Q31.5 By the magnetic force law $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$: the positive charges in the moving bar will flow downward and therefore clockwise in the circuit. If the bar is moving to the left, the positive charge in the bar will flow upward and therefore counterclockwise in the circuit.

Q31.13 The increasing counterclockwise current in the solenoid coil produces an upward magnetic field that increases rapidly. The increasing upward flux of this field through the ring induces an emf to produce clockwise current in the ring. The magnetic field of the solenoid has a radially outward component at each point on the ring. This field component exerts upward force on the current in the ring there. The whole ring feels a total upward force larger than its weight.

Q31.16 (a) The battery makes counterclockwise current $I_1$ in the primary coil, so its magnetic field $B_1$ is to the right and increasing just after the switch is closed. The secondary coil will oppose the change with a leftward field $B_2$, which comes from an induced clockwise current $I_2$ that goes to the right in the resistor.

(b) At steady state the primary magnetic field is unchanging, so no emf is induced in the secondary.

(c) The primary’s field is to the right and decreasing as the switch is opened. The secondary coil opposes this decrease by making its own field to the right, carrying counterclockwise current to the left in the resistor.

P31.1 $\varepsilon = \frac{\Delta \Phi_B}{\Delta t} = \frac{\Delta (NBA)}{\Delta t} = 500 \text{ mV}$
P31.9

(a) \[ \Phi_B = \mathbf{B} \cdot \mathbf{A} = \frac{\mu_0 I}{2\pi R} \int_{h}^{h+w} dx \cdot \Phi_B = \int_{h}^{h+w} \frac{\mu_0 L}{2\pi} dx = \frac{\mu_0 L}{2\pi} \ln \left( \frac{h+w}{h} \right) \]

(b) \[ \varepsilon = -\frac{d\Phi_B}{dt} = -\frac{d}{dt} \left[ \frac{\mu_0 L}{2\pi} \ln \left( \frac{h+w}{h} \right) \right] = -\left[ \frac{\mu_0 L}{2\pi} \ln \left( \frac{h+w}{h} \right) \right] \frac{dI}{dt} \]

\[ \varepsilon = -\left( 4\pi \times 10^{-7} \text{T} \cdot \text{m/A} \right) \left( 1.00 \text{ m} \right) \ln \left( \frac{1.00 + 10 \text{ D}}{1.00} \right) \left( 10 \text{ D} \text{ A/s} \right) = -4.80 \mu\text{V} \]

The long wire produces magnetic flux into the page through the rectangle, shown by the first hand in the figure to the right.

As the magnetic flux increases, the rectangle produces its own magnetic field out of the page, which it does by carrying \textbf{counterclockwise} current (second hand in the figure).

P31.13

\[ B = \mu_0 n I = \mu_0 n \left( 30 \text{ D A} \right) \left( 1 - e^{-1.60t} \right) \]

\[ \Phi_B = \int B dA = \mu_0 n \left( 30 \text{ D A} \right) \left( 1 - e^{-1.60t} \right) \int dA \]

\[ \Phi_B = \mu_0 n \left( 30 \text{ D A} \right) \left( 1 - e^{-1.60t} \right) \pi R^2 \]

\[ \varepsilon = -N \frac{d\Phi_B}{dt} = -N \mu_0 n \left( 30 \text{ D A} \right) \pi R^2 \left( 1.60 \right) e^{-1.60t} \]

\[ \varepsilon = -250 \left[ 4\pi \times 10^{-7} \text{ N/A}^2 \right] \left( 400 \text{ m}^{-1} \right) \left( 30 \text{ D A} \right) \left[ \pi \left( 0.60 \text{ m} \right)^2 \right] \left( 1.60 \text{ s}^{-1} e^{-1.60t} \right) \]

\[ \varepsilon = \left( 68.2 \text{ mV} \right) e^{-1.60t} \text{ counterclockwise} \]

P31.20

\[ I = \frac{\varepsilon}{R} - B\ell \nu \]

\[ v = 1.00 \text{ m/s} \]

P31.21

(a) \[ \mathbf{F}_B = \mathbf{I} \times \mathbf{B} = \mathbf{E} \mathbf{B} \]

When \[ I = \frac{\varepsilon}{R} \]

and \[ \varepsilon = B\ell \nu \]

we get \[ \mathbf{F}_B = \frac{B\ell \nu}{R} \left( \mathbf{B} \right) = \frac{B^2 \ell^2 \nu}{R} = \frac{\left( 2.50 \right)^2 \left( 1.20 \right)^2 \left( 2.00 \right)}{6.00} = 3.00 \text{ N} \]

The applied force is \textbf{3.00 N to the right}.

(b) \[ P = \frac{\mathbf{F}_B \cdot \ell}{R} = 6.00 \text{ W} \]

or \[ P = \nu \mathbf{v} = 6.00 \text{ W} \]
\[ P31.22 \quad E_B = \mathbb{J} B \quad \text{and} \quad \varepsilon = B \ell v \]
\[ I = \frac{\varepsilon}{R} = \frac{B \ell v}{R} \quad \text{so} \quad B = \frac{\mathbb{J} R}{\ell v} \]

(a) \[ E_B = \frac{\mathbb{J} \ell R}{\ell v} \quad \text{and} \quad I = \sqrt{\frac{E_B v}{R}} = 0.500 \, \text{A} \]

(b) \[ \mathbb{J} R = 2.00 \, \text{W} \]

(c) \[ \text{For constant force, } P = \mathbf{F} \cdot \mathbf{v} = (1.00 \, \text{N})(2.00 \, \text{m/s}) = 2.00 \, \text{W} \]

\[ P31.20 \quad I = \frac{\varepsilon}{R} = \frac{B \ell v}{R} \]
\[ v = 1.00 \, \text{m/s} \]

\[ \text{FIG. P31.20} \]

\[ P31.21 \quad (a) \quad | \mathbf{E}_B \| = | \mathbf{J} \times \mathbf{B} | = \mathbb{J} B \]

When \[ I = \frac{\varepsilon}{R} \]
and \[ \varepsilon = B \ell v \]
we get \[ E_B = \frac{B \ell v}{R} (\ell B) = \frac{B^2 \ell^2 v}{R} = \frac{(2.50)^2 (1.20)^2 (2.00)}{6.00} = 3.00 \, \text{N} \]

The applied force is \[ 3.00 \, \text{N} \text{ to the right} \].

(b) \[ P = \mathbb{J} R = \frac{B^2 \ell^2 v^2}{R} = 6.00 \, \text{W} \quad \text{or} \quad P = Fv = 6.00 \, \text{W} \]

\[ P31.22 \quad E_B = \mathbb{J} B \quad \text{and} \quad \varepsilon = B \ell v \]
\[ I = \frac{\varepsilon}{R} = \frac{B \ell v}{R} \quad \text{so} \quad B = \frac{\mathbb{J} R}{\ell v} \]

(a) \[ E_B = \frac{\mathbb{J} \ell R}{\ell v} \quad \text{and} \quad I = \sqrt{\frac{E_B v}{R}} = 0.500 \, \text{A} \]

(b) \[ \mathbb{J} R = 2.00 \, \text{W} \]

(c) \[ \text{For constant force, } P = \mathbf{F} \cdot \mathbf{v} = (1.00 \, \text{N})(2.00 \, \text{m/s}) = 2.00 \, \text{W} \].