11/22 In Class–Waves and some Ch 2-4 review problems
Summary and review of waves:

A traveling wave has a function given by:

$$y = A\sin(\frac{2\pi}{\lambda}x - \omega t) \qquad \text{or} \qquad y = A\cos(\frac{2\pi}{\lambda}x - \omega t)$$

for waves traveling in the $+x$ direction.

All the variables such as A (amplitude), f, frequency, ω angular frequency, and T period, have the same definitions as they did for SHM.

There are two new quantities we defined last time: wavelength (λ) (distance for one complete cycle) and the speed of the wave, $v = \frac{\lambda}{T}$.

There is another way to calculate the speed of a wave on a string.

$$v = \sqrt{\frac{F_T}{\mu}}$$

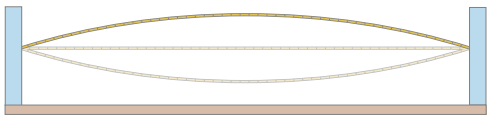
where F_T is the tension in the string, and μ is the mass per unit length of the string.

1. A guitar string has $\mu = 50$g/m and is under tension of 30N. If you pluck the string, what will be the speed of the wave?
2. A wave on a string has an equation of motion given by: $y = .05\sin(4\pi x - \frac{\pi}{3}t)$
   (a) What is the amplitude of the motion?
   (b) What is the period of the motion?
   (c) What is the wavelength of the motion?
   (d) What is the speed of the wave?
   (e) If the mass of the string is 15g and it is 2m long, what is the tension in string?
   (f) Write an expression for the velocity of a particle of the medium at $x = 0$.
   (g) What is the maximum velocity of a particle of the medium?
3. A wave has an amplitude of 10cm, a frequency of 3Hz, and a wavelength of 15cm.
   (a) Write an expression for the wave, assuming that it is a sin wave.
   (b) What is the period of the motion?
   (c) What is the speed of the wave?

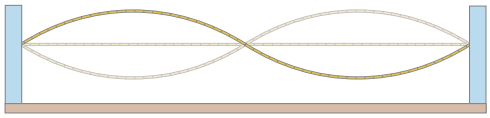
Interference and standing waves

When there are two sources of waves, the waves can interfere with each other. When two wave crests (or two wave troughs, or a crest and a trough, or any part of the wave) hit each other, the "y-value" adds. For

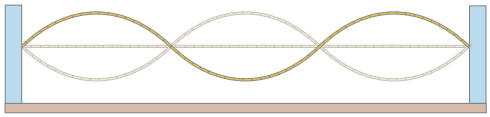
example, if the two waves have amplitude A, then at a place where two crests hit, the height of one particle in the medium will be $2A$. Similarly, if a crest hits a trough, they will "cancel" and have an amplitude of 0 at that one point where the crest and trough meet.



Fundamental or first harmonic, f_1



First overtone or second harmonic, $f_2 = 2f_1$



Second overtone or third harmonic, $f_3 = 3f_1$

4. Just looking at the pictures above, find the relationship between the wavelength of the wave shown in each picture, and the length of the string. Use n to correspond to the number of antinodes, and λ_n for the wavelength of the nth harmonic.

5. Using what you know about the speed of a wave on the same string, find he relationship between each frequency, speed, and length of the string. Again, it should have the n for number of antinodes. (You should solve for f_n.)

6. A guitar string of length 75cm can play a note with the speed of the wave on that string is 425m/s.

   (a) What is the wavelength of the fundamental (=first harmonic)?

   (b) What is the frequency of the fundamental (= first harmonic)?

   (c) What is the frequency of the second harmonic?

   (d) What is the frequency of the third harmonic?

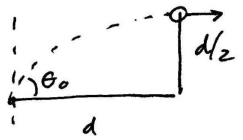
Review Problems

7. Shown below is a problem I found on the MIT open courseware site.[1] Try it :) If you want numbers, feel free to use d=39.2m. (A bit large, but it makes for a nice round number in the calculations.)

[1] Lewin, Walter, Peter Dourmashkin, Thomas Greytak, Craig Watkins, Andy Neely, Sahana Murthy, J. Litster, and Matthew Strafuss. 8.01SC Physics I: Classical Mechanics, Fall 2010. (MIT OpenCourseWare: Massachusetts Institute of Technology), http://ocw.mit.edu/courses/physics/8-01sc-physics-i-classical-mechanics-fall-2010 (Accessed 3 Dec, 2014). License: Creative Commons BY-NC-SA

Problem 6:

A person is a playing a game that requires throwing an object onto a ledge. The ledge is a distance d and a height $d/2$ above the release point. You may neglect air resistance. You may use g for the magnitude of the gravitational acceleration.

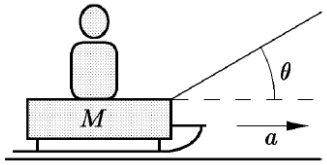


(a) At what angle must the person throw the object and with what magnitude of the velocity if the object is to be exactly at the top of its flight when it reaches the ledge? Briefly describe how you will model this problem and your strategy for finding the answer. Express your answer in terms of the given quantities d and g, as needed.

8. For this one, if you want numbers, use: $M = 25\text{kg}$, $a = 2m/s^2$, and $\theta = 60°$ If you use symbols, assume M, a, and θ are given and find T and F_N in terms of them. (Also from the MIT site[1])

Problem 2: Towing a Sled

A mother tows her daughter on a sled on level ice. The friction between the sled and the ice is negligible, and the tow rope makes an angle of θ to the horizontal. The combined mass of the sled and the child is M. The sled has an acceleration in the horizontal direction of magnitude a. As we will learn to justify in a few weeks, the child and sled can be treated in this problem as if they comprised a single particle.



a) Calculate the tension, T, in the rope and the magnitude of the normal force, N, exerted by the ice on the sled. Briefly describe how you model the problem and your strategy for solving this problem. Show all relevant free body diagrams.

9. Using what you found in the last problem, calculate the work done by each of the forces if the sled moves a distance $d = 5m$ to the right. (You may use d or numbers.)

   (a) Work done by gravity

   (b) Work done by normal force

   (c) Work done by tension

   (d) If the sled started from rest, what is its speed after it moves the 5m?

   (e) Use kinematics and the acceleration from the last problem to check your answer.