Waves and Fields (PHYS 195): Week 7

Spring 2009 v1.0

Intro:

Fields! We will study electric and magnetic fields, although we will spend most of our time on electric fields. This week we'll look at the notion of charge, Coulomb's law and the curious, almost trivial, definition of the electric field.

Due Monday, March 9

Reading: HRW 21

Physics Topics:

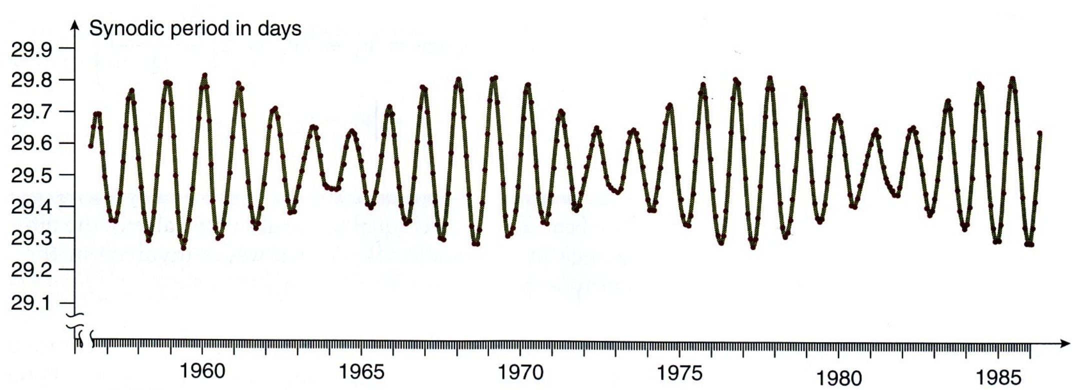
- Charges as sources of field
- Coulomb's law
- Electric fields
- Electric Potential

Problems:

From material in class and reading through Friday, March 6.

(1) HRW 17.60

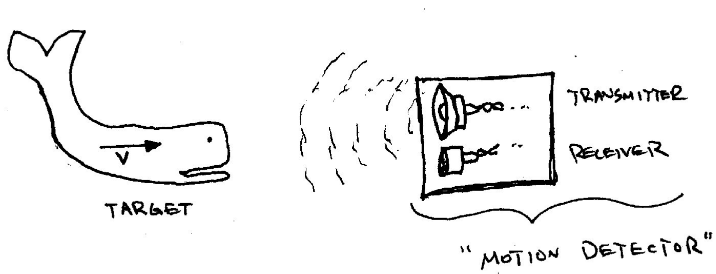
(2) Th following plot shows the variation in the time between full moons. This "synodic period" is, on average, about 29.53 days. The variation as a function of year is shown.



(a) How would you explain the systematic variation in the synodic period?

(b) What are the periods of the two oscillations? (One of these will be roughly equal to a year.)

(3) **Motion Detectors** An audio transmitter and receiver are built into a single box as shown. The transmitter emits a sound of frequency f that is reflected off the moving target.



(a) Show that the received frequency f' is given by

$$\frac{f'}{f} = \frac{c_s + v}{c_s - v}$$

in which c_s is the speed of sound and v is the speed of the target.

(b) Suppose that $v << c_s$, as is usually the case in intro labs, show that

$$\frac{f'}{f} \approx 1 + 2\frac{v}{c_s}$$

Hint: Use our handy relation for $(1 \pm x)^n$ when $x << 1$.

(c) Suppose we used the ultra-sound from the speed of sound lab, and $f = 24.06$ kHz. A curious whale approaches the motion detector at 1.00 m/s. What is the frequency detected by the motion dectector?

(4) **The Tape Experiments:** (You will need Scotch Tape) **I.** Stick a roughly 10 cm strip of tape on a smooth, dry surface such as a desk. Fold over one end to make a handle. With a quick motion, pull up the tape from the surface. Now fix the tape to the edge of the desk, slat of a chair or other convenient surface. Try bringing objects close to the tape. What happens? Make a table of your results. Include as one of your objects in your table another piece of tape prepared in the same way. **II.** Stick two strips of tape sticky side down and label them "B" for bottom. (Be sure to make handles.) Press another strip on top of each of these strips. Label these "T" for top. Briskly pull the pairs off the surface. Then pull the strips apart (separating top and bottom). How do the B strips interact? The T strips? The B and T? Try out the different objects on your B and T strips. Record what happens in your table. Overall, is there a difference between attraction and repulsion? How could you determine which charge was which? How could you characterize the strength of the interactions?

(5) **2009 Coulomb Law Data:** Using your favorite spreadsheet perform the necessary analysis to find the power of r, i.e. n, in

$$F_C = \frac{\kappa}{r^n}.$$

(a) Starting from a free body diagram, show how the measurements of position (x_1 and x_2) can give the power n in the expression above.

(b) Make the necessary plot.

(c) What do you find for n? Does it agree with the accepted value of 2?

When you submit your homework please include a printout of your work and names of folks you worked with, if any.

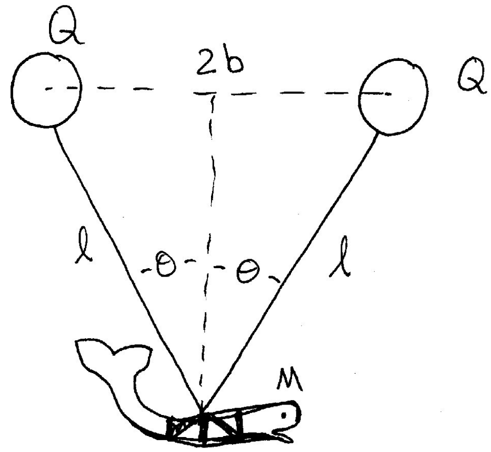
(6) You have two charges of $+4q$ each and one charge of -1q.

(a) How would you place them along a line so that there is no net force on any of the charges?

(b) What is the nature of this equilibrium (stable, neutral, or unstable)? Assume that the two $+4q$ charges are fixed.

(7) **Play electric hockey!** How? Follow the hockey link on the course web site. For the purposes of this problem I'll define "elegant solutions" as those with the smallest number of charges.
  (a) Add the electric field. Click on the 1st level of difficulty. Find an elegant solution. When you have one print out a screen shot of the configuration. Describe your method of solution.
  (b) **Bonus** Move on to the second level of difficulty and find an elegant solution. Print out a screen shot of your solution. Note: "Elegant" does not mean fast!

(8) **Bonus** A whale is lifted aloft on a pair of charged balloons as shown. Assume the whole system is in equilibrium. What the charge Q on each balloon?



(I wonder what the frequency of oscillations around this configuration would be...)

Lab:

Electric field mapping

A look ahead...

Next week we turn to potentials and simple circuits - see HRW 22 and 24.