Physics 109  Homework #5  due Monday Oct. 15, 2001

Formulae: in air $v = 340 \text{ m/s}$. Open: $f_1 = \frac{v}{2L}$; $f_n = nf_1$; Closed: $f_1 = \frac{v}{4L}$

Exercises on pipes:
1. (a) Find the fundamental frequency and the frequencies of the first two overtones of an open pipe of 60 cm length.

   \[ f_1 = \frac{v}{2L} = \frac{340}{1.2} \text{ Hz} \]

   \[ 283 \text{ Hz}, \ 567 \text{ Hz}, \ 850 \text{ Hz}. \]

   (b) if the same pipe is closed at one end, what are the corresponding frequencies?

   \[ f_n = \text{octave below}, \ \text{odd harmonics only} \]

   \[ 142 \text{ Hz}, \ 425 \text{ Hz}, \ 708 \text{ Hz}. \]

2. (a) Make a graph of the pressure at different instances in an open pipe (left) and in a closed pipe (right) oscillating in the fundamental mode.

   (hint: first mark the pressure nodes by letter N - then draw the curves)

   closed end

   make a corresponding graph of the air velocity distribution in the pipe.

   (remember slinky demo - where does it move most, where does it not move at all?)
(b) make corresponding pressure graphs for the next higher mode.

3. Between room temperature (20°C) and body temperature (37°C) the speed of sound increases by 10 m/s. A flute has a frequency of 260 Hz when it is cold. Find the frequency when the flute is warmed to body temperature by the flutist's breath (hint: use proportions to relate frequencies to speed of sound - what is the ratio of speed of sound at the two temperatures? What is the frequency ratio?)

\[
f_2 = \text{warm flute} \quad f_1 = \text{cold flute}
\]

for fixed \( L \), \( f \) is prop. \( v \)

\[
f_2 = \frac{340 + 10}{340} \times 260 \text{ Hz} = 267.6 \text{ Hz}
\]

Exercises on Fourier Analysis

NOTE: we can usually not figure out the amplitudes of the overtones, but can only find out which are present and what their frequencies are. Thus when you are asked to draw a Fourier spectrum the position of the Fourier components should be in the right place, but the intensity is arbitrary.

4 a) What might the Fourier spectrum of a closed pipe with fundamental frequency 300 Hz look like?

4 b) What is the spectrum when the same pipe is open at both ends?

5. What might the Fourier spectrum of a 500 Hz violin string look like when it is plucked 1/3 the length from one end?

\[\hat{3}, \hat{6}, \hat{9} \text{ missing}\]