Waves and Fields (PHYS 195): Week 5

Spring 2009 v1.0

Intro:

We will flesh out our understanding of waves with a brief glance at other types of waves, energy transport, modes in two dimensions and a quick look at Fourier series. Early next week we will see that sound is a wave, working out the derivation of the wave equation for fluid in a pipe.

Reminder: Quiz I *is during lab this coming week, on Feb 25 or 26. To review: carefully go over old assignments. Study those topics that are less than familiar. Ask questions!*

Due Monday, February 23

Reading:

- Wednesday: Finish HRW Ch 16
- Friday: We may start on sound - HRW Ch 17.1 - 17.5
- Monday: HRW Ch 17
- For next Wednesday: None - *Review for the Quiz!*

Physics Topics:

- Sound as a wave
- Intensity
- Beats
- group velocity
- Doppler Effect

Problems:

From material in classes through Friday, February 20.

(1) Open the wave on a string Phet simulation. Fix the right end, decrease the damping, and add the driving force with the "Oscillate" button. By varying the frequency find a standing wave configuration. I find it helpful to vary the damping and driving amplitude. What is the phase velocity for this string? What is the frequency of the nth harmonic? Check your result by predicting a resonant frequency and enjoying the resulting standing wave.

(2) Suppose you have a string with linear mass density 0.100 kg/m and a wave,

$$y(x,t) = 0.050\,\sin(6.00x + 12.0t),$$

propagating on this string. y and x are measured in meters and t is measured in seconds. Find the average rate of energy transport by this wave.

(3) A mass $m = 40.0$ g hangs from a $k = 3.5$ N/m spring. Neglect damping and assume you have 2 significant figures throughout this problem.

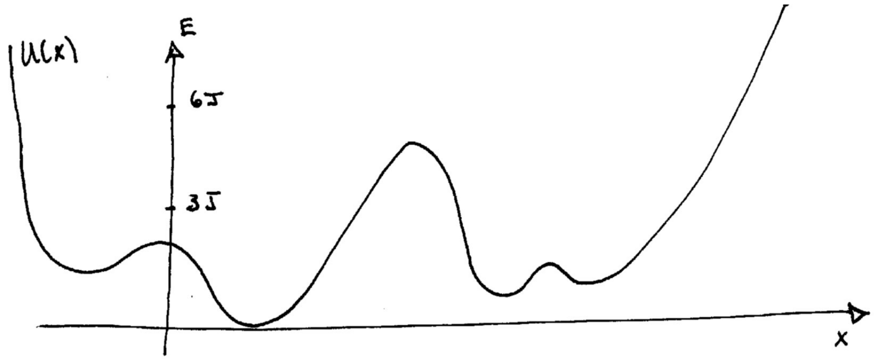
  (a) What is the angular frequency of oscillation?

  (b) If the amplitude of oscillation is $A = 12$ cm then how much energy is stored in the system?

  (c) When $t = 0$ the mass is at equilibrium and is moving upward. Find the solution which describes the displacement.

(4) Using a simple pendulum you find the local acceleration of gravity. After careful data taking, you and your lab partner find that the period is $T = 2.027 \pm 0.002$ s and the length of the pendulum is $\ell = 102.2 \pm 0.1$ cm. What is your result for g? Does this agree with the g you actually found in lab? Explain.

(5) Here is a plot of the potential energy of a particle.



(a) Circle the stable equilibrium points.
(b) If a particle has 3 J of energy sketch how the motion could appear on this plot. Identify the turning points.
(c) In this case, is the motion simple harmonic? Explain your answer.

(6) What is the general solution to

$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \omega_o^2 x = 0?$$

What type of differential equation is this?

(7) A suitably winterized whale out for a lark slides on frictionless ice. Attached to a $k = 1.97 \times 10^6$ N/m spring the whale gently oscillates with a frequency of 0.250 Hz and an amplitude of 3.00 m.
(a) Derive the equation of motion for the whale. Make life easy! Do not plug in numbers. Rather, write the equation of motion in terms of the necessary constants.
(b) If at $t = 0$ the whale is at $x = 2.00m$ with positive velocity find the solution, $x(t)$, to the whale's equation of motion.
(c) Sketch or plot this solution.

(8) Find an empty soda bottle.
(a) What is the height of the bottle?
(b) Make the bottle sing by blowing across the mouth of the bottle. What is the resonant[1] frequency?
(c) Draw a picture of the wave, using a transverse wave picture.
(d) If you fill the bottle 1/3 full, what is the new frequency?

(9) Your favorite cylindrical rubber ducky, with radius r, floats in the tub. You tap it and it oscillates. Derive the equation of motion for vertical displacements around equilibrium.

(10) **Reducing resonance!** The steady state solution for driven, damped oscillation can be written as

$$x_S(t) = A_S \cos(\omega t + \phi_S)$$

where ω is the driving frequency. The amplitude A_S is a function of the driving frequency

$$A_S = \frac{F_o}{m\sqrt{\left(\omega^2 - \omega_o^2\right)^2 + b^2\omega^2/m^2}}$$

[1]Note that there is no periodic driving force here. For details see the first couple pages of the Green-Unruh paper. There's a link on the website.

At LIGO, the huge gravitational wave detectors in Washington and Louisiana, folks are trying to measure tiny deflections in hanging mirrors. These mirror systems are essentially pendula. Noise is a constant problem. To avoid spurious signals they require vibrational isolation (so that $x_S(t) \approx 0$). They have little control over ω and F_o. When designing the suspension systems what quantities should be made large to reduce the unwanted oscillations?

Lab:

Quiz I!

A look ahead. . .

Next week we have a major shift in subject. So far we have used good old Newtonian dynamics to derive oscillations and wave motion. We will end the semester studying light as a wave but it will take a new dynamics to show this - the dynamics of fields. Hence, in the middle 1/3 of the course we will study *fields.* We start with Chapter 21.