PHY 212 General Physics II - Electricity, Magnetism and Light
Summer 2007

Final Exam: Friday, Aug 10 (8.30am - 10.30am)

Name: WORKED OUT COPY

1. (3 points) Two straight, parallel superconducting wires 1 m apart carry equal currents of 10 A in opposite directions. The force between the wires is
   (a) attractive
   (b) repulsive
   (c) zero
   (d) alternating between zero and a maximum value

2. (3 points) The energy density u in a simple electromagnetic wave in vacuum is:
   (a) $u = \frac{1}{2}\epsilon_0 E^2$
   (b) $u = \frac{1}{2\mu_0} B^2$
   (c) $u = \epsilon_0 E^2$
   (d) $u = \frac{1}{\mu_0} B^2$

3. (3 points) When light passes from one material a into a second material b with larger index of refraction, so that $n_b > n_a$, the wave speed
   (a) increases
   (b) decreases
   (c) does not change
   (d) becomes 3×10^8 m/s

4. (3 points) The electromagnetic wave

$$\vec{\mathbf{E}}(x,t) = \hat{\mathbf{j}}\, E_{\max} \cos(kx - \omega t), \quad \vec{\mathbf{B}}(x,t) = \hat{\mathbf{k}}\, B_{\max} \cos(kx - \omega t) \qquad (1)$$

   is said to be polarized in the
   (a) x - direction
   (b) y - direction
   (c) z - direction
   (d) t - direction

5. (10 points) Calculate the magnitude of the magnetic field at point P of Fig. 1 in terms of R, I_1, and I_2. What does your expression give when $I_1 = I_2$?

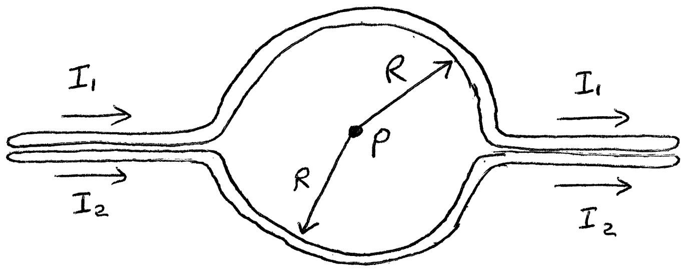

Fig. 1

There is no contribution from the straight wires. The magnetic field from the semicircle is just half that of a complete loop. We have two oppositely oriented contributions from the two semicircles.

$$B = (B_1 - B_2) = \frac{1}{2}\left(\frac{\mu_0}{2R}\right) |I_1 - I_2| \quad \text{into the page.}$$

If the two currents are equal, the magnetic field goes to zero at the center of the loop.

6. (12 points) **The Slidewire Generator.** Fig. 2 shows a U-shaped conductor in a uniform magnetic field $\vec{B}$ perpendicular to the plane of the figure, directed *into* the page. We lay a metal rod of length L across the two arms of the conductor, forming a circuit, and move the rod to the right with constant velocity $\vec{v}$. This induces an emf and a current, which is why this device is called a *slidewire generator.* Find the magnitude and direction of the resulting induced emf.

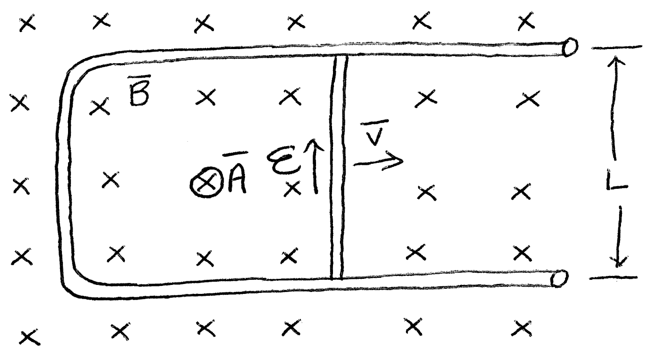

Fig. 2

$\bar{B}$ and $\bar{A}$ point in the same direction. ∴ The angle $\phi = 0$, and $\Phi_B = BA$.

B is constant, but A is changing. So, the induced emf is:

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -B\frac{dA}{dt}$$

$$dA = Lv\,dt$$

$$\therefore \quad \mathcal{E} = -B\frac{Lv\,dt}{dt} = -BLv$$

The minus sign tells us that the emf is directed counterclockwise around the loop. (The induced current is also counterclockwise)

7. (12 points) **An Electromagnetic Car Alarm.** Your latest invention is a car alarm that produces sound at a particularly annoying frequency of 3500 Hz. To do this, the car alarm circuitary must produce an alternating electric current of the same frequency. That's why your design includes an inductor L and capacitor C in series. The maximum voltage across the capacitor is to be 12.0 V (the same voltage as the car battery). To produce a sufficiently loud sound, the capacitor must store 0.0160 J of energy. What values of capacitance and inductance should you choose for your car alarm circuit? (*Hint* : frequency, $f = \frac{1}{2\pi\sqrt{LC}}$)

$V_c = 12.0\text{V}$, $U_c = \frac{1}{2} C V_c^2$

so, $C = \frac{2U_c}{V_c^2} = 2(0.0160\text{J})/(12.0\text{V})^2 = 222\mu\text{F}$

$f = \frac{1}{2\pi\sqrt{LC}}$ so $L = \frac{1}{(2\pi f)^2 C}$

$f = 3500\text{Hz} \rightarrow L = 9.31\mu\text{H}$

8. (10 points) An electromagnetic wave propagates in a dielectric material. At the frequency of light, the dielectric constant of the material is 1.74 and the relative permeability is 1.23. If the magnetic field amplitude is 3.80×10^{-9} T, what is the electric field amplitude?

$$E = vB = \frac{B}{\sqrt{\epsilon\mu}} = \frac{B}{\sqrt{K\epsilon_0 K_m \mu_0}} = \frac{cB}{\sqrt{K K_m}}$$

$$\Rightarrow E = \frac{(3\times10^{8}\,m/s)(3.8\times10^{-9}\,T)}{\sqrt{(1.74)(1.23)}}$$

$$= 0.779\ V/m$$

9. (8 points) Using a fast-pulsed laser and electronic timing circuitry, you find that light travels 2.50 m within a plastic rod in 11.5 ns. What is the refractive index of the plastic? (1 ns = 10^{-9} s.)

$$v = \frac{d}{t} = \frac{2.5\,m}{11.5 \times 10^{-9}\,s} = 2.17 \times 10^{8}\ m/s$$

$$n = \frac{c}{v} = \frac{3 \times 10^{8}\,m/s}{2.17 \times 10^{8}\,m/s} = 1.38$$

10. (10 points) Young's double slit experiment is performed with light from excited helium atoms ($\lambda = 502$ nm). Fringes are measured carefully on a screen 1.20 m away from the double slit, and the center of the twentieth bright fringe (not counting the central bright fringe) is found to be 10.6 mm from the center of the central bright fringe. What is the separation of the two slits? (1 nm $= 10^{-9}$ m.)

For bright fringes :

$$d = \frac{Rm\lambda}{y_m} = \frac{(1.2\,m)(20)(5.02 \times 10^{-7}\,m)}{(0.0106\,m)}$$

$$= 1.14 \times 10^{-3}\,m$$

$$= 1.14\,mm$$

11. (11 points) **Flashlight to the Rescue.** You are the sole crew member of the interplanetary spaceship $T : 1339$ *Vorga*, which makes regular cargo runs between the earth and the mining colonies in the asteroid belt. You are working outside the ship one day. Unfortunately you lose contact with the ship's hull and begin to drift away into space. You use your space suit's rockets to try to push yourself back toward the ship, but they run out of fuel and stop working before you can return to the ship. You find yourself in an awkward position, floating near to the ship with zero velocity relative to it. Fortunately, you are carrying a 200 W flashlight. You turn on the flashlight and use its beam to push yourself back to the ship. (i) Is this possible? Explain why or why not. (ii) Suppose your flashlight batteries are dead. Is there a way you could use the flashlight to accomplish the same job of returning you to the ship (*Hint* : use the law of conservation of linear momentum.)

(i) Yes, this is possible. You can use the flashlight beam as a "light rocket" to push yourself back to the ship. (Light carries momentum.)

(ii) You could throw the flashlight in the direction away from the ship. By the conservation of linear momentum you would move toward the ship with the same magnitude of the momentum as you gave the flashlight.