28.30. **IDENTIFY:** The magnetic field at the center of a circular loop is $B = \dfrac{\mu_0 I}{2R}$. By symmetry each segment of the loop that has length Δl contributes equally to the field, so the field at the center of a semicircle is $\frac{1}{2}$ that of a full loop.**SET UP:** Since the straight sections produce no field at *P*, the field at *P* is $B = \dfrac{\mu_0 I}{4R}$.

EXECUTE: $B = \dfrac{\mu_0 I}{4R}$. The direction of $\vec{B}$ is given by the right-hand rule: $\vec{B}$ is directed into the page.

EVALUATE: For a quarter-circle section of wire the magnetic field at its center of curvature is $B = \dfrac{\mu_0 I}{8R}$.

28.31. **IDENTIFY:** Calculate the magnetic field vector produced by each wire and add these fields to get the total field.
SET UP: First consider the field at *P* produced by the current I_1 in the upper semicircle of wire. See Figure 28.31a.

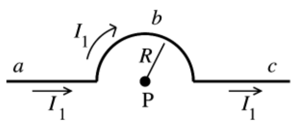


Figure 28.31a

Consider the three parts of this wire
a: long straight section,
b: semicircle
c: long, straight section

Apply the Biot-Savart law $d\vec{B} = \dfrac{\mu_0}{4\pi}\dfrac{I d\vec{l} \times \hat{r}}{r^2} = \dfrac{\mu_0}{4\pi}\dfrac{I d\vec{l} \times \vec{r}}{r^3}$ to each piece.

EXECUTE: <u>part *a*</u> See Figure 28.31b.

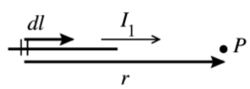


Figure 28.31b

$d\vec{l} \times \vec{r} = 0,$
so $dB = 0$

The same is true for all the infinitesimal segments that make up this piece of the wire, so *B* = 0 for this piece.
<u>part *c*</u> See Figure 28.31c.

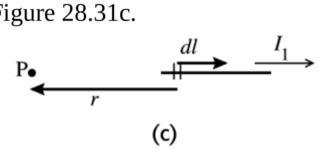


Figure 28.31c

$d\vec{l} \times \vec{r} = 0,$
so $dB = 0$ and $B = 0$ for this piece.

<u>part *b*</u> See Figure 28.31d.

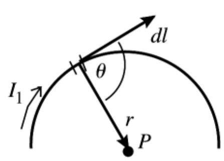


Figure 28.31d

$d\vec{l} \times \vec{r}$ is directed into the paper for all infinitesimal segments that make up this semicircular piece, so $\vec{B}$ is directed into the paper and $B = \int dB$ (the vector sum of the $d\vec{B}$ is obtained by adding their magnitudes since they are in the same direction).

$|d\vec{l} \times \vec{r}| = r\,dl\sin\theta$. The angle θ between $d\vec{l}$ and $\vec{r}$ is 90° and $r = R$, the radius of the semicircle. Thus $|d\vec{l} \times \vec{r}| = R\,dl$

$$dB = \frac{\mu_0}{4\pi}\frac{I|d\vec{l} \times \vec{r}|}{r^3} = \frac{\mu_0 I_1}{4\pi}\frac{R}{R^3}dl = \left(\frac{\mu_0 I_1}{4\pi R^2}\right)dl \qquad B = \int dB = \left(\frac{\mu_0 I_1}{4\pi R^2}\right)\int dl = \left(\frac{\mu_0 I_1}{4\pi R^2}\right)(\pi R) = \frac{\mu_0 I_1}{4R}$$

(We used that $\int dl$ is equal to πR, the length of wire in the semicircle.) We have shown that the two straight sections make zero contribution to $\vec{B}$, so $B_1 = \mu_0 I_1/4R$ and is directed into the page.

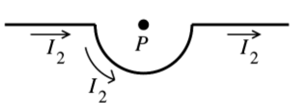


Figure 28.31e

For current in the direction shown in Figure 28.31e, a similar analysis gives $B_2 = \mu_0 I_2/4R$, out of the paper

$\vec{B}_1$ and $\vec{B}_2$ are in opposite directions, so the magnitude of the net field at *P* is $B = |B_1 - B_2| = \dfrac{\mu_0|I_1 - I_2|}{4R}$. When $I_1 = I_2$, $B = 0$.

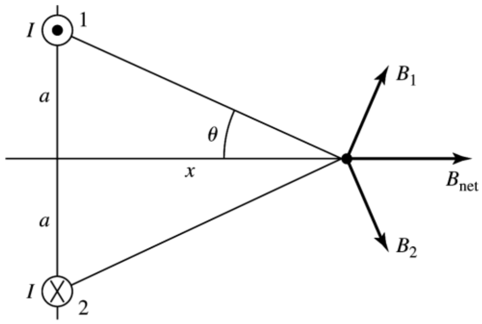
28.60. **IDENTIFY:** Find the vector sum of the magnetic fields due to each wire. **SET UP:** For a long straight wire $B = \frac{\mu_0 I}{2\pi r}$. The direction of $\vec{B}$ is given by the right-hand rule and is perpendicular to the line from the wire to the point where then field is calculated. **EXECUTE:** **(a)** The magnetic field vectors are shown in Figure 28.60a.

(b) At a position on the x-axis $B_{\text{net}} = 2\frac{\mu_0 I}{2\pi r}\sin\theta = \frac{\mu_0 I}{\pi\sqrt{x^2+a^2}}\frac{a}{\sqrt{x^2+a^2}} = \frac{\mu_0 I a}{\pi(x^2+a^2)}$, in the positive x-direction.

(c) The graph of B versus x/a is given in Figure 28.60b.

EVALUATE: **(d)** The magnetic field is a maximum at the origin, $x = 0$.

(e) When $x >> a$, $B \approx \frac{\mu_0 I a}{\pi x^2}$.



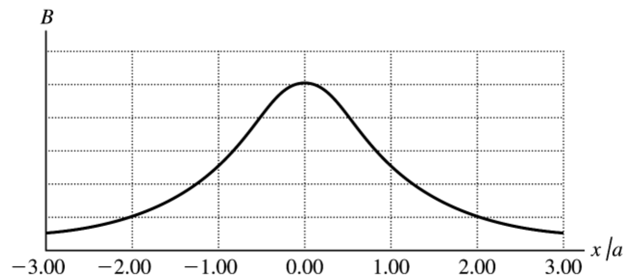


Figure 28.60

28.66. **IDENTIFY:** Apply $d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$.

SET UP: The two straight segments produce zero field at P. The field at the center of a circular loop of radius R is $B = \frac{\mu_0 I}{2R}$, so the field at the center of curvature of a semicircular loop is $B = \frac{\mu_0 I}{4R}$.

EXECUTE: The semicircular loop of radius a produces field out of the page at P and the semicircular loop of radius b produces field into the page. Therefore, $B = B_a - B_b = \frac{1}{2}\left(\frac{\mu_0 I}{2}\right)\left(\frac{1}{a} - \frac{1}{b}\right) = \frac{\mu_0 I}{4a}\left(1 - \frac{a}{b}\right)$, out of page.

EVALUATE: If $a = b$, $B = 0$.

28.68. **IDENTIFY:** Apply $d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$.

SET UP: The contribution from the straight segments is zero since $d\vec{l}\times\vec{r} = 0$. The magnetic field from the curved wire is just one quarter of a full loop.

EXECUTE: $B = \frac{1}{4}\left(\frac{\mu_0 I}{2R}\right) = \frac{\mu_0 I}{8R}$ and is directed out of the page.

EVALUATE: It is very simple to calculate B at point P but it would be much more difficult to calculate B at other points.

28.76. **IDENTIFY:** The net field is the vector sum of the fields due to the circular loop and to the long straight wire.

SET UP: For the long wire, $B = \frac{\mu_0 I_1}{2\pi D}$, and for the loop, $B = \frac{\mu_0 I_2}{2R}$.

EXECUTE: At the center of the circular loop the current I_2 generates a magnetic field that is into the page, so the current I_1 must point to the right. For complete cancellation the two fields must have the same magnitude: $\frac{\mu_0 I_1}{2\pi D} = \frac{\mu_0 I_2}{2R}$. Thus, $I_1 = \frac{\pi D}{R} I_2$.

EVALUATE: If I_1 is to the left the two fields add.

28.77. **IDENTIFY:** Use the current density J to find dI through a concentric ring and integrate over the appropriate cross section to find the current through that cross section. Then use Ampere's law to find $\vec{B}$ at the specified distance from the center of the wire.

(a) SET UP:

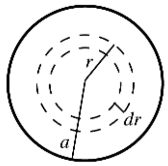


Figure 28.77a

Divide the cross section of the cylinder into thin concentric rings of radius r and width dr, as shown in Figure 28.77a. The current through each ring is $dI = J\,dA = J\,2\pi r\,dr$.

EXECUTE: $dI = \dfrac{2I_0}{\pi a^2}\left[1-(r/a)^2\right]2\pi r\ dr = \dfrac{4I_0}{a^2}\left[1-(r/a)^2\right]r\ dr$. The total current I is obtained by integrating dI over the cross section $I = \int_0^a dI = \left(\dfrac{4I_0}{a^2}\right)\int_0^a \left(1-r^2/a^2\right)r\ dr = \left(\dfrac{4I_0}{a^2}\right)\left[\dfrac{1}{2}r^2 - \dfrac{1}{4}r^4/a^2\right]_0^a = I_0$, as was to be shown.

(b) SET UP: Apply Ampere's law to a path that is a circle of radius $r > a$, as shown in Figure 28.77b.

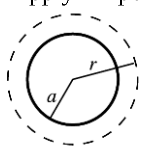


Figure 28.77b

$\oint \vec{B}\cdot d\vec{l} = B(2\pi r)$

$I_{\text{encl}} = I_0$ (the path encloses the entire cylinder)

EXECUTE: $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{\text{encl}}$ says $B(2\pi r) = \mu_0 I_0$ and $B = \dfrac{\mu_0 I_0}{2\pi r}$.

(c) SET UP:

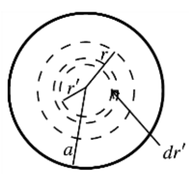


Figure 28.77c

Divide the cross section of the cylinder into concentric rings of radius r' and width dr', as was done in part (a). See Figure 28.77c. The current dI through each ring is

$$dI = \frac{4I_0}{a^2}\left[1-\left(\frac{r'}{a}\right)^2\right]r'\ dr'$$

EXECUTE: The current I is obtained by integrating dI from $r' = 0$ to $r' = r$:

$$I = \int dI = \frac{4I_0}{a^2}\int_0^r \left[1-\left(\frac{r'}{a}\right)^2\right]r'\ dr' = \frac{4I_0}{a^2}\left[\tfrac{1}{2}(r')^2 - \tfrac{1}{4}(r')^4/a^2\right]_0^r$$

$$I = \frac{4I_0}{a^2}(r^2/2 - r^4/4a^2) = \frac{I_0 r^2}{a^2}\left(2-\frac{r^2}{a^2}\right)$$

(d) SET UP: Apply Ampere's law to a path that is a circle of radius $r < a$, as shown in Figure 28.77d.

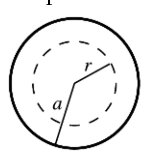


Figure 28.77d

$\oint \vec{B}\cdot d\vec{l} = B(2\pi r)$

$I_{\text{encl}} = \dfrac{I_0 r^2}{a^2}\left(2-\dfrac{r^2}{a^2}\right)$ (from part (c))

EXECUTE: $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{\text{encl}}$ says $B(2\pi r) = \mu_0 \dfrac{I_0 r^2}{a^2}(2-r^2/a^2)$ and $B = \dfrac{\mu_0 I_0}{2\pi}\dfrac{r}{a^2}(2-r^2/a^2)$

EVALUATE: Result in part (b) evaluated at $r = a$: $B = \dfrac{\mu_0 I_0}{2\pi a}$. Result in part (d) evaluated at $r = a$: $B = \dfrac{\mu_0 I_0}{2\pi}\dfrac{a}{a^2}(2-a^2/a^2) = \dfrac{\mu_0 I_0}{2\pi a}$. The two results, one for $r > a$ and the other for $r < a$, agree at $r = a$.

29.15. **IDENTIFY** and **SET UP:** The field of the induced current is directed to oppose the change in flux.
EXECUTE: **(a)** The field is into the page and is increasing so the flux is increasing. The field of the induced current is out of the page. To produce field out of the page the induced current is counterclockwise.
(b) The field is into the page and is decreasing so the flux is decreasing. The field of the induced current is into the page. To produce field into the page the induced current is clockwise.

(c) The field is constant so the flux is constant and there is no induced emf and no induced current.
EVALUATE: The direction of the induced current depends on the direction of the external magnetic field and whether the flux due to this field is increasing or decreasing.

29.45. **IDENTIFY:** Apply Faraday's law and Lenz's law.

SET UP: For a discharging RC circuit, $i(t) = \frac{V_0}{R}e^{-t/RC}$, where V_0 is the initial voltage across the capacitor. The resistance of the small loop is $(25)(0.600 \text{ m})(1.0 \ \Omega/\text{m}) = 15.0 \ \Omega$.

EXECUTE: **(a)** The large circuit is an RC circuit with a time constant of $\tau = RC = (10 \ \Omega)(20\times10^{-6} \text{ F}) = 200 \ \mu\text{s}$. Thus, the current as a function of time is $i = \left((100 \text{ V})/(10 \ \Omega)\right) e^{-t/200 \ \mu\text{s}}$. At $t = 200 \ \mu\text{s}$, we obtain $i = (10 \text{ A})(e^{-1}) = 3.7 \text{ A}$.

(b) Assuming that only the long wire nearest the small loop produces an appreciable magnetic flux through the small loop and referring to the solution of Exercise 29.7 we obtain $\Phi_B = \int_c^{c+a} \frac{\mu_0 ib}{2\pi r} dr = \frac{\mu_0 ib}{2\pi} \ln\left(1 + \frac{a}{c}\right)$. Therefore, the emf induced in the small loop at $t = 200 \mu\text{s}$ is $\mathcal{E} = -\frac{d\Phi}{dt} = -\frac{\mu_0 b}{2\pi} \ln\left(1 + \frac{a}{c}\right)\frac{di}{dt}$.

$\mathcal{E} = -\frac{(4\pi\times10^{-7} \text{ Wb/A}\cdot\text{m}^2)(0.200 \text{ m})}{2\pi} \ln(3.0)\left(-\frac{3.7 \text{ A}}{200\times10^{-6}\text{s}}\right) = +0.81 \text{ mV}$. Thus, the induced current in the small loop is $i' = \frac{\mathcal{E}}{R} = \frac{0.81 \text{ mV}}{15.0 \ \Omega} = 54 \mu\text{A}$.

(c) The magnetic field from the large loop is directed out of the page within the small loop.The induced current will act to oppose the decrease in flux from the large loop. Thus, the induced current flows counterclockwise.
EVALUATE: **(d)** Three of the wires in the large loop are too far away to make a significant contribution to the flux in the small loop–as can be seen by comparing the distance c to the dimensions of the large loop.

29.49. **(a) IDENTIFY:** (i) $|\mathcal{E}| = \left|\frac{d\Phi_B}{dt}\right|$. The flux is changing because the magnitude of the magnetic field of the wire decreases with distance from the wire. Find the flux through a narrow strip of area and integrate over the loop to find the total flux.**SET UP:**

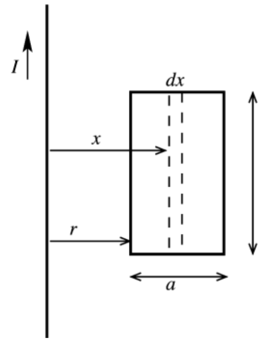


Figure 29.49a

Consider a narrow strip of width dx and a distance x from the long wire, as shown in Figure 29.49a. The magnetic field of the wire at the strip is $B = \mu_0 I/2\pi x$. The flux through the strip is $d\Phi_B = Bb \ dx = (\mu_0 Ib/2\pi)(dx/x)$

EXECUTE: The total flux through the loop is $\Phi_B = \int d\Phi_B = \left(\frac{\mu_0 Ib}{2\pi}\right)\int_r^{r+a} \frac{dx}{x}$

$\Phi_B = \left(\frac{\mu_0 Ib}{2\pi}\right)\ln\left(\frac{r+a}{r}\right) \qquad \frac{d\Phi_B}{dt} = \frac{d\Phi_B}{dt}\frac{dr}{dt} = \frac{\mu_0 Ib}{2\pi}\left(-\frac{a}{r(r+a)}\right)v \qquad |\mathcal{E}| = \frac{\mu_0 Iabv}{2\pi r(r+a)}$

(ii) **IDENTIFY:** $\mathcal{E} = Bvl$ for a bar of length l moving at speed v perpendicular to a magnetic field B. Calculate the induced emf in each side of the loop, and combine the emfs according to their polarity.

SET UP: The four segments of the loop are shown in Figure 29.49b.

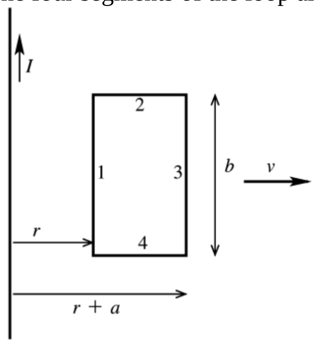


Figure 29.49b

EXECUTE: The emf in each side of the loop is $\mathcal{E}_1 = \left(\dfrac{\mu_0 I}{2\pi r}\right) vb,$

$$\mathcal{E}_2 = \left(\frac{\mu_0 I}{2\pi r(r+a)}\right) vb, \quad \mathcal{E}_2 = \mathcal{E}_4 = 0$$

Both emfs $\mathcal{E}_1$ and $\mathcal{E}_2$ are directed toward the top of the loop so oppose each other. The net emf is

$$\mathcal{E} = \mathcal{E}_1 - \mathcal{E}_2 = \frac{\mu_0 Ivb}{2\pi}\left(\frac{1}{r} - \frac{1}{r+a}\right) = \frac{\mu_0 Iabv}{2\pi r(r+a)}$$

This expression agrees with what was obtained in (i) using Faraday's law.

(b) (i) **IDENTIFY** and **SET UP:** The flux of the induced current opposes the change in flux.

EXECUTE: $\vec{B}$ is $\otimes$. Φ_B is $\otimes$ and decreasing, so the flux Φ_{ind} of the induced current is $\otimes$ and the current is clockwise.

(ii) **IDENTIFY** and **SET UP:** Use the right-hand rule to find the force on the positive charges in each side of the loop. The forces on positive charges in segments 1 and 2 of the loop are shown in Figure 29.49c.

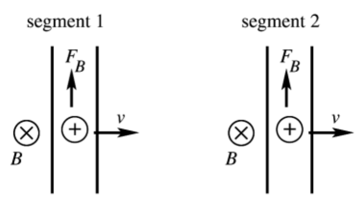


Figure 29.49c

EXECUTE: B is larger at segment 1 since it is closer to the long wire, so F_B is larger in segment 1 and the induced current in the loop is clockwise. This agrees with the direction deduced in (i) using Lenz's law.

(c) EVALUATE: When $v = 0$ the induced emf should be zero; the expression in part (a) gives this. When $a \to 0$ the flux goes to zero and the emf should approach zero; the expression in part (a) gives this. When $r \to \infty$ the magnetic field through the loop goes to zero and the emf should go to zero; the expression in part (a) gives this.

29.53. **IDENTIFY:** Apply Faraday's law in the form $\mathcal{E}_{\text{av}} = -N\dfrac{\Delta\Phi_B}{\Delta t}$ to calculate the average emf. Apply Lenz's law to calculate the direction of the induced current.

SET UP: $\Phi_B = BA$. The flux changes because the area of the loop changes.

EXECUTE: **(a)** $\mathcal{E}_{\text{av}} = \left|\dfrac{\Delta\Phi_B}{\Delta t}\right| = B\left|\dfrac{\Delta A}{\Delta t}\right| = B\dfrac{\pi r^2}{\Delta t} = (0.950\text{ T})\dfrac{\pi(0.0650/2\text{ m})^2}{0.250\text{ s}} = 0.0126\text{ V}.$

(b) Since the magnetic field is directed into the page and the magnitude of the flux through the loop is decreasing, the induced current must produce a field that goes into the page. Therefore the current flows from point a through the resistor to point b.

EVALUATE: Faraday's law can be used to find the direction of the induced current. Let $\vec{A}$ be into the page. Then Φ_B is positive and decreasing in magnitude, so $d\Phi_B/dt < 0$. Therefore $\mathcal{E} > 0$ and the induced current is clockwise around the loop.

29.56. **IDENTIFY:** Apply Newton's 2nd law to the bar. The bar will experience a magnetic force due to the induced current in the loop. Use $a = dv/dt$ to solve for v. At the terminal speed, $a = 0$.

SET UP: The induced emf in the loop has a magnitude BLv. The induced emf is counterclockwise, so it opposes the voltage of the battery, $\mathcal{E}$.

EXECUTE: **(a)** The net current in the loop is $I = \dfrac{\mathcal{E} - BLv}{R}$. The acceleration of the bar is $a = \dfrac{F}{m} = \dfrac{ILB\sin(90°)}{m} = \dfrac{(\mathcal{E} - BLv)LB}{mR}$. To find $v(t)$, set $\dfrac{dv}{dt} = a = \dfrac{(\mathcal{E} - BLv)LB}{mR}$ and solve for v using the method of separation of variables:

$$\int_0^v \frac{dv}{(\mathcal{E} - BLv)} = \int_0^t \frac{LB}{mR}dt \rightarrow v = \frac{\mathcal{E}}{BL}(1 - e^{-B^2L^2t/mR}) = (10\text{ m/s})(1 - e^{-t/3.1\text{ s}})$$

The graph of v versus t is sketched in Figure 29.56. Note that the graph of this function is similar in appearance to that of a charging capacitor.

(b) Just after the switch is closed, $v = 0$ and $I = \mathcal{E}/R = 2.4$ A, $F = ILB = 2.88$ N and $a = F/m = 3.2\text{ m/s}^2$.

(c) When $v = 2.0$ m/s, $a = \dfrac{[12\text{ V} - (1.5\text{ T})(0.8\text{ m})(2.0\text{ m/s})](0.8\text{ m})(1.5\text{ T})}{(0.90\text{ kg})(5.0\ \Omega)} = 2.6\text{ m/s}^2$.

(d) Note that as the speed increases, the acceleration decreases. The speed will asymptotically approach the terminal speed $\dfrac{\mathcal{E}}{BL} = \dfrac{12\text{ V}}{(1.5\text{ T})(0.8\text{ m})} = 10$ m/s, which makes the acceleration zero.

EVALUATE: The current in the circuit is counterclockwise and the magnetic force on the bar is to the right. The energy that appears as kinetic energy of the moving bar is supplied by the battery.

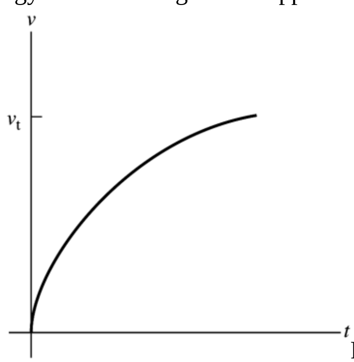


Figure 29.56

29.61. **(a)** and **(b)** **IDENTIFY** and **Set Up:**

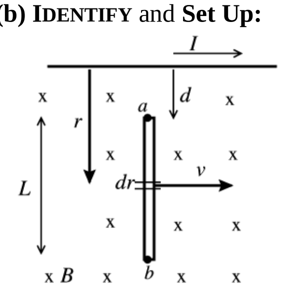


Figure 29.61a

The magnetic field of the wire is given by $B = \dfrac{\mu_0 I}{2\pi r}$ and varies along the length of the bar. At every point along the bar $\vec{B}$ has direction into the page. Divide the bar up into thin slices, as shown in Figure 29.61a.

EXECUTE: The emf $d\mathcal{E}$ induced in each slice is given by $d\mathcal{E} = \vec{v} \times \vec{B} \cdot d\vec{l}$. $\vec{v} \times \vec{B}$ is directed toward the wire, so $d\mathcal{E} = -vB\,dr = -v\left(\dfrac{\mu_0 I}{2\pi r}\right)dr$. The total emf induced in the bar is

$$V_{ba} = \int_a^b d\mathcal{E} = -\int_d^{d+L}\left(\frac{\mu_0 Iv}{2\pi r}\right)dr = -\frac{\mu_0 Iv}{2\pi}\int_d^{d+L}\frac{dr}{r} = -\frac{\mu_0 Iv}{2\pi}[\ln(r)]_d^{d+L}$$

$$V_{ba} = -\frac{\mu_0 Iv}{2\pi}(\ln(d+L) - \ln(d)) = -\frac{\mu_0 Iv}{2\pi}\ln(1 + L/d)$$

EVALUATE: The minus sign means that V_{ba} is negative, point a is at higher potential than point b. (The force $\vec{F} = q\vec{v} \times \vec{B}$ on positive charge carriers in the bar is towards a, so a is at higher potential.) The potential difference increases when I or v increase, or d decreases.

(c) IDENTIFY: Use Faraday's law to calculate the induced emf.

SET UP: The wire and loop are sketched in Figure 29.61b.

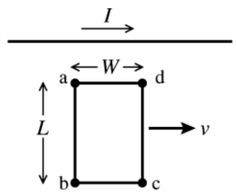


Figure 29.61b

EXECUTE: As the loop moves to the right the magnetic flux through it doesn't change. Thus $\mathcal{E} = -\dfrac{d\Phi_B}{dt} = 0$ and $I = 0$.

EVALUATE: This result can also be understood as follows. The induced emf in section *ab* puts point *a* at higher potential; the induced emf in section *dc* puts point *d* at higher potential. If you travel around the loop then these two induced emf's sum to zero. There is no emf in the loop and hence no current.

29.75. **IDENTIFY:** Apply Eq.(29.10).
SET UP: Use an integration path that is a circle of radius *r*. By symmetry the induced electric field is tangent to this path and constant in magnitude at all points on the path.
EXECUTE: **(a)** The induced electric field at these points is shown in Figure 29.75a.
(b) To work out the amount of the electric field that is in the direction of the loop at a general position, we will use the geometry shown in Figure 29.75b. $E_{\text{loop}} = E\cos\theta$ but $E = \dfrac{\mathcal{E}}{2\pi r} = \dfrac{\mathcal{E}}{2\pi(a/\cos\theta)} = \dfrac{\mathcal{E}\cos\theta}{2\pi a}$. Therefore, $E_{\text{loop}} = \dfrac{\mathcal{E}\cos^2\theta}{2\pi a}$. But $\mathcal{E} = \dfrac{d\Phi_B}{dt} = A\dfrac{dB}{dt} = \pi r^2\dfrac{dB}{dt} = \dfrac{\pi a^2}{\cos^2\theta}\dfrac{dB}{dt}$, so $E_{\text{loop}} = \dfrac{\pi a^2}{2\pi a}\dfrac{dB}{dt} = \dfrac{a}{2}\dfrac{dB}{dt}$. This is exactly the value for a ring, obtained in Exercise 29.30, and has no dependence on the part of the loop we pick.
(c) $I = \dfrac{\mathcal{E}}{R} = \dfrac{A}{R}\dfrac{dB}{dt} = \dfrac{L^2}{R}\dfrac{dB}{dt} = \dfrac{(0.20\text{ m})^2(0.0350\text{ T/s})}{1.90\ \Omega} = 7.37\times10^{-4}$ A.
(d) $\mathcal{E}_{ab} = \dfrac{1}{8}\mathcal{E} = \dfrac{1}{8}L^2\dfrac{dB}{dt} = \dfrac{(0.20\text{ m})^2(0.0350\text{ T/s})}{8} = 1.75\times10^{-4}$ V. But there is potential drop $V = IR = -1.75\times10^{-4}$ V, so the potential difference is zero.
EVALUATE: The magnitude of the induced emf between any two points equals the magnitudes of the potential drop due to the current through the resistance of that portion of the loop.

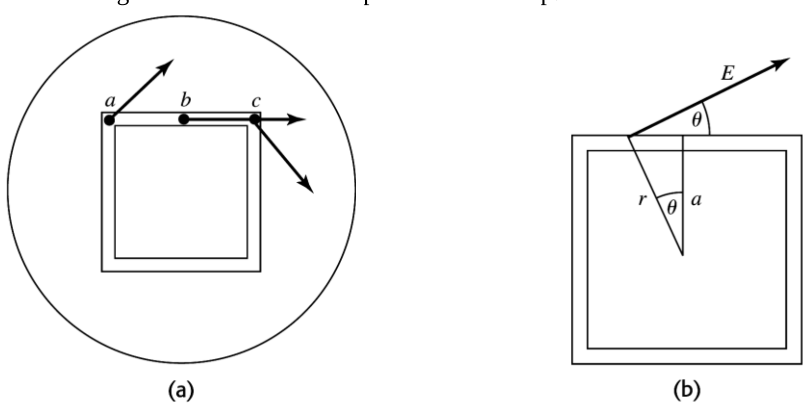


Figure 29.75

29.21. **IDENTIFY:** A conductor moving in a magnetic field may have a potential difference induced across it, depending on how it is moving.
SET UP: The induced emf is $\mathcal{E} = vBL\sin\phi$, where ϕ is the angle between the velocity and the magnetic field.
EXECUTE: **(a)** $\mathcal{E} = vBL\sin\phi = (5.00\text{ m/s})(0.450\text{ T})(0.300\text{ m})(\sin 90°) = 0.675$ V
(b) The positive charges are moved to end *b*, so *b* is at the higher potential.
(c) $E = V/L = (0.675\text{ V})/(0.300\text{ m}) = 2.25$ V/m. The direction of $\vec{E}$ is from, *b* to *a*.
(d) The positive charge are pushed to *b*, so *b* has an excess of positive charge.
(e) (i) If the rod has no appreciable thickness, $L = 0$, so the emf is zero. (ii) The emf is zero because no magnetic force acts on the charges in the rod since it moves parallel to the magnetic field.
EVALUATE: The motional emf is large enough to have noticeable effects in some cases.