Waves and Fields (PHYS 195): Week 1

Spring 2009 v1.0

Intro:

The course starts with an in-depth study of oscillations: "motion that comes back to a point". The tools are familiar from last semester, e.g. Newtonian mechanics, although the emphasis will be different. In addition to the physics of oscillations (with extras such as damping and driving forces) we'll also study the mathematics of $\mathbf{F} = m\mathbf{a}$ *- the idea that this is a "differential equation".*

I highly recommend that you read or skim the "Reading" before lecture. Although you need not read the relevant sections in detail (that can wait until later), to "view" the new material before it is discussed will be a great help to you. I will try to keep the reading for lecture up to date, but I do find that the schedule slips a bit. When that happens I will give the reading in class.

Due Monday, January 26

Reading:

- During the week: Taylor Chapters 1 and 2. For most of you this will be a nice review of uncertainties discussed in lab last fall.
- Monday: HRW 15.1 - 15.3
- Wednesday: HRW 15.4, 15.7
- Friday: HRW 15.5 - 15.6
- For Monday, January 26: the Simmons e-Reserve reading and HRW 12.7 (reading on *Jello*)

Physics Topics:

- Simple harmonic oscillation: springs, pendula, torsion, pendula...
- Energy in SHO
- Oscillations as a universal phenomenon

Math Topics:

- Small angle approximation to trig functions
- Taylor's expansion
- Equations of motion (or "$\mathbf{F} = m\mathbf{a}$") as differential equations

Problems:

From material in classes through Friday, January 23.

(1) Go to http://science.widener.edu/svb/tutorial/sigfigurescsn7.html (there's a link online) and complete 10 of the sig fig problems. For your "solution" record the number of correct answers and any questions you have on the exercises.

(2) Taylor 2.4 (If you are uncertain on these, then work through a similar problem in 2.3. There are answers in the back.)

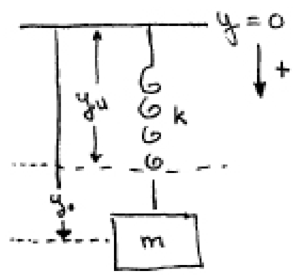
(3) For a simple harmonic oscillator, when (if ever) are the displacement and velocity vectors in the same direction? When are the displacement and acceleration vectors in the same direction?

(4) When a 80 kg person climbs into a 1000 kg car, the car's springs compress vertically by 1.4 cm. What will the frequency of vibration when the car hits a bump. Please ignore the effects of the shock absorbers.

(5) Go to the 195 web site and click on the Phet spring link.

(a) Play for a bit.
(b) Using the handy ruler and anything else you find useful, find the mass of the red mass.
(c) Move the friction slider to “none”. What is the period of oscillation for the green mass on spring 2? Use the stopwatch available by checking the box on the right. Assume that the middle entry is in seconds.
(d) With the friction slider set to “none” and add the energy plot for spring 3. Hang the red mass on spring 3 (with it’s spring constant set at the middle) and displace the it slightly to get the SHM going. Why is the kinetic energy (shown in green) so small?
(e) What did position the programers choose for the zero of the total potential energy?
(f) Move the friction slider up to more than “none” and restart the motion. Describe what happens. What is heating, as represented by “Thermal”?

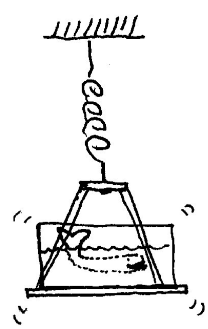
(6) In class on Monday January 19 I mentioned that the vertical mass-on-a-spring has the same equation of motion as the horizontal one we discussed in class. In this problem you demonstrate how this comes about.
(a) The mass shown in the diagram is in equilibrium.



Using the variables in the diagram, make a free body diagram and write down the equilibrium condition, $\sum F = 0$.
(b) Obtain an expression for y_o, the vertical position of the center of the mass in equilibrium.
(c) Now let’s move the mass! Make a sketch of the mass once it is pulled down from equilibrium.
(d) Make a free body diagram for this position.
(e) From the diagram, obtain an equation of motion.
(f) Using part b, show that, indeed, the equation of motion is of the form

$$\frac{d^2y}{dt^2} + \frac{k}{m}y = 0$$

(7) A 450 kg baby whale (comfortable in a tank) oscillates from a vertically hanging light spring once every 0.55 s.



(a) Write down the equation giving the vertical position as a function of time (with + upward), assuming the whale started after being lifted 10 cm from equilibrium ($y = 0$).
(b) How long will it take to reach equilibrium for the first time?
(c) What will be the whale's maximum speed?
(d) What will be the maximum acceleration enjoyed by the whale? Where will this occur?

(8) A suitably winterized right whale sildes comfortably and frictionlessly on ice. Attached to a spring with constant k the whale, with mass M, undergoes simple harmonic motion.
(a) Derive the equation of motion and express it in standard form.
(b) If the whale's mass[1] is $M = 9.18 \times 10^4$ kg and $k = 1.38 \times 10^5$ N/m find the period of the oscillation.
(c) If at $t = 0$ the whale is moving at $v = 1.3$ m/s and is located at $x = 0$ m find the specific solution to the equation of motion.

(9) Energy in oscillations:
(a) Given the relation $F = -kx$, integrate (directly or by guessing the answer) to find the form of the potential. Recall that $F = -\frac{dU}{dx}$
(b) Sketch the potential energy well for this potential, assuming $k = 2$ N/m.
(c) Use your graph to show the turning points of the motion of a mass with 4 J of *total* energy oscillating in this well.

Lab:

Labs start this week! We will be working with dimensional analysis and the simple pendulum. See the lab handout on the web site for reading in Taylor.

A look ahead...

Next week we add some spice and complication to SHM by adding damping and driving forces. For a preview see HRW 15.8 and 15.9. The material is given a full treatment in KK 10.3.

[1] "The North Atlantic right whale weighs up to 100,000 kg (220,000 lb) and is up to 17 m (56') long," according to http://www.animalinfo.org/species/cetacean/eubaglac.htm