^2)(\cos 90° - \cos 0°)} = \boxed{0.16\text{ T}}$$

---

27. $\boxed{\text{SSM}}$ $\boxed{\text{WWW}}$ ***REASONING*** The energy dissipated in the resistance is given by Equation 6.10b as the power P dissipated multiplied by the time t, Energy = Pt. The power, according to Equation 20.6c, is the square of the induced emf ξ divided by the resistance R, $P = \xi^2/R$. The induced emf can be determined from Faraday's law of electromagnetic induction, Equation 22.3.

SOLUTION Expressing the energy consumed as Energy = Pt, and substituting in $P = \xi^2/R$, we find

$$\text{Energy} = Pt = \frac{\xi^2 t}{R}$$

The induced emf is given by Faraday's law as $\xi = -N(\Delta\Phi/\Delta t)$, and the resistance R is equal to the resistance per unit length (3.3×10^{-2} Ω/m) times the length of the circumference of the loop, $2\pi r$. Thus, the energy dissipated is change. The induced magnetic field will oppose this decrease in flux by pointing into the page, in the same direction as the field produced by I. According to RHR-2, the induced current must flow clockwise around the loop in order to produce such an induced field. The current then flows from $\boxed{\text{left-to-right}}$ through the resistor.

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35. SSM ***REASONING*** In solving this problem, we apply Lenz's law, which essentially says that the change in magnetic flux must be opposed by the induced magnetic field.

SOLUTION
a. The magnetic field due to the wire in the vicinity of position 1 is directed out of the paper. The coil is moving closer to the wire into a region of higher magnetic field, so the flux through the coil is increasing. Lenz's law demands that the induced field counteract this increase. The direction of the induced field, therefore, must be into the paper. The current in the coil must be $\boxed{\text{clockwise}}$.

b. At position 2 the magnetic field is directed into the paper and is decreasing as the coil moves away from the wire. The induced magnetic field, therefore, must be directed into the paper, so the current in the coil must be $\boxed{\text{clockwise}}$.

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36. ***REASONING*** According to Lenz's law, the induced current in the triangular loop flows in such a direction so as to create an induced magnetic field that opposes the original flux change.

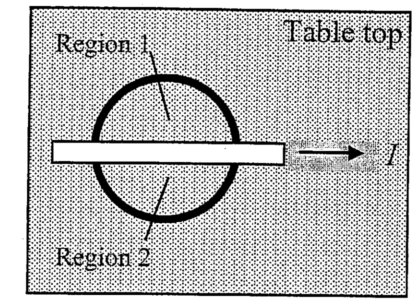
SOLUTION
a. As the triangle is crossing the $+y$ axis, the magnetic flux down into the plane of the paper is increasing, since the field now begins to penetrate the loop. To offset this increase, an induced magnetic field directed up and out of the plane of the paper is needed. By applying RHR-2 it can be seen that such an induced magnetic field will be created within the loop by a $\boxed{\text{counterclockwise induced current}}$.

b. As the triangle is crossing the $-x$ axis, there is no flux change, since all parts of the triangle remain in the magnetic field, which remains constant. Therefore, there is no induced magnetic field, and $\boxed{\text{no induced current appears}}$.

c. As the triangle is crossing the $-y$ axis, the magnetic flux down into the plane of the paper is decreasing, since the loop now begins to leave the field region. To offset this decrease, an induced magnetic field directed down and into the plane of the paper is needed. By applying RHR-2 it can be seen that such an induced magnetic field will be created within the loop by a $\boxed{\text{clockwise induced current}}$.

d. As the triangle is crossing the $+x$ axis, there is no flux change, since all parts of the triangle remain in the field-free region. Therefore, there is no induced magnetic field, and $\boxed{\text{no induced current appears}}$.

REASONING The current I in the straight wire produces a circular pattern of magnetic field lines around the wire. The magnetic field at any point is tangent to one of these circular field lines. Thus, the field points perpendicular to the plane of the table. Furthermore, according to Right-Hand Rule No. 2, the field is directed up out of the table surface in region 1 above the wire and is directed down into the table surface in region 2 below the wire (see the drawing at the right). To deduce the direction of any induced current in the circular loop, we consider Faraday's law and the change that occurs in the magnetic flux through the loop due to the field of the straight wire.



SOLUTION As the current I decreases, the magnitude of the field that it produces also decreases. However, the directions of the fields in regions 1 and 2 do not change and remain as discussed in the reasoning. Since the fields in these two regions always have opposite directions and equal magnitudes at any given radial distance from the straight wire, the flux through the regions add up to give zero for any value of the current. With the flux remaining constant as time passes, Faraday's law indicates that there is no induced emf in the coil. Since there is no induced emf in the coil, there is $\boxed{\text{no induced current}}$.

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38. ***REASONING AND SOLUTION*** If the applied magnetic field is decreasing in time, then the flux through the circuit is decreasing. Lenz's law requires that an induced magnetic field be produced which attempts to counteract this decrease; hence its direction is out of the paper. The sense of the induced current in the circuit must be CCW. Therefore, the lower plate of the capacitor is positive while the upper plate is negative. The electric field between the plates of the capacitor points from positive to negative so the electric field points $\boxed{\text{upward}}$.

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39. ***REASONING AND SOLUTION***
a. **Location I**
As the loop swings downward, the normal to the loop makes a smaller angle with the applied field. Hence, the flux through the loop is increasing. The induced magnetic field must point generally to the left to counteract this increase. The induced current flows

$$\boxed{x \to y \to z}$$

71. SSM ***REASONING*** We can use the information given in the problem statement to determine the area of the coil A. Since it is square, the length of one side is $\ell = \sqrt{A}$.

SOLUTION According to Equation 22.4, the maximum emf ξ_0 induced in the coil is $\xi_0 = NAB\omega$. Therefore, the length of one side of the coil is

$$\ell = \sqrt{A} = \sqrt{\frac{\xi_0}{NB\omega}} = \sqrt{\frac{75.0\ \text{V}}{(248)(0.170\ \text{T})(79.1\ \text{rad/s})}} = \boxed{0.150\ \text{m}}$$

72. ***REASONING*** The magnitude $|\xi|$ of the emf induced in the loop can be found using Faraday's law of electromagnetic induction:

$$|\xi| = \left| -N\frac{\Phi - \Phi_0}{t - t_0} \right| \qquad (22.3)$$

where N is the number of turns, Φ and Φ_0 are, respectively, the final and initial fluxes, and $t - t_0$ is the elapsed time. The magnetic flux is given by $\Phi = BA\cos\phi$ (Equation 22.2), where B is the magnitude of the magnetic field, A is the area of the surface, and ϕ is the angle between the direction of the magnetic field and the normal to the surface.

SOLUTION Setting $N = 1$ since there is only one turn, noting that the final area is $A = 0\ \text{m}^2$ and the initial area is $A_0 = 0.20\ \text{m} \times 0.35\ \text{m}$, and noting that the angle ϕ between the magnetic field and the normal to the surface is 0°, we find that the magnitude of the emf induced in the coil is

$$|\xi| = \left| -N\frac{BA\cos\phi - BA_0\cos\phi}{t - t_0} \right|$$

$$= \left| -(1)\frac{(0.65\ \text{T})(0\ \text{m}^2)\cos 0° - (0.65\ \text{T})(0.20\ \text{m} \times 0.35\ \text{m})\cos 0°}{0.18\ \text{s}} \right| = \boxed{0.25\ \text{V}}$$

73. SSM ***REASONING*** The current I produces a magnetic field, and hence a magnetic flux, that passes through the loops A and B. Since the current decreases to zero when the switch is opened, the magnetic flux also decreases to zero. According to Lenz's law, the current induced in each coil will have a direction such that the induced magnetic field will oppose the original flux change.

SOLUTION

a. The drawing in the text shows that the magnetic field at coil A is perpendicular to the plane of the coil and points down (when viewed from above the table top). When the switch is opened, the magnetic flux through coil A decreases to zero. According to Lenz's law, the induced magnetic field produced by coil A must oppose this change in flux. Since the magnetic field points down and is decreasing, the induced magnetic field must also point down. According to Right-Hand Rule No. 2 (RHR-2), the induced current must be $\boxed{\text{clockwise}}$ around loop A.

b. The drawing in the text shows that the magnetic field at coil B is perpendicular to the plane of the coil and points up (when viewed from above the table top). When the switch is opened, the magnetic flux through coil B decreases to zero. According to Lenz's law, the induced magnetic field produced by coil B must oppose this change in flux. Since the magnetic field points up and is decreasing, the induced magnetic field must also point up. According to RHR-2, the induced current must be $\boxed{\text{counterclockwise}}$ around loop B.

74. ***REASONING AND SOLUTION*** The step down transformer reduces the voltage by a factor of 13:

$$V_2 = \tfrac{1}{13}(120\ \text{V}) = \boxed{9.2\ \text{V}}$$

75. SSM ***REASONING AND SOLUTION*** The emf ξ induced in the coil of an ac generator is given by Equation 22.4 as

$$\xi = NAB\omega \sin\omega t = (500)(1.2\times10^{-2}\ \text{m}^2)(0.13\ \text{T})(34\ \text{rad/s})\sin 27° = \boxed{12\ \text{V}}$$

76. ***REASONING AND SOLUTION*** The energy stored in a capacitor is given by Equation 19.11b as $\frac{1}{2}CV^2$. The energy stored in an inductor is given by Equation 22.10 as $\frac{1}{2}LI^2$. Setting these two equations equal to each other and solving for the current I, we get

$$I = \sqrt{\frac{C}{L}}\,V = \sqrt{\frac{3.0\times10^{-6}\ \text{F}}{5.0\times10^{-3}\ \text{H}}}(35\ \text{V}) = \boxed{0.86\ \text{A}}$$

77. ***REASONING*** The magnitude $|\xi|$ of the average emf induced in the triangle is given by $|\xi| = \left| -N\frac{\Delta\Phi}{\Delta t} \right|$ (see Equation 22.3), which is Faraday's law. This expression can be used directly to calculate the magnitude of the average emf. Since the triangle is a single-turn coil, the number of turns is $N = 1$. According to Equation 22.2, the magnetic flux Φ is

$$\Phi = BA\cos\phi = BA\cos 0° = BA \quad (1)$$

where B is the magnitude of the field, A is the area of the triangle, and $\phi = 0°$ is the angle between the field and the normal to the plane of the triangle (the magnetic field is perpendicular to the plane of the triangle). It is the change $\Delta\Phi$ in the flux that appears in Faraday's law, so that we use Equation (1) as follows:

$$\Delta\Phi = BA - BA_0 = BA$$

where $A_0 = 0\ \text{m}^2$ is the initial area of the triangle just as the bar passes point A, and A is the area after the time interval Δt has elapsed. The area of a triangle is one-half the base (d_{AC}) times the height (d_{CB}) of the triangle. Thus, the change in flux is

$$\Delta\Phi = BA = B\left(\tfrac{1}{2}d_{AC}d_{CB}\right)$$

The base and the height of the triangle are related, according to $d_{CB} = d_{AC}\tan\theta$, where $\theta = 19°$. Furthermore, the base of the triangle becomes longer as the rod moves. Since the rod moves with a speed v during the time interval Δt, the base is $d_{AC} = v\Delta t$. With these substitutions the change in flux becomes

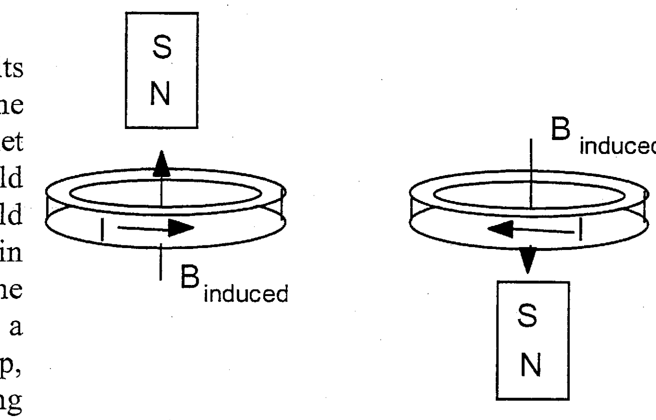
$$\Delta\Phi = B\left(\tfrac{1}{2}d_{AC}d_{CB}\right) = B\left[\tfrac{1}{2}d_{AC}\left(d_{AC}\tan\theta\right)\right] = \tfrac{1}{2}B\left(v\Delta t\right)^2\tan\theta \quad (2)$$

SOLUTION Substituting Equation (2) for the change in flux into Faraday's law, we find that the magnitude of the induced emf is

$$|\xi| = \left|-N\frac{\Delta\Phi}{\Delta t}\right| = \left|-N\frac{\frac{1}{2}B\left(v\Delta t\right)^2\tan\theta}{\Delta t}\right| = N\tfrac{1}{2}Bv^2\Delta t\tan\theta$$

$$= (1)\tfrac{1}{2}(0.38\ \text{T})(0.60\ \text{m/s})^2(6.0\ \text{s})\tan 19° = \boxed{0.14\ \text{V}}$$

REASONING AND SOLUTION



a. When the magnet is above the ring its magnetic field points down through the ring and is increasing as the magnet falls. The induced magnetic field attempts to reduce the increasing field and points up. The induced current in the ring is as shown in the drawing at the right, and then the ring looks like a magnet with its north pole at the top, repelling the north pole of the falling magnet and retarding its motion.

When the magnet is below the ring, its magnetic field still points down through the ring but is decreasing as the magnet falls. The induced magnetic field attempts to bolster the decreasing field and points down. The induced current in the ring is as shown in the drawing, and the ring then looks like a magnet with its north pole at the bottom, attracting the south pole of the falling magnet and retarding its motion.

b. The motion of the magnet is unaffected, since no induced current can flow in the cut ring. No induced current means that no induced magnetic field can be produced to repel or attract the falling magnet.

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79. SSM ***REASONING*** According to Equation 22.3, the average emf ξ induced in a single loop (N = 1) is $\xi = -\Delta\Phi/\Delta t$. Since the magnitude of the magnetic field is changing, the area of the loop remains constant, and the direction of the field is parallel to the normal to the loop, the change in flux through the loop is given by $\Delta\Phi = (\Delta B)A$. Thus the magnitude $|\xi|$ of the induced emf in the loop is given by $|\xi| = \left|-(\Delta B)A/\Delta t\right|$.

Similarly, when the area of the loop is changed and the field B has a given value, we find the magnitude of the induced emf to be $|\xi| = \left|-B(\Delta A)/\Delta t\right|$.

SOLUTION

a. The magnitude of the induced emf when the field changes in magnitude is

$$|\xi| = \left|-A\left(\frac{\Delta B}{\Delta t}\right)\right| = (0.018\ \text{m}^2)(0.20\ \text{T/s}) = \boxed{3.6\times10^{-3}\ \text{V}}$$

b. At a particular value of B (when B is changing), the rate at which the area must change can be obtained from

$$|\xi| = \left|-\frac{B\Delta A}{\Delta t}\right| \quad \text{or} \quad \frac{\Delta A}{\Delta t} = \frac{|\xi|}{B} = \frac{3.6\times10^{-3}\ \text{V}}{1.8\ \text{T}} = \boxed{2.0\times10^{-3}\ \text{m}^2/\text{s}}$$