

**6.551J/HST.714J ACOUSTICS OF SPEECH AND HEARING
FALL 2004**

Problem Set 6

11/02/04

Problem 1

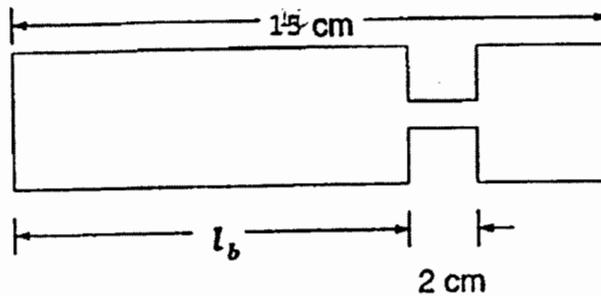


Fig. 1.1

The tube in Fig. 1.1 contains a narrow constriction whose cross-sectional area is 0.2 cm^2 and the cross-sectional area of the remainder of the tube is 4 cm^2 . The overall length of the tube is 15 cm, and the length of the constriction is 2 cm. In this problem, make appropriate approximations, such as assuming the tube has hard walls and assuming that the sound pressure is zero at the open end of the tube.

- (a) What is the length l_b of the back cavity (shown in the figure) such that the second and third natural frequencies of the entire tube are about equal?
- (b) For the value l_b found in (a), what is the lowest natural frequency F_1 ?
- (c) What is the greatest length l_b such that the fourth and fifth natural frequencies of the entire tube are about equal?
- (d) The front part of the tube is narrowed so that its cross-sectional area is small and equal to that of the constriction, as in Fig. 1.2. Repeat parts (a) and (b) for this condition.

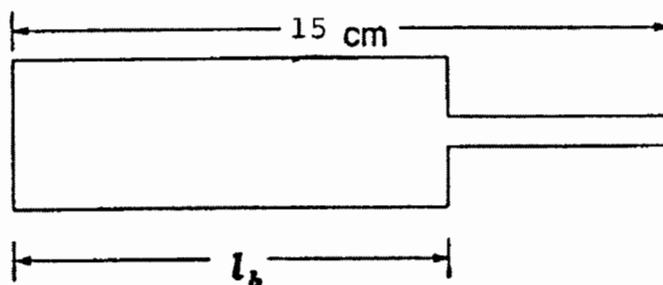


Fig. 1.2

Problem 2

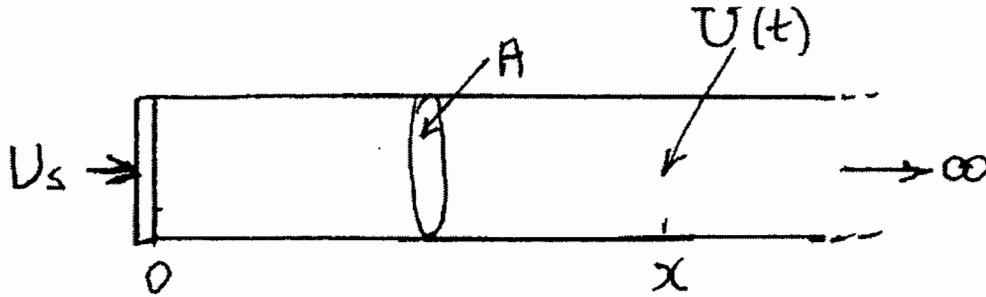


Fig. 2.1

A sinusoidal volume velocity source $U_s(t) = U_0 \cos 2\pi ft$ is applied at the end of a tube with a cross-sectional area A , as shown in Figure 2.1. Assume that the cross dimension of the tube is sufficiently small that one-dimensional waves propagate in the tube. There is no acoustic loss in the tube.

- Assume that the tube has infinite length. At a distance x from the source it is observed that the volume-velocity waveform is $U(t) = U_0 \sin 2\pi ft$. What is the smallest value of x for which this waveform is observed?
- For the same point in the tube as in (a) write an expression for the waveform of the sound pressure.
- The same tube is cut off at a length ℓ , and is closed at that end, as in Figure 2.2. The length ℓ is between $\frac{c}{2f}$ and $\frac{c}{f}$, where $c =$ velocity of sound. The same source U_s is applied. Write an expression for the sound pressure waveform immediately in front of the source.
- At a distance x in front of the source in (c), it is observed that the sound pressure is zero for all t . What is the largest value of x (i.e., smallest value of $\ell - x$) for which this condition occurs?

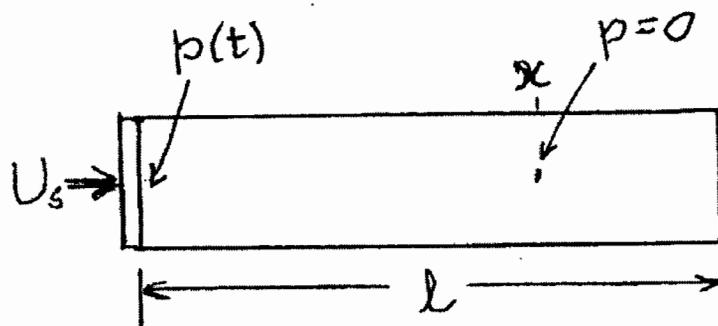


Fig. 2.2

Problem 3.

a) In some experiments it would be convenient to use a masking noise that produced tone detection thresholds that were independent of frequency. What would be the shape of the spectrum of such a masking noise? Assume that the masked tone detection thresholds are to be well above the quiet thresholds of the tones. If the total noise power is limited to 80 dB SPL, over what frequency range would such a spectrum yield tone thresholds that were independent of frequency?

b) According to the data of Hawkins and Stevens, at a given frequency the Critical Ratio is constant, independent of the spectrum level N_0 of the noise, for sufficiently high values of N_0 . At moderate sound levels, the critical ratio for 1000 Hz tones is roughly 70 Hz (18.5 dB). How much would tone detection thresholds change if the critical ratio were twice this value, 140 Hz.

c) Fletcher's analysis of the results of his masking experiments in terms of Critical Bands has been criticized because he assumed that tones were detected when the ratio of tone power P_T to noise power N at the output of the critical band was unity, i.e., $P_T/N = 1$. How would Fletcher's estimates of the critical bandwidths change if he had assumed that $P_T/N = 2.5$?

d) Moore's data on the detection of 2000 tones in noises of various bandwidths (Fig. 15 on p 25 of the Notes on Auditory Sensitivity) can be used to estimate the ratio of tone power P_T to noise power N at the output of the critical band. Assuming that the width of the critical band is 400 Hz when the tone frequency is 2000 Hz, plot a graph of the ratio P_T/N as a function of the bandwidth of the external noise bandwidth. Since Moore does not report the power spectral density of his masking noise, you should assume that his thresholds would be the same as those obtained by Hawkins and Stevens at wide bandwidths.