29.50. The changing current in the large *RC* circuit produces a changing magnetic flux through the small circuit, which induces an emf in the small circuit. This emf causes a current in the small circuit.

For a charging *RC* circuit, $i(t) = \frac{\varepsilon}{R} e^{-t/RC}$, where ε is the emf (90.0 V) added to the large circuit.

$$\Phi_B = \int_c^{c+a} \frac{\mu_0 ib}{2\pi r} dr = \frac{\mu_0 ib}{2\pi} \ln\left(1 + \frac{a}{c}\right).$$

For each turn of the small circuit, and $\varepsilon_{\text{induced}} = -\frac{d\Phi_B}{dt}$.

$\frac{d\Phi_B}{dt} = \frac{\mu_0 b}{2\pi} \ln(1 + a/c) \frac{di}{dt}$. $\frac{di}{dt} = -\frac{\varepsilon}{R^2 C} e^{-t/RC}$ and

$$|\varepsilon_{\text{induced}}| = N\left|\frac{d\Phi_B}{dt}\right| = \frac{N\mu_0 b}{2\pi} \ln(1 + a/c) \frac{\varepsilon}{R^2 C} e^{-t/RC} = \frac{N\mu_0 b}{2\pi} \ln(1 + a/c) \frac{1}{RC} i.$$

The resistance of the small loop is $(25)(0.600 \text{ m})(1.0 \ \Omega/\text{m}) = 15.0 \ \Omega$.

$$|\varepsilon_{\text{induced}}| = (25)(2.00 \times 10^{-7} \text{ T} \cdot \text{m/A})(0.200 \text{ m}) \ln(1 + 10.0/5.0) \frac{1}{(10 \ \Omega)(20 \times 10^{-6} \text{ F})}(5.00 \text{ A}).$$

$|\varepsilon_{\text{induced}}| = 0.02747$ V. The induced current is $\frac{|\varepsilon_{\text{induced}}|}{R} = \frac{0.02747 \text{ V}}{15.0 \ \Omega} = 1.83 \times 10^{-3} \text{ A} = 1.83 \text{ mA}.$

The current in the large loop is counterclockwise. The magnetic field through the small loop is into the page and the flux is increasing, so the flux due to the induced current in the small loop is out of the page and the induced current in the small loop is counterclockwise.

29.60. Apply Newton's second 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, $a = 0$.

The induced emf in the loop has a magnitude BLv. The induced emf is counterclockwise, so it opposes the voltage of the battery, ε.

(a) The net current in the loop is $I = \frac{\varepsilon - BLv}{R}$. The acceleration of the bar is

$a = \frac{F}{m} = \frac{ILB\sin(90°)}{m} = \frac{(\varepsilon - BLv)LB}{mR}$. To find $v(t)$, set $\frac{dv}{dt} = a = \frac{(\varepsilon - BLv)LB}{mR}$ and solve for *v* using the method of separation of variables:

$\int_0^v \frac{dv}{(\varepsilon - BLv)} = \int_0^t \frac{LB}{mR} dt \to v = \frac{\varepsilon}{BL}(1 - e^{-B^2L^2 t/mR}) = (22 \text{ m/s})(1 - e^{-t/15 \text{ s}})$. The graph of *v* versus *t* is sketched in Figure 29.60. 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 $I = \varepsilon/R = 2.4$ A, $F = ILB = 1.296$ N, and

$a = F/m = 1.4 \text{ m/s}^2$.

(c) When $v = 2.0$ m/s, $a = \frac{[12 \text{ V} - (1.5 \text{ T})(0.36 \text{ m})(2.0 \text{ m/s})](0.36 \text{ m})(1.5 \text{ T})}{(0.90 \text{ kg})(5.0 \ \Omega)} = 1.3 \text{ m/s}^2$.

(d) Note that as the speed increases, the acceleration decreases. The speed will asymptotically approach the terminal speed $\frac{\varepsilon}{BL} = \frac{12 \text{ V}}{(1.5 \text{ T})(0.36 \text{ m})} = 22$ m/s, which makes the acceleration zero.

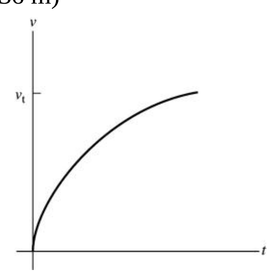
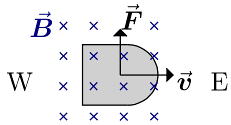


Figure29.60

62.

a)



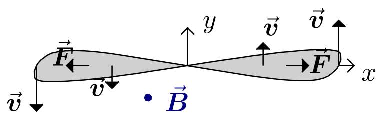
$$\mathcal{E} = v\,B\,d_{\text{bullet}} = (300\,\text{m/s})\,(8\times 10^{-5}\,\text{T})\,(4\times 10^{-3}\,\text{m}) = 9.6\times 10^{-5}\,\text{V}$$

(more positive on the top).

b) If the bullet is going south, then $\vec{\boldsymbol{v}}$ is parallel to $\vec{\boldsymbol{B}}$, so $\vec{\boldsymbol{F}} = q\,\vec{\boldsymbol{v}}\times\vec{\boldsymbol{B}} = 0$ and there is no emf.

c) If the bullet is moving horizontally, then $\vec{\boldsymbol{v}}\times\vec{\boldsymbol{B}}$ points straight up; therefore the charges are not pushed toward the front or back of the bullet, so the emf between the front and the back is zero.

72.



a) $\vec{\boldsymbol{v}} = x\,\omega\,\hat{\boldsymbol{j}}$, $\mathcal{E} = \int_0^{L/2}\left(\vec{\boldsymbol{v}}\times\vec{\boldsymbol{B}}\right)\cdot \mathrm{d}\vec{\boldsymbol{\ell}} = \int_0^{L/2} x\,\omega\,B\left(\hat{\boldsymbol{j}}\times\hat{\boldsymbol{k}}\right)\cdot\hat{\boldsymbol{\imath}}\,\mathrm{d}x = \omega\,B\,\frac{1}{2}\left(\frac{L}{2}\right)^2 = \frac{1}{8}\,\omega\,B\,L^2.$

b) $\mathcal{E} = \int_{-L/2}^{L/2} x\,\omega\,B\left(\hat{\boldsymbol{j}}\times\hat{\boldsymbol{k}}\right)\cdot\hat{\boldsymbol{\imath}}\,\mathrm{d}x = \omega\,B\,\frac{1}{2}\left[\left(\frac{L}{2}\right)^2 - \left(\frac{L}{2}\right)^2\right] = 0$

c) $\mathcal{E} = \frac{1}{8}\,(220\,\text{rev/min})\left(\frac{2\,\pi\,\text{rad}}{\text{rev}}\right)\left(\frac{1\,\text{min}}{60\,\text{s}}\right)(0.50\,\text{G})\left(\frac{1\,\text{T}}{10^4\,\text{G}}\right)(2.0\,\text{m})^2 = 5.8\times 10^{-4}\,\text{V}$; this is unlikely to be a concern.