

SPEECH COMMUNICATION
6.541J-24.968J-HST710J
Spring 2004

Problem Set 2

Assigned: 02/10/04

Due: 02/19/04

Read pages 1-27; 127-152.

Problem 1

Answer true or false. If false, restate correctly!

- (a) Contraction of the lower fibers of the genioglossus muscle decreases the cross-sectional area of the pharynx.
- (b) The tension on the vocal folds is increased by contracting the cricothyroid muscle.
- (c) The mandible is usually in a higher position for the sound /s/ than for the sound /i/.
- (d) On average, the ratio of the length of the oral cavity to the length of the pharyngeal cavity is greater for adult males than for adult females.
- (e) Contraction of the sternohyoid muscle pulls the larynx upwards.
- (f) Downward displacement of the larynx results in a lengthening of the vocal folds.
- (g) The cross-sectional area of the vocal tract is greater in the pharyngeal region for the vowel /i/ than it is for the vowel /A/.

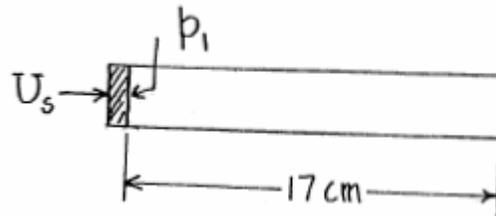
Problem 2

Fig. 2.1

A sinusoidal volume-velocity source with amplitude $U_s = 100 \text{ cm}^3/\text{s}$ and frequency 400 Hz is applied at the left end of a lossless tube of length 17 cm and cross-sectional area 4 cm^2 , as shown in Fig. 2.1. The tube is open at the right end (i.e., assume zero sound pressure at the right end). What is the amplitude of the sound pressure p_1 at the location of the source?

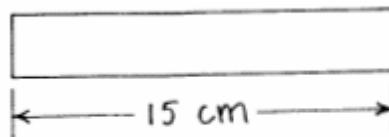
Problem 3

Fig. 3.1

- (a) A uniform tube with a length ℓ of 15 cm and a cross-sectional area A of 4 cm^2 is closed at one end and open at the other, as shown in Fig. 3.1. (Assume the sound pressure is zero at the open end.) What are the first four natural frequencies of this tube?
- (b) The tube in (a) is now modified by adding a short section at the front of the tube, as in Fig. 3.2. Estimate the first two natural frequencies of this configuration. Note that the addition of this short extension adds a small acoustic mass at the end of the tube, and this effectively lengthens the tube.

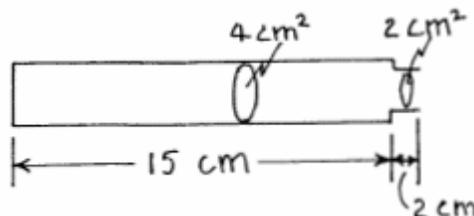


Fig. 3.2

- (c) The tube in (a) is now modified by creating a small opening at the left end, as in Fig. 3.3. The opening has a length ℓ_c of 0.3 cm and a cross-sectional area A_c of 0.02 cm^2 . (This opening simulates the glottal opening at the lower end of the vocal tract.) Determine the first two natural frequencies for this configuration. Note that these frequencies are shifted slightly from those in (a).

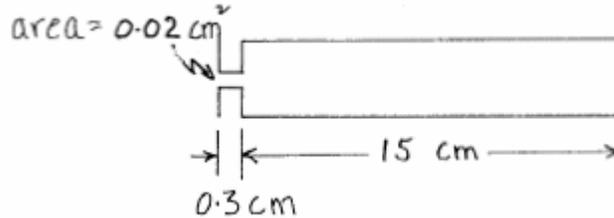


Fig. 3.3

The natural frequencies are the frequencies for which the sum of the impedances looking to the left (Z_L) and to the right (Z_R) at the left end (as shown) is equal to zero, i.e.,

$$Z_L + Z_R = 0$$

where $Z_L = j\omega \frac{\rho \ell_c}{A_c}$ and $Z_R = j \frac{\rho c}{A} \tan \frac{\omega \ell}{c}$ $\rho = 0.00114 \text{ gm/cm}^3$ and $c = 35400 \text{ cm/s}$.

This equation can be solved for $\omega = 2\pi f$ in several ways:

- i. Since the solution is expected to be very close to the frequencies in (a), i.e., where $\frac{\omega \ell}{c} = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}$, and $\frac{7\pi}{2}$, you can write an approximate expression for $\tan \frac{\omega \ell}{c}$ in the vicinity of these points. (Recall, for example, that $\tan x \cong \frac{1}{\frac{\pi}{2} - x}$ when $x \cong \frac{\pi}{2}$.) (You

should check to see whether this approximation is valid in this example.) Thus you can

write $\frac{\rho c}{A} \cdot \frac{1}{\frac{\pi}{2} - \frac{\omega \ell}{c}} \cong -\omega_1 \frac{\rho \ell_c}{A_c}$, where $\omega_1 = 2\pi f_1$ and f_1 is the frequency determined in (a).

Then you can find a solution for ω .

- ii. Find a solution graphically.
- iii. Use Matlab, or write a program in some other language to solve for f with an accuracy of a few Hz.

You may use one of these three ways to solve this problem.

(d) Another way of looking at the configuration in part (c) is to note that the natural frequencies of the tube are the same as the natural frequencies of a tube that is slightly shorter than the original configuration in Fig. 3.1. Figure 3.4 shows a hypothetical terminating point, marked by a dashed line.

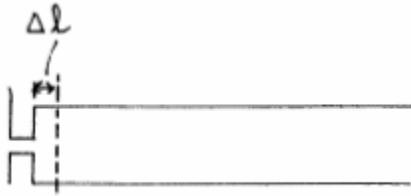


Fig. 3.4

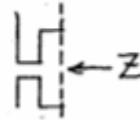


Fig. 3.5

Thus the problem can be solved approximately by finding the length Δl for which the impedance Z looking into the short tube in Fig. 3.5 is infinity at each of the original two lowest natural frequencies of the tube. Note that this short tube is effectively a Helmholtz resonator.