Modern Physics

Fall 2018

Assignment 1:

- **You should study the sections on mechanical waves and optics in your General Physics Textbook.** I will spend some time reviewing both mechanical waves and optics. The concepts of superposition and interference are especially important.
- **Turn in the problems below on Friday, September 7**.

SHOW any WORK!!!

1. A steel wire has a length of 0.8m, a mass of 4 grams and has a tension of 40N. It is fixed at both ends. (Watch the mixed units!)
   a.) What will be the speed of a transverse wave on the string?
   b.) What will be the frequencies of the first two resonant frequencies?
2. A sound wave in air has a pressure variation given by
   $p(x,t) = 2[Pa] \cos(6\pi x/m - 360\pi t/s)$
   where x is distance and t is time. Note that I've included the units of pressure in brackets [Pa]. Find (a) the speed of the wave, (b) the amplitude of the pressure, (c) the wavelength, and (d) the frequency in Hz. (Watch your units!)
3. Write down the expression for a traveling wave (on a string) whose frequency is 9π rad/s and moving in the + x direction with a speed of 40m/s. The amplitude is 1cm. Assume the amplitude at x=0 and t=0 is zero.
4. A string with a linear density of 0.02kg/m, has a tension of 32N. A wave of frequency 12π rad/s has an amplitude of 0.01m as it propagates down the string. What is the average rate at which energy is transmitted down the string, (i.e. the average power)?
5. A string is fixed at both ends and its fundamental frequency of vibration is 200Hz. If I decrease the tension in the string by 5N, the frequency of the fundamental decreases to 195Hz. What was the original tension in the string? (Assume the linear density and length do not change.)

6.* A slightly harder problem is to find the form of the solution for the fundamental vibration on a string which is fixed at x=0, but free to move up and down at the end x=L. (This could be "sort of" achieved by attaching the string to a light ring that is on a frictionless post so the ring can move up and down. However this type of condition is seen more often in air vibrations in an organ pipe.) The condition at x=L is that the vertical (y component) of the force is zero.
   a) Show that this implies that the derivative of y(x,t) is zero, i.e. $\frac{\partial y}{\partial x} = 0$, at x=L.
   b) Find y(x,t) if the wave speed is c.
   c) Find the frequency of the fundamental in terms of c and L.

7. If f(x,t) and g(x,t) are differentiable functions that each satisfy the wave equation, i.e.
   $\frac{\partial^2 f(x,t)}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 f(x,t)}{\partial t^2}$ and $\frac{\partial^2 g(x,t)}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 g(x,t)}{\partial t^2}$
   show that the function
   $$y(x,t) = Af(x,t) + Bg(x,t)$$
   also satisfies the equation, i.e.
   $$\frac{\partial^2 y(x,t)}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 y(x,t)}{\partial t^2}$$
   if A and B are constants.