Chapter 20 Homework

(6) For solenoid, $B = \mu_0 n I = \mu_0 \frac{N}{L} I$

$N = $ # of turns, $L = $ length of solenoid

$\Rightarrow B = \left(4\pi \times 10^{-7} \frac{T \cdot m}{A}\right)\left(\frac{250}{0.200\,m}\right)(15.0\,A) = 2.36 \times 10^{-2}\,T$

$\Rightarrow$ Flux $= \phi_B = BA\cos\theta$

$= (2.36 \times 10^{-2}\,T)\left(\frac{\pi(4 \times 10^{-2}\,m)^2}{4}\right)\cos 0°$

$= \boxed{2.96 \times 10^{-5}\,T \cdot m^2}$

(14) $B = \mu_0 n I = \left(4\pi \times 10^{-7} \frac{T \cdot m}{A}\right)\left(\frac{100}{0.200\,m}\right)(3\,A) = 1.88 \times 10^{-3}\,T$

a) $\phi_B = BA\cos\theta = (1.88 \times 10^{-3}\,T)(1 \times 10^{-2}\,m)^2 \cos 0°$

$= \boxed{1.88 \times 10^{-7}\,T \cdot m^2}$

b) When the current is zero, the flux through the loop is $\phi_B = 0$, and the average induced EMF is

$|\mathcal{E}| = \frac{\Delta\phi_B}{\Delta t} = \frac{1.88 \times 10^{-7}\,T \cdot m^2 - 0}{3\,s} = 6.28 \times 10^{-8}\,V$

(18) $|\mathcal{E}| = B l v$

$$\Rightarrow v = \frac{\mathcal{E}}{Bl} = \frac{IR}{Bl} = \frac{(0.5\,A)(6.0\,\Omega)}{(2.5\,T)(1.2\,m)} = \boxed{1.0\,m/s}$$

(20) Beam starts from rest $\Rightarrow V_{oy} = 0$

$$V_y = \sqrt{V_{oy}^2 + 2a_y(\Delta y)} = \sqrt{0 + 2(-9.8\,m/s^2)(-9.0\,m)} = 13.3\,m/s$$

Induced emf $\mathcal{E} = B_\perp l v$, where

$B_\perp$ is the component of the magnetic field perpendicular to the velocity.

$$\mathcal{E} = (18.0 \times 10^{-6}\,T)(12.0\,m)(13.3\,m/s) = 2.87 \times 10^{-3}\,V$$
$$= \boxed{2.87\,mV}$$

(26) When the switch is closed, the magnetic field inside the coil will point to the left. According to Lenz's Law, the current from the induced emf creates a magnetic field that opposes the change in magnetic flux. Therefore, the induced current will create a magnetic field that points to the right inside the coil. Using the second right hand rule, the induced current moves **left to right** in the resistor.

(28) a) When the switch is closed, the current is going to move through the coil such that (according to the second right hand rule) a magnetic field is created that points to the right. Therefore, according to Lenz's law, an induced current will be created that opposes this magnetic flux change. The magnetic field will point right to left along the axis. Therefore, the induced current must be left to right through the resistor.

b) Once the battery is current, and the field it produces have stabalized, the flux through the rightmost coil is constant and there is no induced current.

c) As the switch is opened, the battery current and the field it produces rapidly decrease in magnitude. To oppose this decrease in the rightward directed field, the induced current must produce a field toward the right along the axis, so the induced current is right to left through the resistor.

(39) a) For solenoid, $L = \dfrac{\mu_0 N^2 A}{\ell}$

$$\Rightarrow L = \frac{(4\pi \times 10^{-7}\ T\cdot m/A)(400)^2(\pi(2.5\times 10^{-2}\ m)^2)}{0.20\ m}$$

$$= 2.0\times 10^{-3}\ H = \boxed{2.0\ mH}$$

b) $|\varepsilon| = L\dfrac{\Delta I}{\Delta t} \Rightarrow \dfrac{\Delta I}{\Delta t} = \dfrac{|\varepsilon|}{L} = \dfrac{75\times 10^{-3}\ V}{2.0\times 10^{-3}\ H}$

$$\Rightarrow \boxed{|\varepsilon| = 37.5\ A/s}$$

(45) $I = I_{max}(1 - e^{-t/\tau}) \Rightarrow e^{-t/\tau} = 1 - \dfrac{I}{I_{max}}$

At $t = 3s$, $\dfrac{I}{I_{max}} = 0.90$, so

$$e^{-3s/\tau} = 0.10 \Rightarrow \tau = \frac{-3s}{\ln(0.10)} = 1.30\ s$$

In RL circuit, $\tau = L/R$

$$\Rightarrow R = L/\tau = \frac{2.50\ H}{1.30\ s} = \boxed{1.92\ \Omega}$$

(53) a) $I = I_{max}(1 - e^{-t/\tau})$

When $t = \tau$, $I = I_{max}\left(1 - \frac{1}{e}\right) \approx .632\, I_{max}$.

$\Rightarrow t = \tau = L/R$

$$L = \frac{\mu_0 N^2 A}{\ell} = \frac{(4\pi \times 10^{-7}\ T\cdot m/A)(12{,}500)^2(1\times 10^{-4}\ m^2)}{7\times 10^{-2}\ m.}$$

$= 0.280\ H.$

$$\Rightarrow t = \frac{0.280\ H}{14.0\ \Omega} \approx 2.0\times 10^{-2}\ s = \boxed{20.0\ ms}$$

b) Change in solenoid current:

$$\Delta I = 0.632\, I_{max} - 0 = 0.632\left(\frac{\Delta V}{R}\right) = 0.632\left(\frac{60\ V}{14\ \Omega}\right)$$

$= 2.71\ A$

$$\mathcal{E}_{back} = L\frac{\Delta I}{\Delta t} = (0.280\ H)\left(\frac{2.71\ A}{20\times 10^{-3}\ s}\right) \approx \boxed{37.9\ V}$$

c) $$\frac{\Delta \phi_B}{\Delta t} = \frac{(\Delta B)A}{\Delta t} = \frac{\frac{1}{2}[\mu_0 n\, \Delta I]A}{\Delta t} = \frac{\mu_0 N(\Delta I)A}{2\ell\cdot \Delta t}$$

$$= \frac{(4\pi\times 10^{-7}\ T\cdot m/A)(12{,}500)(2.71\ A)(1\times 10^{-4}\ m^2)}{2(7\times 10^{-2}\ m)(20.0\times 10^{-3}\ s)}$$

$= \boxed{1.52\times 10^{-3}\ V}$

53 d) $I = \dfrac{|\mathcal{E}_{coil}|}{R_{coil}} = \dfrac{N_{coil}(\Delta\Phi_B/\Delta t)}{R_{coil}} = \dfrac{(850)(1.52\times10^{-3}\,V)}{24.0\,\Omega}$

$= 0.0519\,A = \boxed{51.9\,mA}$

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10 $|\mathcal{E}| = \dfrac{\Delta\Phi_B}{\Delta t} = \dfrac{B(\Delta A)\cos\theta}{\Delta t}$

$= \dfrac{(0.15\,T)(\pi(0.12\,m)^2 - 0)\cos 0^\circ}{0.20\,s} = 3.4\times10^{-2}\,V = \boxed{34\,mV}$

13 $|\mathcal{E}| = IR = (0.10\,A)(8.0\,\Omega) = 0.80\,V$

$|\mathcal{E}| = \dfrac{\Delta\Phi_B}{\Delta t} = \dfrac{\Delta B}{\Delta t} NA\cos\theta$

$\Rightarrow \dfrac{\Delta B}{\Delta t} = \dfrac{|\mathcal{E}|}{NA\cos\theta} = \dfrac{0.80\,V}{(75)[(0.05\,m)(0.08\,m)]\cos 0^\circ} = 2.7\,T/s$

22 During each revolution, one of the rotor blades sweeps out a horizontal circular area of radius l, $A = \pi l^2$. The number of magnetic field lines cut per revolution is $\Delta\Phi_B = B_\perp A = B_{vertical} A$.

$\longrightarrow$

(22) contd.

The induced emf is

$$\mathcal{E} = \frac{\Delta \phi_B}{\Delta t} = \frac{B_{vertical}(\pi l^2)}{1/f} = \frac{(5\times10^{-5}\,T)(\pi(3\,m)^2)}{0.50\,s}$$

$$= 2.8\times10^{-3}\,V = \boxed{2.8\,mV}$$

(31) There is a similarity between the situation in this problem and a generator. In both cases, $\mathcal{E} = \mathcal{E}_{max}\sin(\omega t)$ where $\mathcal{E}_{max} = NBA\omega$ is induced in the loop. The loop in this case consists of a single band ($N=1$) around the perimeter of a red blood cell with diameter $d = 8\times10^{-6}\,m$. The angular frequency of the oscillating flux through the area of the loop is $\omega = 2\pi f = 2\pi(60\,Hz) = 120$ rad/s.

$$\Rightarrow \mathcal{E}_{max} = NBA\omega = B\left(\frac{\pi d^2}{4}\right)\omega$$

$$= \frac{(1\times10^{-3}\,T)(\pi)(8\times10^{-6}\,m)^2(120\pi\,s^{-1})}{4}$$

$$= \boxed{1.9\times10^{-11}\,V}$$

(35) $\omega = \left(120 \frac{rev}{min}\right)\left(\frac{1\ min}{60 s}\right)\left(\frac{2\pi\ rad}{1\ rev}\right) = 4\pi \left(\frac{rad}{s}\right)$

and the period is $T = \frac{2\pi}{\omega} = 0.50\ s$

a) $\mathcal{E}_{max} = NBA\omega = 500(0.60T)[(0.08\ m)(0.20m)] = \boxed{60\ V}$

b) $\mathcal{E} = \mathcal{E}_{max} \sin(\omega t) = (60\ V) \sin\left[(4\pi\ rad/s)\left(\frac{\pi}{32} s\right)\right] = \boxed{57 V}$

c) emf is first maximum at

$$t = \frac{T}{4} = \frac{0.50 s}{4} = \boxed{0.13 s.}$$

(48) a) $L = \frac{\mu_0 N^2 (\pi r^2)}{\ell} = \frac{(4\pi \times 10^{-7}\ T \cdot m/A)(300)^2 \pi (5.0 \times 10^{-2} m)^2}{0.20\ m}$

$= \boxed{4.44 \times 10^{-3}\ H}$

b) when solenoid carries current $I = 0.50\ A$, energy stored is

$PE_L = \frac{1}{2} L I^2 = \frac{1}{2}(4.44 \times 10^{-3}\ H)(0.500\ A)^2$

$= \boxed{5.55 \times 10^{-4}\ J}$

(58) When A + B are 3 m apart, the area enclosed by the loop consists of four triangular sections, each having hypotenuse of 3 m, altitude of 1.5 m, and a base of $\sqrt{(3m)^2-(1.5m)^2} = 2.6$ m.

The decrease in the area enclosed:

$$\Delta A = A_i - A_f = (3\,m)^2 - 4\left[\tfrac{1}{2}(1.5\,m)(2.6\,m)\right]$$

$$= 1.21\,m^2$$

Induced current,

$$I_{AVG} = \frac{|\mathcal{E}_{AVG}|}{R} = \frac{(\Delta\phi_B/t)}{R} = \frac{B(\Delta A/t)}{R}$$

$$= \frac{(0.1\,T)(1.21\,m^2/0.100\,s)}{10.0\,\Omega} = \boxed{0.121\,A}$$

As enclosed area decreases, the flux into the page decreases. Thus, the induced current will be directed $\boxed{\text{clockwise}}$ around the loop to create additional flux directed into the page through the enclosed area.