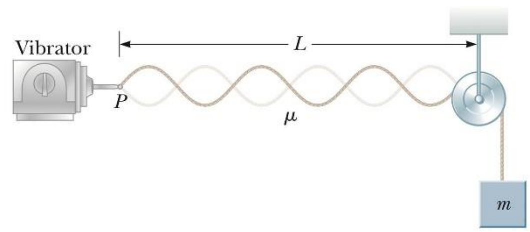
University Physics II

Homework Set 13

Unless otherwise stated or a temperature given, use 343 m/s as the speed of sound in air.

1. A string that is 30.0 *cm* long and has a linear mass density of 9.00×10^{-3} *kg*/*m* is stretched to a tension of 20.0 N.
   a. Find the fundamental frequency
   b. Find the next three frequencies possible on the string

2. In the setup at right, an object of mass $m = 5.00$ *kg* hangs from a chord around a light pulley. The length of the cord between point *P* and the pulley is $L = 2.00$ *m* and the frequency of the vibrator is 150 Hz. Under these conditions, six standing wave loops are observed.



   a. What is the linear mass density of the string?
   b. How many loops (*if any*) would result if the hanging mass were changed to 45 *kg*?
   c. How many loops (*if any*) would result if the hanging mass were changed to 10 *kg*?

3. An air column in a glass tube is open at one end and closed at the other by a movable piston. The air in the tube is warmed above room temperature. A 384 Hz tuning fork is held at the open end, producing a resonance when the piston is at a distance $d_1 = 22.8$ *cm* from the open end and again at $d_2 = 68.3$ *cm*.

   a. What is the speed of sound during this experiment?
   b. Where would the piston need to be located from the open end for the next resonance (d_3)?

4. The wave function of a standing wave is given by

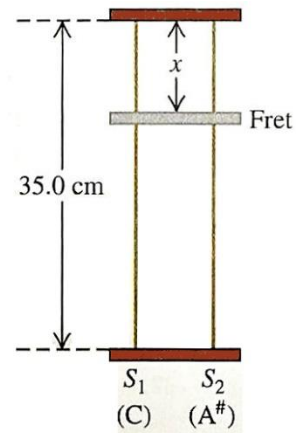
$$\Psi_{sw}(x,t) = (4.44\,mm)\sin(32.5x)\cos(754t)$$

   with *x* in meters and *t* in sec. For the two traveling waves that make up this standing wave, find the
   a. Amplitude of each traveling wave
   b. Wavelength of each traveling wave
   c. Frequency of each traveling wave
   d. Speed of each traveling wave
   e. The wave function of each traveling wave

5. The fundamental frequency of sound in a pipe that is open at both ends is 524 Hz.
   a. How long is this pipe?
   b. If one end is now closed, what is the wavelength and frequency of the new fundamental?

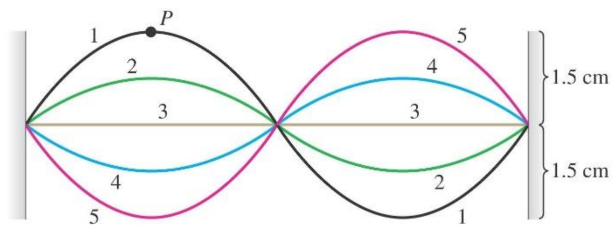
6. Many opera singers (and some pop singers) have a range of about 2½ octaves or even greater. Suppose a soprano's range extends from A (220 Hz) below middle C up to E-flat (1244 Hz) above high C. Although the vocal tract is quite complicated, we can model it as a resonating air column in a closed pipe extending from the mouth down to the diaphragm in the chest cavity. How long is this cavity (*in cm*) if we assume the lowest note is the fundamental and $v_s = 354$ *m*/*s*. Does your result seem reasonable?

7. You are designing a two-string instrument with metal strings 35.0 *cm* long as shown in the figure at right. Both strings are under the same tension. String S_1 has a mass of 8.00 *g* and produces the note middle C (262 Hz) in its fundamental mode.
   a. What is the tension in the string?
   b. What should the mass be (*in g*) of string S_2 so that it will produce an A-sharp (466 Hz) as its fundamental?



   To extend the range of your instrument, you include a fret located just under the strings but not touching them.
   c. How far from the upper end (*in cm*) should you put this fret so that when you press S_1 against it, it produces a C-sharp (277 Hz) as a fundamental on the lower part of the string?
   d. If you press S_2 against the fret, what frequency of sound will it produce as its fundamental?

8. A vibrating string 50.0 *cm* long is under a tension of 1.00 N. The results of five successive stroboscopic pictures are shown at right. The strobe rate is 5000 flashes per minute. Observations reveal that the maximum displacement occurred at flashes 1 and 5 with no other maxima between.

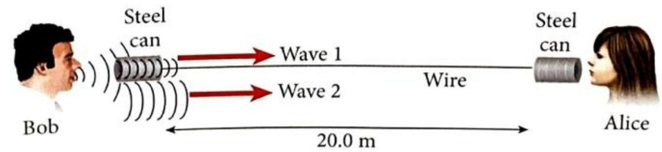


   a. Find the period for the standing waves on this string
   b. Find the frequency of the standing waves on this string
   c. Find the wavelength of the standing waves on this string
   d. In what harmonic is the string vibrating?
   e. What is the speed of the traveling waves on the string?
   f. What is the mass of the string (*in g*)?

9. Evaluate each of the following:
   a. **Whale Communication**: Blue whales apparently communicate with each other using sound at a frequency of 17 Hz, which can be heard nearly 1000 *km* away in the ocean. What is the wavelength (*in m*) of such a sound in seawater (v_s = 1531 *m*/*s*)?
   b. **Dolphin clicks**: One type of sound that dolphins emit is a sharp click of wavelength 1.5 *cm* in the ocean. What is the frequency of such clicks (*in* kHz)?
   c. **Dog whistles**: One brand of dog whistles claims a frequency of 25 kHz for its product. What is the wavelength (*in cm*) of this sound?
   d. **Sonograms**: Ultrasound is used to view the interior of the body, much like x-rays. For sharp images, the wavelength of the sound should be around one-fourth (or less) the size of the object being viewed. What is the approximate frequency (*in* MHz) of sound needed to produce a clear image of a tumor that is 1.0 *mm* across if the speed of sound in tissue is 1550 *m*/*s*.

10. Two organ pipes, one 1.14 m long and the other 1.16 m long, are open at one end and closed at the other. Find the beat frequency that is produced when they are played together.

11. Bob is talking to Alice using a tin can telephone, which consists of two steel cans connected by a 20.0 *m* long steel wire. The wire has a linear mass density of 6.13 *g*/*m* and the tension on the wire is 25.0 N. The sound waves leave Bob's mouth, are collected by the can on the left, which create vibrations in the wire that are transmitted to Alice's can and are transformed back into sound waves. As this is a simplistic system, Alice is able to hear the sound of Bob speaking (Wave 2) as well as the sound transmitted through the cans & the wire (Wave 1). Do the two sounds reach Alice at the same time? If not, which one arrives first and by how much? Assume the speed of sound in air is 343 m/s and the waves in the wire are traverse waves.



12. A soprano sings the note C6 (1047 Hz) across the mouth of a soda bottle. For a fundamental frequency equal to this note to be produced in the bottle, how far below the top of the bottle must the surface level of the liquid be (*in cm*)?

13. Find the resonance frequency of the ear canal. Treat it as a closed pipe of diameter 8 *mm* and length 25 *mm*. Assume the temperature inside the ear is at body temperature (37 ^{o}C).

14. **In a physics lab, an oscillator is attached to one end of a horizontal string. The other end of the string passes over a frictionless pulley. You suspend a mass M from the free end, producing a tension of Mg in the string. The oscillator produces transverse waves of frequency f that are fixed for the duration of the experiment. During the experiment, you try strings with three different linear mass densities (μ), but keep the distance between the oscillator and the pulley fixed. (*See Problem 2 for setup*). To produce standing waves on the string, you vary the mass M. When you produce a standing wave pattern, you record the node-to-node distance for each standing wave pattern. The data from this experiment is listed in the table below.

String	***A***	***A***	***B***	***B***	***C***
μ (g/cm)	0.0260	0.0260	0.0374	0.0374	0.0482
M (g)	559	249	365	207	262
d (cm)	48.1	31.9	32.0	24.2	23.8

a) Using the wave speed equation, the equation for the speed of a wave on a string under tension and the fact that $\lambda = 2d$, determine an expression relating μd^2 and M.

b) Using your result from part (*a*), if you graph μd^2 *vs* M, you should get a straight line. Graph the above data and determine the best-fit line.

c) Using the slope of your best-fit line, determine the frequency of the oscillator (*use* $g = 9.8\ m/s^2$).