Physics 101 PART I
Simple Harmonic Motion:

1. Rubi picks two springs out of a box. The first has a length of 20 cm and a spring constant of k1= 3.0 N/m; the second has a length of 15 cm and a spring constant k2**=**2.2 N/m. These are attached on either side of a block which is 5 cm wide (the first spring on the left and the second spring on the right) and then attached to either end of a the inside of a box which is 1 m wide. The mass weighs 5 g and the floor of the box is frictionless. The block then finds itself in a position which places the newly established system in equilibrium.

a) Determine the equilibrium position with respect to the left-hand wall of the box.
b) If the mass is disturbed from equilibrium by shifting it to the left x cm, what is the net force acting on it?
c) The mass is disturbed from equilibrium by shifting it 3 cm to the left. What is the equation of its motion? What is the period of its motion?

2. A ball which is 800 g is attached to a 2 m long "weightless" wire and then suspended from the ceiling; once suspended, the ball is 1 m from the ground. The ball is shifted an angle 7 degrees from equilibrium and let go.

a) Find an equation to describe how far the ball is from the ground at any time later assuming no air resistance.
b) What is the speed of the ball at the bottom of the swing?
c) If, over time, the maximum angle decreases to 4 degrees, how much work has been done by friction?

3. Eddy suspends a spring from a tree branch which has an unextended length of 35 cm and a spring constant of 30 N/m. A mass of 50 g is now attached to the spring without allowing the spring to stretch at all (that is, the experimenter, Eddy, is supporting the weight of the mass). Now the mass is released.

a) How far will the mass drop?
b) How far back up will it come assuming that there is no energy lost due to friction?
c) Write the equation of motion of the mass with respect to the equilibrium position. (Hint, the equilibrium position is NOT the point at which the mass is released in this case!)
d) Find the maximum speed of the mass.

4. A mass of 2 kg is attached to a 2.5 m long spring (k=60N/m). At some point earlier the system was perturbed and the mass is now oscillating. If it is found that the maximum displacement from equilibrium is x=0.15 m, that x=0.06m when t=0.2s, and that x is increasing at t=0.2s.
a) What is the period?
b) What is the frequency?
c) What is the maximum speed?
d) What is the equation of motion?

Waves:
5. An equation describing a transverse wave traveling on a string is given by y=0.3cos(0.75x+12t) where y is measured in metres.
a) What is the displacement when x=2.7 m and t=0.63 s?
b) Why does a moving wave need to have two variables for displacement: x and y? What are their physical interpretations?
c) Write an equation for a wave which, when superimposed over this wave will produce a standing wave. What is the *simplified* equation for the resulting standing wave. Hint: Cos(A+B)= CosACosB-SinASinB
d) What is the displacement in the standing wave when x=2.7 and t=0.63 s?

6. The equation describing a wave traveling in a wire is given by
$y=4\cos(2x+10t)$
a) What direction is the wave traveling?
b) What is the wavelength?
c) What is the speed of the wave?
d) What is the maximum acceleration of a particle on the wave?
e) How far apart are points that are 30 degrees out of phase at a given time?

Beats
7. Two trains each blow a whistle of frequency 125 Hz. One train is motionless while the other moves. A stationary observer hears a beat frequency of 2 Hz. What are the two possible speeds and directions of the moving train?

8. Someone in your choir can't keep a tune. You know that you are singing at a frequency of 512 Hz but you hear Mrs. Snodgrass singing out of key. You remember back to Physics 101 and note that the beat frequency is 3 Hz.
a) What are the possible notes that Mrs. Snodgrass is singing?
b) The equation of motion of a sound wave is given by $y=A\cos(kx-\omega t)$ and another is given by $y=A\cos(kx-(\omega+\varepsilon)t)$. Assume that you are standing at the origin (x=0) and assume that ε is much less than ω.
i) Write and simplify the equation that describes the superimposition of the two waves. Hint: $\cos A + \cos B = 2\cos((A+B)/2)\cos((A-B)/2)$
ii) Draw a picture of what the resultant wave looks like.
iii)What does this have to do with you and Mrs. Snodgrass?

Vibration of Strings:
9. A violin string of length 50 cm and mass 40 g is vibrating in its fundamental frequency at 196 Hz when played without any fingering.
a) What is the speed of the wave in the string?
b) At what frequency will it vibrate when fingered 1/3 of the way down from the top end of the string.
c) What is the tension in the string?
d) How long must a pipe be in order to be in resonance with the unfingered string if the pipe is open on both ends?

10. A wire of mass 0.025 kg and length 3.00 m is fixed at both ends. The wire is vibrating in its fundamental and it is noted that there are 100 oscillations in 0.8 s.
a) What is the frequency of the oscillations?
b) What is the tension in the wire?
c) By what fraction must the tension be increased to double the frequency?
d) Sketch the first three harmonics of the system.

11. Two identical steel wires each fixed at both ends are under identical tension and are vibrating in their third harmonic at 963 Hz. The tension in one wire is increased by 3%. Determine the beat frequency that is perceived when both are played in their fundamental modes.

12. A mass of 25kg is hanging from a 2.3 m long wire of mass 46g.
a) What frequency is heard if the wire is vibrating in its fundamental?

b) The mass is now immersed in a fluid of unknown density while the wire remains in air. It is discovered that when the wire vibrates in its first overtone that the frequency heard is the same as the fundamental heard earlier (when the fluid was not present). What is the density of the fluid if the density of the block is 3000 kg/m^3?