Physics 111 Homework Solutions for Weeks 4-5

Monday, October 6, 2014

Chapters 17

Questions

- None

Multiple-Choice

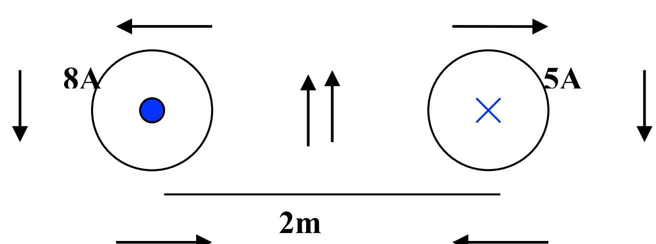
17.12 B
17.13 B
17.14 D

Problems

17.16 Two long vertical wires

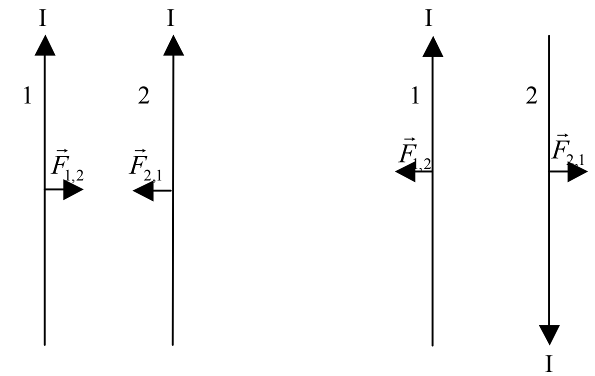
a. At the center between the two wires, the directions of the fields are shown in the diagram below. Taking up the page as the positive y-direction, we find that the fields add and the result is $B_{net} = B_{8A} + B_{5A} = \frac{\mu_0}{2\pi a}(I + I') = \frac{4\pi \times 10^{-7}\,\frac{Tm}{A}}{2\pi(1m)}(13A) = 2.6 \times 10^{-6}\,T$ in the positive y-direction.

b. Using the same diagram and letting I = 8A and I' = 5A, define the distance from I' to where the field will vanish on the right of I' as d. Thus the distance from I to this point is d+2m. Here the field will vanish, so $B_{net} = 0 \rightarrow B_{8A} = B_{5A} = \frac{\mu_0 I}{2\pi(d+2)} = \frac{\mu_0 I'}{2\pi(d)} \rightarrow d = \frac{2I'}{I - I'} = 3.33m$ to the right of the 5A wire.



17.18 The magnetic force on a wire (#1) due to a current flowing in another wire (#2) located at a distance d away has magnitude $\frac{F_{1,2}}{L} = \frac{F_{2,1}}{L} = I_1 B_2 = \frac{\mu_0 I^2}{2\pi d}$. When the currents are in the same direction, the magnetic field at wire #1 (due to the current flowing in wire #2) is directed out of the page. Then, by the right hand rule applied to wire #1, we have the force directed towards the right. Again for currents flowing in the same direction, the direction of the force on wire #2 is to the left, since the magnetic field at wire #2 is directed into the page. Thus when the currents flow in the same direction we have an attractive force.

When the currents flow in opposite directions we have a repulsive force between the two wires.



17.19 A current balance

a. As before, $B = \dfrac{\mu_0 I}{2\pi r}$ where r is the distance from the bottom wire to the top wire. Since the B field forms circles around the bottom current, it points out of the paper at the top wire. Then, using the right hand rule for the *force = ILB*, we find the magnetic force on the top wire to be up as shown in the figure in the text.

b. We find B = 2 x 10^{-7} (10 A/0.005 m) = 4 x 10^{-4} T and then F = ILB = (10A)(0.4m)(4 x 10^{-4} T) = 1.6x10^{-3} N. To balance this force requires mg = 1.6x10^{-3} N, which give m = 0.16g.

17.20 The magnetic field is given as

$B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{2\times10^{-7}\,Tm}{r} \rightarrow r = \dfrac{2\times10^{-7}\,Tm}{B} = \dfrac{2\times10^{-7}\,Tm}{5\times10^{-11}\,T} = 4000m$, pointing out how weak this magnetic field really is.

17.23 Rail Guns

a. Assuming that the current flows through the rails in a clockwise fashion the magnetic field will point vertically down into the loop described by the rails with a magnitude of

$$B_{net} = B_{top\ wire} + B_{bottom\ wire} = 2\frac{\mu_o I}{2\pi r} = 2\times\frac{4\pi\times10^{-7}\,\frac{Tm}{A}\times30A}{2\pi\times0.0175m} = 6.9\times10^{-4}\,T.$$

b. The force on the bar is given by $F = ILB = 30A\times0.035m\times10\times6.9\times10^{-4}\,T = 7.2\times10^{-3}\,N = 7.2mN$ and points to the right by the right hand rule.

c. The acceleration of the bar is given by Newton's 2nd law and we have $a = \dfrac{F}{m} = \dfrac{7.2\times10^{-3}\,N}{0.005kg} = 1.44\,\frac{m}{s^2}$ pointing to the right and the acceleration is assumed constant if the magnetic force is constant.

d. If the projectile travels for *1m* then its velocity is $v_f^2 = v_i^2 + 2a\Delta x \rightarrow v_f = \sqrt{2a\Delta x} = \sqrt{2\times 1.44\,\frac{m}{s^2}\times 1m} = 1.7\,\frac{m}{s}$ in the direction of the applied force.

e. If the velocity needs to be larger by a factor of 50, then we would need an acceleration of $a = \frac{v_f^2}{2\Delta x} = \frac{\left(50\times 1.7\,\frac{m}{s}\right)^2}{2\times 1m} = 3613\,\frac{m}{s^2}$. This equates to a force of $F = ma = 0.005kg\times 3613\,\frac{m}{s^2} = 18.1N$. The magnetic force will dictate the current that we need. From the magnetic force we have

$$F = ILB = IL\left(\frac{10\times 2\mu_o I}{2\pi r}\right)$$

$$\rightarrow I = \sqrt{\frac{2\pi rF}{20\mu_o L}} = \sqrt{\frac{2\pi\times 0.0175m\times 18N}{20\times 4\pi\times 10^{-7}\,\frac{Tm}{A}\times 0.035m}} = 1500A$$

Wednesday, October 8, 2014

Chapter 18

Questions

18.1 Since the number of magnetic field lines per unit area can be thought of as the strength of the magnetic field, then we can think of the magnetic flux as the total number of magnetic field lines that pass through a loop of wire that has cross sectional area A. The magnetic flux is given .as cosθBA_B=Φ . In order to change the magnetic flux any one of the above three can change.

18.4

a) since the magnetic field is increasing into the page, by Faraday's law the current will be counter clockwise in order to oppose the changing magnetic flux.
b) Given the direction of rotation the current flow will initially be clockwise to oppose the decreasing magnetic flux. Then the current flow will change direction and become counter clockwise as the magnetic flux changes across the area of the coil. Thus the induced current will alternate its direction.
c) Since the coil is being stretched its area is changing and the magnetic field is decreasing, so the induced current is clockwise.
d) Since both the field and the coil rotate together, there is no change in magnetic flux through the coil, so the current induced is zero.

18.5

a) As the current increases steadily along the x-axis the magnetic flux will increase in the coil and there will be a counter clockwise induced current to oppose the change in flux.
b) If the current in the wire is constant and the coil moves downward the magnetic flux will decrease (since the magnetic field is decreasing) and there will be a clockwise induced current.
c) If the current is constant and the loop remains stationary then there is no change in magnetic flux and the induced current is zero.
d) If the current decreases and the coil moves downward then the magnetic field is decreasing as well as the magnetic flux. Thus there will be a clockwise-induced

current.
e) For the current decreasing and the coil moving upwards toward the wire there is an ambiguity. As the current decreases in the wire the flux through the loop will decrease. However the loop is also moving toward the wire and the flux is increasing. Which one is the more dominant effect is unclear.

Multiple-Choice

18.2 A
18.3 A
18.4 C
18.5 B

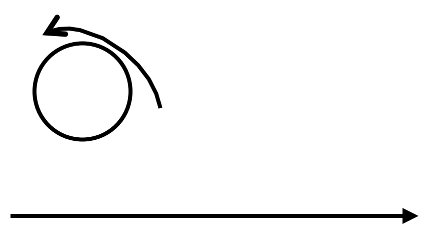
Problems

18.1 The induced *emf* is given by Faraday's Law. We have therefore

$$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t} = -100\frac{((0.5\times10^{-12}\,\mathrm{T})(\pi(0.01\mathrm{m})^2) - 0)}{0.1\mathrm{s}} = -1.57\times10^{-13}\,\mathrm{V}$$

18.2 The magnetic field at the coil is given by **Error! Objects cannot be created from editing field codes.** The induced *emf* is given by Faraday's law:

$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t} = -1\frac{((5\times10^{-7}\,\mathrm{T})(\pi(2.5\times10^{-3}\,\mathrm{m})^2) - 0)}{0.2\mathrm{s}} = -4.91\times10^{-11}\,\mathrm{V}$. Since the flux is decreasing with time the induced current is *ccw* as shown in the figure below.



Thursday, October 9, 2014

Chapter 18

Questions

- None

Multiple-Choice

- None

Problems

- None

Friday, October 10, 2014
Chapter 18
Questions
18.6

a) If the current in the small coil is increasing as shown then the current in the large coil is ccw.
b) If the small coil is moving away then the flux is decreasing in the larger coil, so the induced current is cw.
c) If the large coil is moving toward the smaller coil then the flux through the larger coil is increasing and the induced current in the large coil is ccw.
d) If the small coil is rotated ccw around a vertical axis, then the induced current is alternating, first in the cw direction and then in the ccw direction.

18.8 As the north pole of the magnet approaches, the flux increases through the cross sectional area of the coil. To oppose this change in flux, the coil produces a magnetic field that points out. The direction of the induced current is ccw when viewed looking at the coil along the bar magnet (from S to N). As the magnet recedes the magnetic flux is decreasing and thus a current and a field will be produce to oppose this change. The induced current is cw viewed looking at the coil along the bar magnet (from S to N).

Multiple-Choice
18.7 A
18.8 D
18.9 D

Problems
18.4 The magnetic field is given by $B(t) = 0.1 + 0.05t$ so that

$\frac{\Delta B(t)}{\Delta t} = \frac{(5.1-0.1)\text{T}}{(100-0)\text{s}} = 0.05\,\frac{\text{T}}{\text{s}}$ The induced *emf* is

$$\varepsilon = \text{-N}\frac{\Delta\Phi_B}{\Delta t} = -(7..85\times10^{-3}\,\text{m}^2)(0.05\,\tfrac{\text{T}}{\text{s}}) = -3.93\times10^{-4}\,\text{V}\ .$$

18.6The emf is given by

$$\varepsilon = Bl\bar{v} = Bl\left(\frac{l\omega}{2}\right) = \tfrac{1}{2}Bl^2\omega$$

$$= \tfrac{1}{2}\times50\times10^{-6}T\times(2.5m)^2\times\left(4\,\tfrac{rev}{s}\times\frac{2\pi rad}{1rev}\right) = 0.00395M = 3.95mV$$

and here the average velocity of the blade was used since all parts of the blade do not experience the same translational speed through space.

An alternate solution $\varepsilon = \left|\frac{\Delta\phi_B}{\Delta t}\right| = \left|\frac{\Delta(BA\cos\theta)}{\Delta t}\right| = \left|\frac{B\Delta A}{\Delta t}\right| = \left|\frac{B(\Delta\theta)L^2}{2\Delta t}\right| = \left|\frac{B\omega L^2}{2}\right|$, where the fraction of the area of the circle swept out after a time $t > 0$ is given by

$\Delta A = fraction \times A = \left(\dfrac{\Delta\theta}{2\pi}\right)\pi r^2 = \dfrac{(\Delta\theta)L^2}{2}$.Inserting the known values, we have that the induced potential difference across the bar is

$$\varepsilon = \left|\frac{B\omega L^2}{2}\right| = \left|\frac{50\times10^{-6}T\times25.1\,\tfrac{rad}{s}\times(2.5m)^2}{2}\right| = 0.00395V = 39.5mV\ .$$

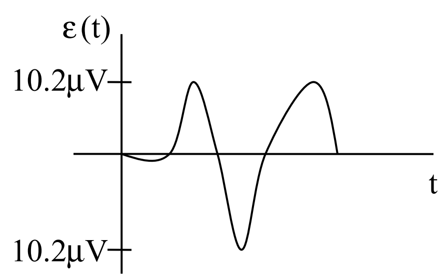
18.7 The *emf* is given by $\varepsilon = Blv$ so that the speed of the 737 would be

$$v = \frac{\varepsilon}{Bl} = \frac{1.5V}{50\times10^{-6}T\times40m} = 750\,\tfrac{m}{s}\ .$$

18.8 The emf is given as

$$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t} = -NB\cos\theta\frac{\Delta A}{\Delta t}$$

$$\varepsilon = -200\times50\times10^{-6}T\times\cos62\times\left(\frac{39cm^2\times\dfrac{1m^2}{(100cm)^2}}{1.8s}\right) = -1.02\times10^{-5}V = -10.2\mu V$$



18.11 The electric field is given as $\mathrm{E} = \dfrac{\varepsilon}{l} = \dfrac{vlB}{l} = vB = (2\,\tfrac{\mathrm{m}}{\mathrm{s}})(1.2\mathrm{T}) = 2.4\,\tfrac{\mathrm{N}}{\mathrm{C}}$.

18.12 The force needed to pull the rod is

$$F = IlB = \frac{\varepsilon}{R}lB = \frac{Blv}{R}lB = \frac{vl^2B^2}{R} = \frac{2\,\tfrac{m}{s}\times(0.2m)^2\times(1.2T)^2}{(100\Omega)} = 0.00115N = 1.15\mathrm{mN}\,.$$

18.14 The *emf* is given from Faraday's law as a motional *emf*, $\varepsilon = vlB$ where the velocity is obtained from the continuity of the fluid flow. We have the flow rate given as $Av = \pi r^2 v = 10\,\frac{\text{gallons}}{\text{min}}$ and converting 10 gallons to cubic meters we have

$$10\text{ gallons} \times \frac{3.78\text{ L}}{1\text{ gallon}} \times \frac{1\times10^{-3}\,\text{m}^3}{1\text{ liter}} = 0.0378\text{m}^3.$$ Therefore the velocity is

$$v = \frac{0.0378\text{m}^3}{60\text{s}} \times \frac{1}{\pi(0.1\text{m})^2} = 0.020\,\tfrac{\text{m}}{\text{s}}$$ and the induced *emf* is

$$\varepsilon = (0.020\,\tfrac{\text{m}}{\text{s}})(0.2\text{m})(0.05\text{T}) = 0.2\text{mV}.$$

Monday, October 12, 2014

Chapter 18

Questions

- None

Multiple-Choice

- None

Problems

- None