Physics 2010 (Schroeder) Name ______________________________
spring 2004

Problem Set 12

(due Friday, April 9)

1. Show that the formula $\sqrt{B/\rho}$ for the speed of sound has the correct units.

2. A rule for finding your distance in miles from a lightning flash is to count seconds from the time you see the flash until you hear the thunder, then divide the count by five. (a) Explain this rule and determine the percent error in it at 20°C, assuming that the sound travels to you along a straight path. (b) Devise a similar rule for obtaining the distance in kilometers.

3. Earthquakes generate sound waves inside the earth. Unlike a gas, a solid can transmit both transverse (S) and longitudinal (P) waves. In typical locations, the speed of the S waves is about 4.5 km/s and the speed of the P waves is 8.0 km/s. A seismograph records P and S waves from an earthquake. The first P waves arrive 3.0 minutes before the first S waves. Assuming that the waves traveled in a straight line, how far away did the earthquake occur?

4. The audibile frequency range for normal hearing is from about 20 Hz to 20 kHz. What are the wavelengths (in air) of sound waves at those frequencies?

5. Two loudspeakers in an open space are aimed eastward, separated in the N-S direction by 2.0 meters. They produce identical signals, in phase with each other. A listener is positioned 3.75 m directly east of one of the speakers (and is therefore somewhat farther away from the other). For what frequencies in the audible range does the listener hear a minimum-intensity signal? For what frequencies is the intensity a maximum? (Hint: Draw a picture, and use it to calculate the difference in path length from the two speakers to the listener. How should this difference relate to the wavelength for constructive/destructive interference?)

6. A one-watt point source emits sound waves equally in all directions. Assuming that the energy of the waves is conserved as they travel outward, what are the intensity (in W/m^2) and sound level (in decibels) (a) 1.0 meter from the source and (b) 2.5 meters from the source?

7. An ambulance is racing down the road at 60 mph, with its siren blaring at a frequency of 800 Hz. What is the frequency of the sound that you hear as it is coming toward you? As it is moving away?

8. A "half step" on the musical scale corresponds to a 6% change in frequency. Do you think you could run fast enough toward a trumpet player (or any other stationary source) to hear the sound a half-step higher in pitch? Could you go fast enough on a bicycle, or in a car?

9. A cardboard tube, closed at one end, is used as a "musical" instrument. For each of the three longest-wavelength resonances of the tube, carefully draw a graph of the air's displacement as a function of the position along the tube. Be sure to label which end is open and which end is closed. Then, for each of the three resonances, draw a graph of the air's *pressure* (or density) as a function of position. What are the wavelengths and frequencies of the three resonances?

10. Suppose that you wish to make an organ pipe with a fundamental resonant frequency of 256 Hz (middle-C). How long should you make the pipe, if it is open at one end and closed at the other? What if it is open at both ends? If the pipe has the same fundamental frequency in both cases, how does the sound differ?

Study Guide

You should understand what sound waves are (in terms of density and pressure variations). You needn't know the general formula for the speed of sound ($v = \sqrt{B/\rho}$), but you should understand what it means qualitatively—how the density and stiffness of the medium affect the speed of sound. You should memorize the approximate value of the speed of sound in air at room temperature (340 m/s).

You should understand the Doppler effect, and be able to explain when the observed frequency of a wave is higher and when it is lower than the frequency of the source (and why). When the motion of source and/or detector is slow compared to the speed of the wave, the observed frequency is shifted by a percentage equal to their relative velocity as a percentage of the wave speed. (For higher velocities, the precise formula depends on whether it is the source or the detector that is moving. But you needn't know the precise formulas.)

You should be able to predict the resonant frequencies of wind instruments (such as organ pipes), by drawing graphs of the various wave patterns, relating the wavelengths to the length of the pipe, and calculating the frequencies from these wavelengths. (Do *not* simply memorize a formula for the resonant frequencies—you need to be able to figure them out from scratch and understand every step of the logic.)

You learned how to predict resonant frequencies of string instruments last week. Don't forget, though, that the speed of a wave *on the string* has nothing to do with the speed of the sound wave that is produced in the air. The frequencies of these waves will be the same, and therefore their wavelengths will be different.