# Physics 6C, Summer 2006 Homework 1 Solutions

All problems are from the 2<sup>nd</sup> edition of Walker. Numerical values are different for each student.

## **Chapter 22 Conceptual Questions**

**18.** Consider the four wires shown in **Figure 22–33**, each carrying a current of the same magnitude. The currents in wires 1, 2, and 3 are out of the page; the current in wire 4 is into the page. What is the direction of the magnetic force experienced by wire 2?



### Solution:

The force between wires carrying currents in the same direction is attractive, and inversely proportional to the distance between the wires: Similarly, the force between wires with oppositely directed currents is repulsive. It follows from simple geometry (as explained below) that the net force acting on wire 2 is directed toward wire 4.

Consider a length  $\ell$  of wire 2 and let *d* be the length of a side of the square above.

The distance between wire 2 and wire 4 is:

$$D = \sqrt{d^2 + d^2} = d\sqrt{2}$$

Wire 2 experiences a repulsive force  $F_4$  from wire 4 that is directed **away from wire 4** with magnitude:

$$F_4 = \left(\frac{\mu_0 I^2 \ell}{2\pi}\right) \frac{1}{D} = \left(\frac{\mu_0 I^2 \ell}{2\pi}\right) \frac{1}{d\sqrt{2}}$$

Wire 2 experiences an attractive force  $F_1$  directed toward wire 1 and a force  $F_3$  directed toward wire 3:

$$F_1 = F_3 = \left(\frac{\mu_0 I^2 \ell}{2\pi}\right) \frac{1}{d}$$

The vector sum of  $F_1$  and  $F_3$  is directed **toward wire 4** with magnitude:

$$F_{13} = \sqrt{F_1^2 + F_3^2} = \left(\frac{\mu_0 I^2 \ell}{2\pi}\right) \frac{\sqrt{2}}{d}$$

Since the force  $F_{13}$  is stronger than for force  $F_4$ , the **net force** on wire 2 is **toward wire 4**.

**20.** Consider the four current-carrying wires described in Figure 22–33. Each of these wires is long and straight, and carries the current I either into or out of the page, as shown. What is the direction of the net magnetic field produced by these four wires at the center of the square? Explain.



Solution:

At the center of the square:

- $B_1$  = magnetic field due to wire 1  $B_2$  = magnetic field due to wire 2
- $B_3$  = magnetic field due to wire 3
- $B_4$  = magnetic field due to wire 4



The center of the square is equidistant from all four wires. Thus, at the center of the square, the magnetic field produced by each wire has equal magnitude. Now consider the directions of each magnetic field. If we apply the right-hand rule to wires 2 and 4, we see that they produce magnetic fields at the center of the square that point toward wire 3. On the other hand, the right hand rule shows that the magnetic fields produced by wires 1 and 3 at the center of the square cancel one another. It follows that the total (net) magnetic field at the center of the square of the square points toward wire 3.

## **Chapter 22 Problems**

2. An electron moves at right angles to a magnetic field of 0.12 T. What is its speed if the force exerted on it is  $8.9 \times 10^{-15}$  N?



#### Solution:

In this case q = e and  $\theta = 90^{\circ}$  so  $\sin \theta = 1$ . In general,  $F = qvB\sin \theta$ . Solving this for v gives:

$$v = \frac{F}{eB} = \frac{8.9 \times 10^{-15} \text{ N}}{(1.6 \times 10^{-19} \text{ C})(0.12 \text{ T})} = 4.6 \times 10^5 \text{ m/s}$$

15. The velocity selector in Figure 22-37 is designed to allow charged particles with a speed of  $4.5 \times 10^3$  m/s to pass through undeflected. Find the direction and magnitude of the required electric field, given that the magnetic field has a magnitude of 0.96 T.



#### Solution:

According to the RHR, the force due to the magnetic field is in the positive y-direction. Since the force due to the electric field must oppose the magnetic force,  $\vec{\mathbf{E}}$  must point in the negative y-direction.  $\vec{\mathbf{E}} = vB(-\hat{\mathbf{y}}) = \left(4.5 \times 10^3 \frac{\text{m}}{\text{s}}\right)(0.96 \text{ T})(-\hat{\mathbf{y}}) = \boxed{(-4.3 \times 10^3 \text{ N/C})\hat{\mathbf{y}}}$ 

19. When a charged particle enters a region of uniform magnetic field it follows a circular path, as indicated in Figure 22-38. (a) Is this particle positively or negatively charged? Explain. (b) Suppose that the magnetic field has a magnitude of 0.180 T, the particle's speed is  $6.0 \times 10^6$  m/s, and the radius of its path is 52.0 cm. Find the mass of the particle, given that its charge has a magnitude of  $1.60 \times 10^{-19}$  C. Give your result in atomic mass units, u, where  $1 \text{ u} = 1.67 \times 10^{-27}$  kg.



Solution:

(a) According to the RHR, a positively charged particle would experience a force to the left. Since the particle is experiencing a force to the right, it must be negatively charged.

**(b)** 
$$m = \frac{erB}{v} = \frac{(1.60 \times 10^{-19} \text{ C})(0.520 \text{ m})(0.180 \text{ T})}{\left(1.67 \times 10^{-27} \frac{\text{kg}}{\text{u}}\right) \left(6.0 \times 10^6 \frac{\text{m}}{\text{s}}\right)} = \boxed{1.5 \text{ u}}$$

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**28.** The long, thin wire shown in **Figure 22-39** is in a region of constant magnetic field **B**. The wire carries a current of 6.2 A and is oriented at an angle of 7.5° to the direction of the magnetic field. (a) If the magnetic force exerted on this wire per meter is 0.033 N, what is the magnitude of the magnetic field? (b) At what angle will the force exerted on the wire per meter be equal to 0.015 N?

Solution:

(a) 
$$\frac{F}{L} = IB\sin\theta$$
  
 $B = \frac{F}{L}\cos\theta = \frac{0.033 \,\text{N}}{(6.2 \,\text{A})\sin7.5^{\circ}} = \boxed{41 \,\text{mT}}$   
(b)  $\theta = \sin^{-1}\frac{F}{L}=\sin^{-1}\frac{0.015 \,\text{N}}{(6.2 \,\text{A})(0.04078 \,\text{T})} = \boxed{3.4^{\circ}}$ 



74. Solenoids produce magnetic fields that are relatively intense for the amount of current they carry. To make a direct comparison, consider a solenoid with 55 turns per centimeter, a radius of 1.25 cm, and a current of 0.150 A. (a) Find the magnetic field at the center of the solenoid. (b) What current must a long, straight wire carry to have the same magnetic field as that found in part (a)? Let the distance from the wire be the same as the radius of the solenoid, 1.25 cm.



Solution:

(a) 
$$B = \mu_0 n I_s = \left(4\pi \times 10^{-7} \, \frac{\mathrm{T} \cdot \mathrm{m}}{\mathrm{A}}\right) (55 \, \mathrm{cm}^{-1}) \left(\frac{100 \, \mathrm{cm}}{1 \, \mathrm{m}}\right) (0.150 \, \mathrm{A}) = 1.0 \, \mathrm{mT}$$

(b) 
$$B = \frac{\mu_0 I}{2\pi r} = \mu_0 n I_s$$
  
 $I = 2\pi r n I_s = 2\pi (1.25 \text{ cm})(55 \text{ cm}^{-1})(0.150 \text{ A}) = 65 \text{ A}$ 

# **Chapter 23 Problems**

2. A uniform magnetic field of 0.0250 T points vertically upward. Find the magnitude of the magnetic flux through each of the five sides of the open-topped rectangular box shown in Figure 23-26, given that the dimensions of the box are L = 32.5 cm, W = 12.0 cm, and H = 10.0 cm.



### Solution:

The sides of the box are parallel to the field, so the magnetic flux through the sides is zero. The magnetic flux through the bottom is:

$$\Phi = BA\cos\theta = (0.0250 \text{ T})(0.325 \text{ m})(0.120 \text{ m})\cos 0^\circ = 9.75 \times 10^{-4} \text{ Wb}$$

71. Transcranial magnetic stimulation (TMS) is a noninvasive method for studying brain function, and possibly for treatment as well. In this technique, a conducting loop is held near a person's head. When the current in the loop is changed rapidly, the magnetic field it creates can change at the rate of  $3.00 \times 10^4$  T/s. This rapidly changing magnetic field induces an electric current in a restricted region of the brain that can cause a finger to twitch, a bright spot to appear in the visual field, or a feeling of complete happiness to overwhelm a person. If the magnetic field changes at the previously mentioned rate over an area of  $1.13 \times 10^{-2}$  m<sup>2</sup>, what is the induced emf?



Solution:

$$|\mathcal{E}| = \left|\frac{\Delta\Phi}{\Delta t}\right| = \left|\frac{A\Delta B}{\Delta t}\right| = A \left|\frac{\Delta B}{\Delta t}\right|$$
$$= (1.13 \times 10^{-2} \text{ m}^2) \left(3.00 \times 10^4 \frac{\text{T}}{\text{s}}\right)$$
$$= \boxed{339 \text{ V}}$$

**30.** Figure 23-33 shows a zero-resistance rod sliding to the right on two zero-resistance rails separated by the distance L = 0.45 m. The rails are connected by a  $12.5 \cdot \Omega$  resistor, and the entire system is in a uniform magnetic field with a magnitude of 0.750 T. (a) Find the speed at which the bar must be moved to produce a current of 0.125 A in the resistor. (b) Would your answer to part (a) change if the bar was moving to the left instead of to the right? Explain.

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0	$\odot$	$\odot$	$\odot$	$\odot$	$\odot$	· ·
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Solution:

(a) The motional emf between the top and bottom of the rod must equal the voltage drop across the resistor:  $|\mathcal{E}| = IR = vBL$ 

From this we can solve this for the speed *v*:

$$v = \frac{IR}{BL} = \frac{(0.125 \text{ A})(12.5 \Omega)}{(0.750 \text{ T})(0.45 \text{ m})} = \boxed{4.6 \text{ m/s}}$$

(b) The equation for v is independent of the direction of motion of the bar, the answer to part (a) would not change.

**47.** The current in an *RL* circuit increases to 95% of its final value 2.00 s after the switch is closed. (a) What is the time constant for this circuit? (b) If the inductance in the circuit is 0.275 H, what is the resistance?



Solution:

(a) Start with equation (23-16) and solve for  $\tau$ :

$$0.95I_{\text{final}} = 0.95 \frac{\mathcal{E}}{R} = \frac{\mathcal{E}}{R} [1 - e^{-(2.00 \text{ s})/\tau}]$$

$$e^{-(2.00 \text{ s})/\tau} = 0.05$$

$$-\frac{2.00 \text{ s}}{\tau} = \ln 0.05$$

$$\tau = -\frac{2.00 \text{ s}}{\ln 0.05}$$

$$= 0.7 \text{ s}$$

$$(b) R = \frac{L}{\tau} = \frac{0.275 \text{ H}}{-\frac{2.00 \text{ s}}{\ln 0.05}} = 0.4 \Omega$$

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 $1.0(\varepsilon/R)$ 

**55.** You would like to store 8.3 J of energy in the magnetic field of a solenoid. The solenoid has 500 circular turns of diameter 7.0 cm distributed uniformly along its 31-cm length. (a) How much current is needed? (b) What is the magnitude of the magnetic field inside the solenoid? (c) What is the energy density (energy/volume) inside the solenoid?

