Problem 1

58. (*a*) The clockwise current in the left-hand loop produces a magnetic field which is into the page within the loop and out of the page outside the loop. Thus the right-hand loop is in a magnetic field that is directed out of the page. Before the current in the left-hand loop reaches its steady state, there will be an induced current in the right-hand loop that will produce a magnetic field into the page to oppose the increase of the field from the left-hand loop. Thus the induced current will be $\boxed{\text{clockwise}}$.

(*b*) After a long time, the current in the left-hand loop is constant, so there will be $\boxed{\text{no induced current}}$ in the right-hand coil.

(*c*) If the second loop is pulled to the right, the magnetic field out of the page from the left-hand loop through the second loop will decrease. During the motion, there will be an induced current in the right-hand loop that will produce a magnetic field out of the page to oppose the decrease of the field from the left-hand loop. Thus the induced current will be $\boxed{\text{counterclockwise}}$.

Problem 2

59. The electrical energy is dissipated because there is current flowing in a resistor. The power dissipation by a resistor is given by $P = I^2 R$, and so the energy dissipated is $E = P\Delta t = I^2 R\Delta t$. The current is created by the induced emf caused by the changing B-field. The average induced emf is given by the "difference" version of Eq. 29-2b.

$$\mathcal{E} = -\frac{\Delta\Phi_B}{\Delta t} = -\frac{A\Delta B}{\Delta t} \qquad I = \frac{\mathcal{E}}{R} = -\frac{A\Delta B}{R\Delta t}$$

$$E = P\Delta t = I^2 R\Delta t = \frac{A^2(\Delta B)^2}{R^2(\Delta t)^2} R\Delta t = \frac{A^2(\Delta B)^2}{R(\Delta t)} = \frac{\left[(0.270\,\text{m})^2\right]^2\left[(0-0.755\,\text{T})\right]^2}{(7.50\,\Omega)(0.0400\,\text{s})}$$

$$= \boxed{1.01\times10^{-2}\,\text{J}}$$

Problem 3

$\boxed{61.}$ The charge on the capacitor can be written in terms of the voltage across the battery and the capacitance using Eq. 24-1. When fully charged the voltage across the capacitor will equal the emf of the loop, which we calculate using Eq. 29-2b.

$$Q = CV = C\frac{d\Phi_B}{dt} = CA\frac{dB}{dt} = \left(5.0\times10^{-12}\ \text{F}\right)\left(12\ \text{m}^2\right)\left(10\ \text{T/s}\right) = \boxed{0.60\ \text{nC}}$$

Problem 4

Model: Assume that the magnet is a bar magnet with field lines pointing away from the north end.
Visualize: As the magnets move, if they create a change in the flux through the solenoid, there will be an induced current and corresponding field. According to Lenz's law, the induced current creates an induced field that opposes the *change* in flux.

Solve: **(a)** When magnet 1 is close to the solenoid there is flux to the left through the solenoid. As magnet 1 moves away there is less flux to the left. The induced current will oppose this *change* and produce an induced current and a corresponding flux to the left. By the right-hand rule, this corresponds to a current in the wire into the page at the top of the solenoid and out of the page at the bottom of the solenoid. So, the current will be *right to left* in the resistor.
(b) When magnet 2 is close to the solenoid the diverging field lines of the bar magnet produce a flux to the left in the left half of the solenoid and a flux to the right in the right half. Since the flux depends on the orientation of the loop, the flux on the two halves have opposite signs and the net flux is zero. Moving the magnet away changes the strength of the field and flux, but the total flux is still zero. Thus there is *no induced current*.

Problem 5

Model: Assume the field is uniform across the loop.
Visualize: There is a current in the loop so there must be an emf that is due to a changing flux. With the loop fixed the area is constant so the change in flux must be due to a changing field strength.
Solve: The induced emf is $\mathrm{E} = |d\Phi/dt|$ and the induced current is $I = \mathrm{E}/R$. The B field is changing, but the area A is not. Take $\vec{A}$ as being into the page and parallel to $\vec{B}$, so $\Phi = AB$ and $d\Phi/dt = A(dB/dt)$. We have

$$\mathrm{E} = \left|\frac{d\Phi}{dt}\right| = A\left|\frac{dB}{dt}\right| \Rightarrow \left|\frac{dB}{dt}\right| = \frac{IR}{A} = \frac{(150\times10^{-3}\,\mathrm{A})(0.20\,\Omega)}{(0.080\,\mathrm{m})^2} = 4.7\ \mathrm{T/s}$$

The original field and flux is into the page. The induced counterclockwise current produces an induced field and flux that is out of the page. Since the induced field opposes the change, the field must be *increasing*.

Problem 6

Model: Assume there is no resistance in the rails. If there is any resistance, it is accounted for by the resistor.
Visualize: .The moving wire will have a motional emf that produces a current in the loop.
Solve: **(a)** At constant velocity the external pushing force is balanced by the magnetic force, so

$$F_{\mathrm{push}} = F_{\mathrm{mag}} = IlB = \frac{\mathrm{E}}{R}lB = \left(\frac{Blv}{R}\right)lB = \frac{B^2l^2v}{R} = \frac{(0.50\ \mathrm{T})^2(0.10\ \mathrm{m})^2(0.50\ \mathrm{m/s})}{2.0\Omega} = 6.25\times10^{-4}\ \mathrm{N} \approx 6.3\times10^{-4}\ \mathrm{N}$$

(b) The power is

$$P = Fv = (6.25\times10^{-4}\ \mathrm{N})(0.50\ \mathrm{m/s}) = 3.1\times10^{-4}\ \mathrm{W}$$

(c) The flux is out of the page and decreasing and the induced current/field will oppose the change. The induced field must have a flux that is out of the page so the current will be *counterclockwise*.
The magnitude of the current is

$$I = \left(\frac{Blv}{R}\right) = \frac{(0.50\ \mathrm{T})(0.10\ \mathrm{m})(0.50\ \mathrm{m/s})}{2.0\Omega} = 1.25\times10^{-2}\ \mathrm{A}$$

(d) The power is

$$P = I^2R = (1.25\times10^{-2}\ \mathrm{A})^2(2.0\ \Omega) = 3.1\times10^{-4}\ \mathrm{W}$$

Assess: From energy conservation we see that the mechanical energy put in by the pushing force shows up as electrical energy in the resistor.

Problem 7

Model: Assume the magnetic field is uniform over the region where the bar is sliding and that friction between the bar and the rails is zero.
Visualize: Please refer to Figure P34.52. The battery will produce a current in the rails and bar and the bar will experience a force. With the battery connected as shown in the figure, the current in the bar will be down and by

the right-hand rule the force on the bar will be to the right. The motion of the bar will change the flux through the loop and there will be an induced emf that opposes the change.

Solve: **(a)** As the bar speeds up the induced emf will get larger until finally it equals the battery emf. At that point, the current will go to zero and the bar will continue to move at a constant velocity. We have

$$\mathrm{E} = Blv_{\text{term}} = \mathrm{E}_{\text{bat}} \Rightarrow v_{\text{term}} = \frac{\mathrm{E}_{\text{bat}}}{Bl}$$

(b) The terminal speed is

$$v_{\text{term}} = \frac{1.0 \text{ V}}{(0.50 \text{ T})(0.060 \text{ m})} = 33 \text{ m/s}$$

Assess: This is pretty fast, about 70 mph.