Waves and Fields (PHYS 195): Week 12

Spring 2009 v1.0

Intro:

We continue our study of geometrical optics, moving onto curved mirrors, lenses and systems of lenses. There are some wonderfully distracting topics related to this including Galileo's original observations of Jupiter and the "burning mirrors" of the Siege of Syracuse (a bonus question).

It is worth taking care on your ray tracing. For a better results use a full sheet of paper and a ruler.

Due Monday, April 27

Reading:

- Wednesday: More from HRW Chapter 33
- Friday: HRW 34

Physics Topics:

- Ray tracing
- Mirrors
- Images
- Lenses

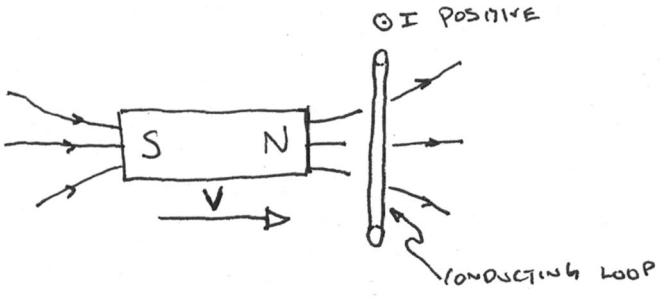
Problems:

(1) In lecture we saw the Thomson Jumping Ring demo. An aluminum ring sat on a wooden structure containing a coil of wire. When I turned on the current (oscillating at 60 Hz) through the coil, the ring jumped into the air. Explain this demo including the role of the alternating current.

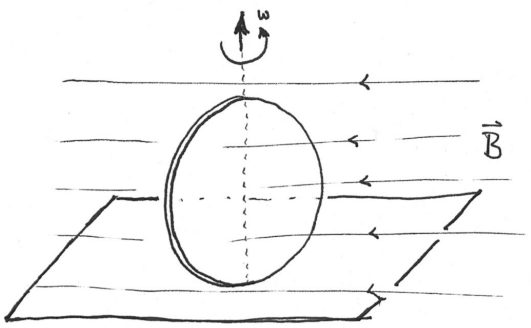
(2) As seen in lecture, interesting behavior occurs when a bar magnet moves through a coil. Assume that the ring has a resistance R

(a) Given the position and velocity (Assumed to be constant) shown sketch the induced voltage (or "emf") as a function of time. Indicate the positions of the ring and magnet on your time axis.

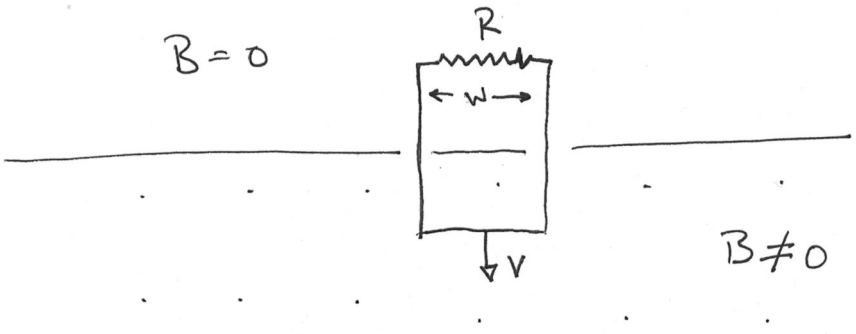
(b) Sketch the power dissipated in the loop as a function of time.



(3) Bored in physics lecture you idly spin a quarter on your desk. Initially it spins at a constant 200 rpm. "Holy Cow!" you say, realizing that the quarter has an induced current. Why? The Earth's **B**-field is about 1 gauss and let's assume that its direction is as shown (it actually points down slightly). Find the induced **E**-field on the edge of the quarter and sketch its amplitude as a function of time.



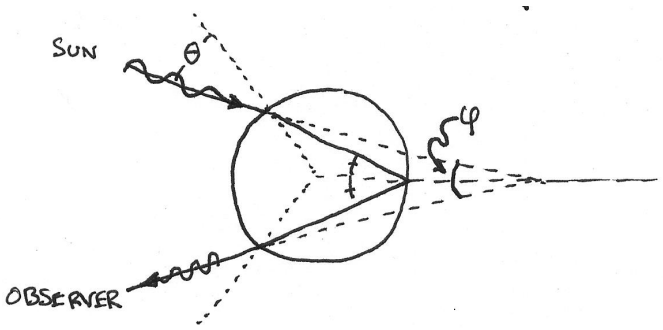
(4) A rectangular conducting loop with resistance R, mass m, and width w falls into a uniform magnetic field **B** that points out of the page. If the magnetic field region is large the loop will reach terminal velocity.
   (a) Why?
   (b) Find an expression for the terminal speed.
   (c) What is the direction of the current in the loop?
   (d) If the loop was dropped while it was entirely in the magnetic field, what would happen?



(5) HRW 33.14
(6) HRW 33.63
(7) Starting with the boundary conditions for incident, reflected and transmitted electric fields at a boundary, show that the angle of incidence is equal to the angle of reflection. (We did this in class, but the derivation was brief.)
(8) On bright sunny days, the main entrance of the Science Center is graced by a very nice spectrum. What produces it? How?

(9) **Rainbow** *Why do we see it where we see it?* Using the geometry discussed in class and Snell's law show that the angle ϕ is related to the angle of incidence via

$$\phi = 4 \arcsin\left(\frac{\sin\theta}{n}\right) - 2\theta$$



(10) *Rainbow continued...*
   (a) Using the results of the last problem and a little calculus, find the maximum angle $\phi_{max} \simeq 42^o$. (Feel free to use Maple here.)
   (b) Using Maple, or other plotting device/program, plot the function and locate the maximum.
   (c) Why is the rainbow brightest at this angle? Hint: Use part b.

(11) **Bonus (1 pt.):** Show that when you see a secondary rainbow it appears at an angle of about 51^o.

(12) **Bonus (2 pts.):** Find the relation for the angular location of the nth rainbow for all n. The list starts with $n = 1$ 42^o, $n = 2$ 51^o, ...

(13) **Bonus (1 pt):** In a physics text you see the statement: *Archimedes is said to have burned the whole Roman fleet in the harbor of Syracuse by focusing sunlight using an army of polished shields.* Is such a feat possible? There is a lot of material online. To get started follow the links on burning mirrors on the course web site. I'm interested in *your* analysis. Work this out carefully using the intensity of sunlight, the temperature at which wood burns, and anything else that is relevant. Write up your calculations and submit the work on a separate paper from your regular solutions.

Lab:

Thin Lenses

A look ahead...

Next week we study interference and diffraction - our last topic.