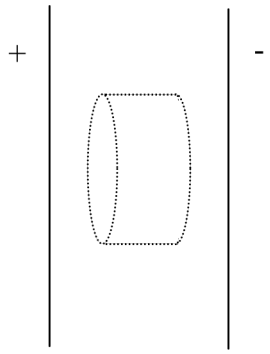
HW #10 Due Friday April 8, 2011

Reading: On Monday we start Chapter 23 on Geometric Optics – the study of reflection and refraction of light rays. By the end of the week we will try to get through the first 7 sections. Some of sections 23-4 to 23-7 will be covered in lab this week.

There are some good problems in Ch 22, but I decided this week to take problems from other sources.

Part 1

1) (Maxwell #1) (6 points) A capacitor is made from two parallel metal plates each with a radius of 3.5 cm. The plates have air between them and are separated by 2.5 cm. The plates are connected to a 250 V DC power supply.
a) What is the capacitance of the plates?
b) What is the charge on each plate?
c) What is the electric field between the plates?
d) Imagine a closed cylindrical surface located between the plates, with a radius of 1.0 cm and a length of 1.0 cm, as shown. What is the electric flux through the left circular face of the cylinder? the right circular face?



e) What is the electric flux through the side of the cylinder?
f) According to Gauss's Law, what is the total electrical flux through the cylindrical surface? Justify in light of your answers to d) and e).

2) (Maxwell #2) A solenoid containing 475 turns of wire is connected to a 7.5 V battery. The solenoid has a diameter of 4.5 cm, a length of 8.3 cm and a total resistance of 15 Ω.

a) What is the current through the solenoid?

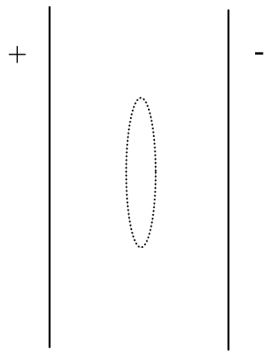
b) What is the magnitude of the magnetic field inside the solenoid?

c) Imagine a cylindrical surface like that in problem 1 inside the solenoid, oriented so that the axis cylinder is parallel to the axis of the solenoid. What is the magnetic flux through the left side of the cylinder? Assume the magnetic field goes from left to right. What is the magnetic flux through the right side of the cylinder?

d) What is the magnetic flux through the side of the cylinder?

e) According to Maxwell's second equation, what is the total magnetic flux through the solenoid? Justify in light of your answers to c) and d).

3) (Maxwell #3) Consider the capacitor in problem #1, but this time imagine a circular loop inside the capacitor with a radius of 1.0 cm, as shown. The plane of the loop is parallel to the plates of the capacitor.



Suppose that the capacitor is completely discharged in 0.15 s, by connecting one plate to the other with a wire.

a) What is the average rate of change of the electric flux through the loop?

b) What is the magnitude of the induced magnetic field at any point on the perimeter of the loop?

c) Your result should make it pretty clear why, in Maxwell's time, no one had ever observed that a changing electric flux through a loop induces a magnetic field around the loop. Explain.

4) (Maxwell #4) Consider the solenoid in problem #2, but this time imagine a circular loop inside the cylinder with a radius of 1.0 cm. The loop is oriented so that the axis of the cylinder is perpendicular to the plane of the loop. Suppose that a switch in the solenoid battery circuit is opened and that the current in the solenoid drops to zero in 0.082 s.

a) What is the average rate of change of the magnetic flux through the loop?

b) What is the magnitude of the induced electric field at any point on the perimeter of the loop?

5) Cell phones in the United States typically send and receive electromagnetic waves with a frequency between 1850 MHz and 1990 MHz. What is the wavelength range of the waves? What part of the electromagnetic spectrum is this?

6) The helium-neon lasers that we use in lab produce light waves with an average power of 0.85 mW. Suppose that at a distance of 1.0 m from the laser the beam has a diameter of 1.1 mm. a) What is the average intensity of the laser beam 1.0 m from the laser? b) What is the maximum electric field 1.0 m from the laser?

Part II

7) The average intensity of electromagnetic radiation hitting the earth because of the sun is about 1000 watts/m^2. The distance from the sun to the earth is 150,000,000 km. What is the total amount of electromagnetic radiation emitted by the sun? Hint: surface area of a sphere = $4\pi R^2$.

8) a) About 30% of the total energy hitting the earth because of the sun is in the visible part of the spectrum. Ignoring losses due to the atmosphere, what is the intensity of the visible light hitting the surface of the earth.

b) A typical 100 watt light bulb is about 6% efficient, meaning that about 6% of the energy needed to operate the bulb gets converted into light in the visible part of the spectrum. Most of the 94% of the energy that is wasted is turned into heat. What is the intensity of the visible light emitted by a 100 W light bulb at a distance of 0.35 m? Compare to the intensity of visible sunlight?

9) The maximum allowed average transmitted power of the electromagnetic waves produced by a cell phone used in the United States is 1.0 watts. If the cell phone transmits equally in all directions,

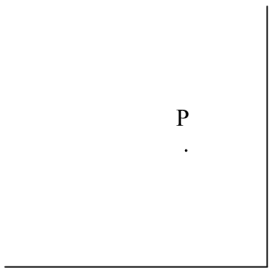
a) what is the maximum magnitude of the electric field 3.0 cm from a cell phone?

b) what is the maximum magnitude of the magnetic field 3.0 cm from a cell phone?

10) Ch. 23 P#1

11) Ch. 23 P#4

12) To see yourself as others see you, a corner mirror can be used. A corner mirror is just two plane mirrors at right angles to each other. Consider the point L, located as shown below, representing your left ear. Using careful and accurate ray tracing, find the 3 images of the point produced by the two mirrors. Add a point R located near L but along a diagonal, representing your right ear. Find its 3 images. Do you see why the middle image shows you what other people see?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