

# Physics 23 Problem Set 3

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Due Monday, October 10

Please make your work neat, clear, and easy to follow. It is hard to grade sloppy work accurately. Generally, make a clear diagram, and label quantities. Derive symbolic answers, and then plug in numbers after a symbolic answer is available.

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1. A recorder (a flute-like instrument) plays a  $C_5$ , which has frequency 523.3 Hz, when played in air at a temperature of 293 K. The  $C_5$  is in musical notation, where  $C_4$  with frequency 261.6 Hz is an octave below  $C_5$ ,  $C_6$  with frequency 1046.6 Hz is an octave above  $C_5$ . The other notes in the octave are found by multiplying by  $2^{1/12}$  for each half-step up; the scale was discussed in the last problem set. Both ends of the recorder are open.
  - (a) What is the length of the recorder?
  - (b) The recorder is played in different gases, at the same temperature; complete the following table (you will have to look up atomic weights, and to convert frequencies to notes with the equal tempered scale describe in the second problem set). Helium and Xenon are monatomic gases with only translational degrees of freedom, and  $UF_6$  is a complex molecule that has all three rotational degrees of freedom in addition to its translational degrees of freedom:

Gas	Molecular Weight (gm/mole)	Speed of Sound $v$ (m/s)	Frequency (Hz)	note
Air	29	343	523.3	$C_5$
He				
Xe				
$UF_6$				

2. A drumhead is made from a stiff, square frame of  $L = 0.3$  m, over which a skin of 0.003" and density  $\rho = 1$  gm/cm<sup>3</sup> is stretched. You would like the fundamental frequency of the drumhead to be  $\nu_1 = 110$  Hz, which is also the note  $A_2$ .
    - (a) What surface tension must be applied to the skin to achieve the desired fundamental frequency?
    - (b) The drumhead is attached to a resonator body to make a drum. The body and the head form a pipe with one closed end. How long should the resonator body be to have its fundamental frequency in air equal that of the drumhead?
    - (c) What frequency (and corresponding note) is the first overtone of the drumhead?
  3. A guitar string of length  $L$  is stretched initially into the shape  $y(x, 0) = (2a/L)x$  for  $x < L/2$  and  $y(x, 0) = (2a/L)(L - x)$  for  $x > L/2$ , and then released from rest.
    - (a) Plot  $y(x, 0)$ .
    - (b) Find the Fourier series that describes the initial condition of the string. Are there values of  $n$  for which the Fourier coefficients  $B_n$  are zero?
    - (c) Include only the first two non-zero terms in the series, and compute and plot the string at three times:  $t = 0$ ,  $t = 0.3L/v$ , and  $t = 0.6L/v$ , where  $v$  is the speed of sound on the string.
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