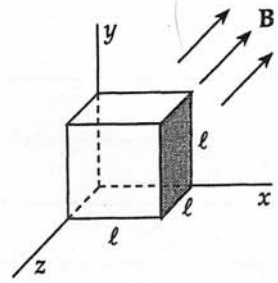
SOLUTIONS CHAPTER 20

8. As water falls, it gains velocity and kinetic energy. It then pushes against the blades of a turbine transferring this energy to the rotor or coil of a large alternating current generator. The rotor moves in a strong external magnetic field and a voltage is induced in the coil. This induced emf is the voltage source for the current in our electric power lines.

20.7 (a) The magnetic flux through an area A may be written as



$$\Phi_B = (B\cos\theta)A$$
$$= (\text{component of } B \text{ perpendicular to } A)\cdot A$$

Thus, the flux through the shaded side of the cube is

$$\Phi_B = B_x \cdot A = (5.0\ \text{T})\cdot(2.5\times10^{-2}\ \text{m})^2 = \boxed{3.1\times10^{-3}\ \text{T}\cdot\text{m}^2}$$

(b) Unlike electric field lines, magnetic field lines always form closed loops, without beginning or end. Therefore, no magnetic field lines originate or terminate within the cube and any line entering the cube at one point must emerge from the cube at some other point. The net flux through the cube, and indeed through any *closed* surface, is $\boxed{\text{zero}}$.

20.10 $$|\mathcal{E}| = \frac{\Delta\Phi_B}{\Delta t} = \frac{B(\Delta A)\cos\theta}{\Delta t}$$

$$= \frac{(0.15\ \text{T})\left[\pi(0.12\ \text{m})^2 - 0\right]\cos 0^\circ}{0.20\ \text{s}} = 3.4\times10^{-2}\ \text{V} = \boxed{34\ \text{mV}}$$

20.14 The initial magnetic field inside the solenoid is

$$B = \mu_0 nI = (4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})\left(\frac{100}{0.200\ \text{m}}\right)(3.00\ \text{A}) = 1.88\times10^{-3}\ \text{T}$$

(a) $$\Phi_B = BA\cos\theta = (1.88\times10^{-3}\ \text{T})(1.00\times10^{-2}\ \text{m})^2\cos 0^\circ$$

$$= \boxed{1.88\times10^{-7}\ \text{T}\cdot\text{m}^2}$$

20.18 From $\varepsilon = B\ell v$, the required speed is

$$v = \frac{\varepsilon}{B\ell} = \frac{IR}{B\ell} = \frac{(0.500\ \text{A})(6.00\ \Omega)}{(2.50\ \text{T})(1.20\ \text{m})} = \boxed{1.00\ \text{m/s}}$$

20.23 (a) To oppose the motion of the magnet, the magnetic field generated by the induced current should be directed to the right along the axis of the coil. The current must then be $\boxed{\text{left to right}}$ through the resistor.

(b) The magnetic field produced by the current should be directed to the left along the axis of the coil, so the current must be $\boxed{\text{right to left}}$ through the resistor.

20.26 When the switch is closed, the magnetic field due to the current from the battery will be directed to the left along the axis of the cylinder. To oppose this increasing leftward flux, the induced current in the other loop must produce a field directed to the right through the area it encloses. Thus, the induced current is $\boxed{\text{left to right}}$ through the resistor.

20.30

$$\mathcal{E}_{max} = NB_{horizontal}A\omega = 100\left(2.0\times10^{-5}\text{ T}\right)(0.20\text{ m})^2\left[\left(1500\ \frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi\text{ rad}}{1\text{ rev}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)\right]$$

$$= 1.3\times10^{-2}\text{ V} = \boxed{13\text{ mV}}$$

20.32 (a) Immediately after the switch is closed, the motor coils are still stationary and the back emf is zero. Thus, $I_{max} = \dfrac{\mathcal{E}}{R} = \dfrac{240\text{ V}}{30\ \Omega} = \boxed{8.0\text{ A}}$

(b) At maximum speed, $\mathcal{E}_{back} = 145\text{ V}$ and

$$I = \frac{\mathcal{E}-\mathcal{E}_{back}}{R} = \frac{240\text{ V}-145\text{ V}}{30\ \Omega} = \boxed{3.2\text{ A}}$$

(c) $\mathcal{E}_{back} = \mathcal{E} - IR = 240\text{ V} - (6.0\text{ A})(30\ \Omega) = \boxed{60\text{ V}}$

20.57 (a) To move the bar at uniform speed, the magnitude of the applied force must equal that of the magnetic force retarding the motion of the bar. Therefore, $F_{app} = BI\ell$. The magnitude of the induced current is

$$I = \frac{|\mathcal{E}|}{R} = \frac{\left(\Delta\Phi_B/\Delta t\right)}{R} = \frac{B\left(\Delta A/\Delta t\right)}{R} = \frac{B\ell v}{R},$$

so the field strength is $B = \dfrac{IR}{\ell v}$, giving $F_{app} = I^2R/v$.

Thus, the current is

$$I = \sqrt{\frac{F_{app} \cdot v}{R}} = \sqrt{\frac{(1.00\ \text{N})(2.00\ \text{m/s})}{8.00\ \Omega}} = \boxed{0.500\ \text{A}}$$

(b) $\wp = I^2 R = (0.500\ \text{A})^2 (8.00\ \Omega) = \boxed{2.00\ \text{W}}$

(c) $\wp_{input} = F_{app} \cdot v = (1.00\ \text{N})(2.00\ \text{m/s}) = \boxed{2.00\ \text{W}}$

20.59 If d is the distance from the lightning bolt to the center of the coil, then

$$|\mathcal{E}| = \frac{N(\Delta\Phi_B)}{\Delta t} = \frac{N(\Delta B)A}{\Delta t} = \frac{N[\mu_0(\Delta I)/2\pi d]A}{\Delta t} = \frac{N\mu_0(\Delta I)A}{2\pi d(\Delta t)}$$

$$= \frac{100(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(6.02\times10^{6}\ \text{A}-0)\left[\pi(0.800\ \text{m})^2\right]}{2\pi(200\ \text{m})(10.5\times10^{-6}\ \text{s})}$$

$$= 1.15\times10^{5}\ \text{V} = \boxed{115\ \text{kV}}$$