

- ~~(b) Carefully draw the wave (y versus x) at $t = 0$, and at $t = 1/400$ sec.~~
- ~~(c) Find the maximum transverse speed of any mass element of the string.~~
- ~~(d) Suppose that you clamp the string at two points L cm apart and you observe a standing wave of the same wavelength as in part (a). For what values of L less than 10 cm is this possible?~~

Problem 8.5

~~Standing waves on a string.~~

~~The equation of a transverse standing wave on a string is given by $y = 0.3 (\sin 3x) (\cos 1200t)$ where y and x are in cm, and t in seconds.~~

- ~~(a) What is the wavelength, wave number, frequency, and period, of this wave?~~
- ~~(b) Carefully draw the wave (y versus x) at $t = 0$, at $t = 1.31 \times 10^{-3}$ sec, and at $t = 2.62 \times 10^{-3}$ sec.~~
- ~~(c) What is the maximum transverse speed?~~
- ~~(d) What is the speed of propagation (of a transverse disturbance) along the string?~~

Problem 8.6

~~Distance sensing with sound.~~

~~A bat can sense its distance from the wall of a cave (or whatever) by emitting a sharp ultrasonic pulse that reflects off the wall. The bat can tell the distance from the time the echo takes to return.~~

- ~~(a) If a bat is to determine the distance to a wall 8 m away with an error of less than ± 0.2 m, how accurately must it sense the time interval between emission and return of the pulse?~~
- ~~(b) Suppose that a bat flies into a cave filled with methane (swamp gas). By what factor will this gas distort the bat's perception of distances? At 20°C , the speed of sound in methane is 432 m/s.~~

Problem 8.7

~~Design a flute.~~

~~A flute can be regarded as a tube open at both ends. It will emit a musical note if the flutist excites a standing wave in the air column inside the tube.~~

- ~~(a) The lowest musical note that can be played on a flute is C (261.7 Hz). What must be the length of the tube? Assume that the air column is vibrating in its fundamental mode.~~
- ~~(b) In order to produce higher musical notes, the flutist opens valves along the tube. Since the holes in these valves are large, an open valve has the same effect as shortening the tube. The flutist opens one valve to play C^\sharp , two valves to play D , etc. Calculate the successive spacing between the valves of a flute for one complete octave. (The actual spacings used on flutes differ slightly from the results of this simple theoretical evaluation because the mouth cavity of the flutist affects the frequency.)~~

Problem 8.7*Design a flute.*

(a) When the system oscillates in the fundamental mode, the length of the tube (open open) is half the wavelength, so the length of the flute should be $L = \lambda/2$. Wavelength is related to frequency f (in Hertz) and sound speed v_a by $f\lambda = v_a$, or $\lambda = v_a/f$, so that $L = v_a/2f$. For $f = 261.7$ Hz and $v_a = 344$ m/s,

$$L = 0.657 \text{ meters} .$$

(b) For a modern equal-tempered scale, the frequency of any given note is $\sqrt[12]{2} \simeq 1.0595$ times the frequency of the note one half-step below (note frequencies may also be found tabulated). This allows us to calculate the necessary effective tube lengths for each note from $L = v_a/2f$, and hence the corresponding key spacings ΔL :

Note	f (Hz)	L (m)	ΔL (m)
C	261.7	0.657	(0)
$C\sharp/D\flat$	277.3	0.620	0.037
D	293.7	0.586	0.034
$D\sharp/E\flat$	311.2	0.553	0.033
E	329.7	0.522	0.031
F	349.3	0.492	0.030
$F\sharp/G\flat$	370.1	0.465	0.027
G	392.1	0.439	0.026
$G\sharp/A\flat$	415.4	0.414	0.025
A	440.1	0.391	0.023
$A\sharp/B\flat$	466.3	0.369	0.022
B	494.0	0.348	0.021
C	523.4	0.329	0.019

(Note: the somewhat jumpy progression of ΔL 's is due to round-off error.)

END