Physics 111 Homework Solutions for Friday 1/30 and Monday 2/2

Friday, January 30, 2015
None due to the Exam

Monday, February 2, 2015
Chapter 17
Questions
- None

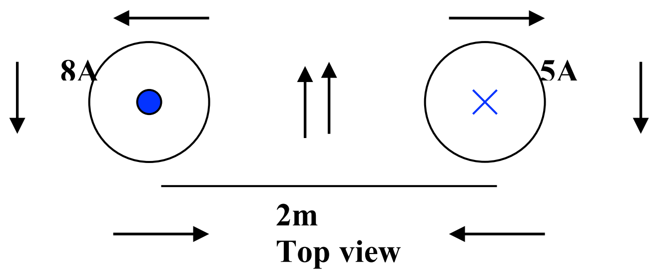
Multiple-Choice
17.12 B
17.13 B
17.14 D

Problems
17.10 From a free body diagram we find for the forces in the vertical direction
$F_B - ky - ky = 0 \rightarrow F_B = 2kx$. The magnetic force is given as ILB and this produces for the stretch $x = \frac{ILB}{2k} = \frac{2.5A \times 0.5m \times 2T}{2 \times 10\frac{N}{m}} = 0.125m = 12.5cm$

17.11. The torque is given by $\tau = IAB\sin\theta$. The cross sectional area of the loop is $A = \pi r^2 = \pi(0.025m)^2 = 1.96 \times 10^{-3} m^2$. The minimum torque (which equals *0 Nm*)is then the magnetic moment is parallel to the magnetic field and the maximum torque is when the magnetic moment is perpendicular to the magnetic field. The maximum torque is $\tau = IAB\sin\theta = 2A \times 1.96 \times 10^{-3} m^2 \times 0.5T \times \sin 90 = 1.96 \times 10^{-3} Nm$

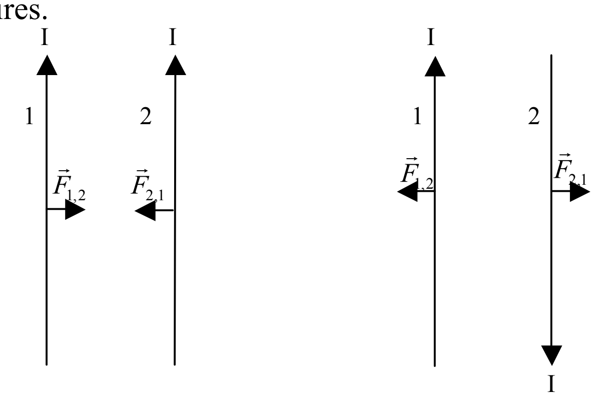
17.16 Two long vertical wires
a. At the center between the two wires, the directions of the fields are shown in the diagram below. Taking up the page as the positive y-direction, we find that the fields add and the result is
$B_{net} = B_{8A} + B_{5A} = \frac{\mu_0}{2\pi a}(I + I') = \frac{4\pi \times 10^{-7} \frac{Tm}{A}}{2\pi(1m)}(13A) = 2.6 \times 10^{-6} T$ 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 $B_{net} = 0 \rightarrow B_{8A} = B_{5A} = \dfrac{\mu_0 I}{2\pi(d+2)} = \dfrac{\mu_0 I'}{2\pi(d)} \rightarrow d = \dfrac{2I'}{I - I'} = 3.33m$ to the right of the 5A wire.



17.18 The magnitude of the magnetic force on a wire (#1) due to a current flowing in another wire (#2) located at a distance *d* away is given by $\dfrac{F_{1,2}}{L} = \dfrac{F_{2,1}}{L} = I_1 B_2 = \dfrac{\mu_0 I^2}{2\pi d}$. 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

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

17.21 A cyclotron

a. To calculate the radii of a particle of mass *m* and charge *q*, we equate the magnetic force to the centripetal force experienced by the mass. This gives for the radius of a particle of mass $m, F_B = F_C \to qvB = \dfrac{mv^2}{r} \to r = \dfrac{mv}{qB}$.

b. We want the particle to travel a semi-circle of distance πr and calculate the amount of time that this takes. To do this we need to know that velocity of the particle. Again we equate the centripetal force experienced by the particle to the magnetic force and this time solve for the velocity. Doing this we find $F_B = F_C \to qvB = \dfrac{mv^2}{r} \to v = \dfrac{qrB}{m}$. The velocity, a constant, is the ratio of the distance traveled by the time it takes to travel this distance. Thus the time is $v = \dfrac{\pi r}{t} \to t = \dfrac{\pi r}{v} = \dfrac{\pi r m}{qrB} = \dfrac{\pi m}{qB}$.

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

$v_f^2 = v_i^2 + 2a\Delta x \rightarrow v_f = \sqrt{2a\Delta x} = \sqrt{2 \times 1.44 \tfrac{m}{s^2} \times 1m} = 1.7 \tfrac{m}{s}$ 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 $a = \dfrac{v_f^2}{2\Delta x} = \dfrac{\left(50 \times 1.7 \tfrac{m}{s}\right)^2}{2 \times 1m} = 3613 \tfrac{m}{s^2}$. This equates to a force of $F = ma = 0.005kg \times 3613 \tfrac{m}{s^2} = 18.1N$. The magnetic force will dictate the current that we need. From the magnetic force we have

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

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