

SPEECH COMMUNICATION
6.541J-24.968J-HST710J
Spring 2004

Problem Set 1

Assigned: 02/03/04

Due: 02/10/04

Read Chapter 1, pages 1-37.

Problem 1

The waveform of the glottal volume velocity during a vowel is shown schematically in Fig. 1.1. The maximum volume velocity in this waveform is observed to be $600 \text{ cm}^3/\text{sec}$ for a male speaker. The subglottal pressure is $7 \text{ cm H}_2\text{O}$, and the length of the vibrating vocal folds is 1.0 cm . Note that the approximate relation between pressure drop across the glottis (ΔP), area of glottal opening (A), air density (ρ), and volume velocity of air (U) is

$$\Delta P = \frac{1}{2} \frac{\rho U^2}{A^2} \quad (1)$$

The air density at body temperature is $\rho = 0.00114 \text{ gm/cm}^3$. Note that the units are cgs units, so that the pressure must be in dynes/cm². Or you may use mks units.

(a) Using equation (1), calculate the maximum glottal width during the vibratory cycle, assuming (somewhat erroneously) that the entire vocal fold moves laterally back and forth during a cycle of vibration.

(b) A more exact expression for the relation between pressure drop and volume velocity should include a viscosity term, so that the expression for ΔP becomes

$$\Delta P = \frac{1}{2} \frac{\rho U^2}{A^2} + \frac{12\mu U d}{ba^3} \quad (2)$$

where $\mu = 1.94 \times 10^{-4} \text{ dyne-sec/cm}^2$

a = width of glottis

b = horizontal length of glottis = 1.0 cm

d = vertical length of glottis = 0.3 cm

$A = ab$

The dimensions are shown schematically in Fig. 1.2. Determine whether the addition of the second term in equation (2) has a significant effect on the result found in (a).

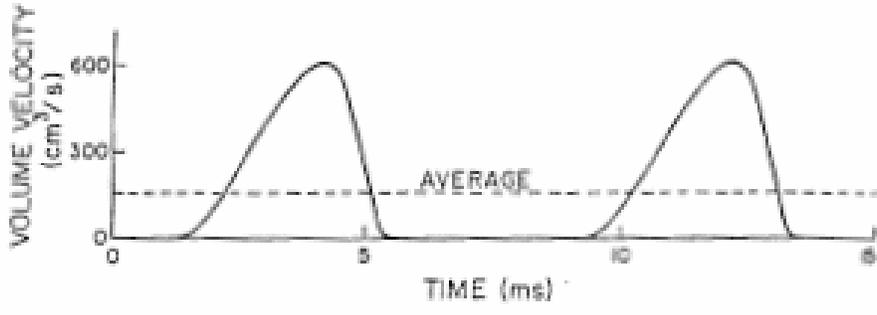


Fig. 1.1

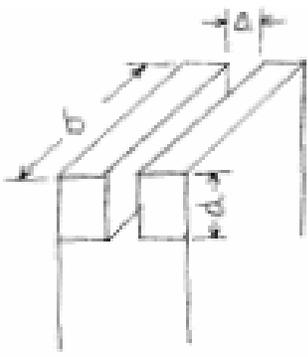


Fig. 1.2

Problem 2

During the production of a particular fricative consonant [s], suppose that there are two constrictions in the airway: a constriction at the glottis (the space between the vocal folds) of cross-sectional area 0.2 cm^2 , and a constriction formed by the tongue blade against the hard palate of area 0.10 cm^2 . The subglottal pressure is $6 \text{ cm H}_2\text{O}$. Note that U is the same at the two constrictions, and the sum of the pressure drops across the two constrictions is $6 \text{ cm H}_2\text{O}$. Note also that $1 \text{ cm H}_2\text{O} = 980 \text{ dynes/cm}^2$.

Note that the approximate relation between pressure drop across the glottis (ΔP), area of glottal opening (A), air density (ρ), and volume velocity of air (U) is

$$\Delta P = \frac{1}{2} \frac{\rho U^2}{A^2} \quad (3)$$

- a. What is the volume velocity U flowing through the two constrictions?
- b. What is the pressure in the volume between the two constrictions?
- c. In order to produce a voiced fricative consonant (the consonant [z]), the cross-sectional area of the glottal constriction is reduced, whereas the constriction formed by the tongue blade remains the same. The vocal folds will vibrate if the pressure drop across the glottis is $3 \text{ cm H}_2\text{O}$ or more. What is the cross-sectional area of the glottis for which vocal-fold vibration will occur?

Problem 3

This is an experiment that you can do in your dorm or at home. The aim is to obtain an estimate of the subglottal pressure that is used during normal phonation and, if possible, to determine the transglottal pressure below which vocal-fold vibration ceases, i.e., the threshold transglottal pressure. You will need an assistant for this problem.

- (1) You will need a tall glass (say 6 inches tall), filled with water, a regular straw used to drink a soda, and a ruler in centimeters. Attach a scale on the side of the glass indicating centimeters down from the water surface. (See Fig. 3.1.)
- (2) Phonate at a comfortable level with the straw in your mouth. Hold your nose so that air does not pass out your nose.
- (3) While you are phonating, place the straw in the water, and gradually lower the end of the straw in the glass. When the end of the straw is near the surface of the water, bubbles will, of course, emerge from the straw as phonation continues. As the straw is lowered, you should try to maintain the same “effort” during phonation. Try not to push harder. As the end of the straw is lowered, a point should be reached where phonation stops, but some bubbles continue to flow. Ask the assistant to note the water depth at this point.

With continued lowering, you will reach a point where there is cessation of the flow of bubbles. Observe the water depth at this point. You may need to practice a bit, to train yourself to keep a constant subglottal pressure P_s and to observe the water depths as accurately as possible. Do the experiment several times.

Estimate the subglottal pressure P_s and the transglottal pressure $P_s - P_m$ at the threshold of phonation. The measures should be in $\text{cm H}_2\text{O}$.

- (4) What are possible sources of error in estimating the threshold of phonation by this method?

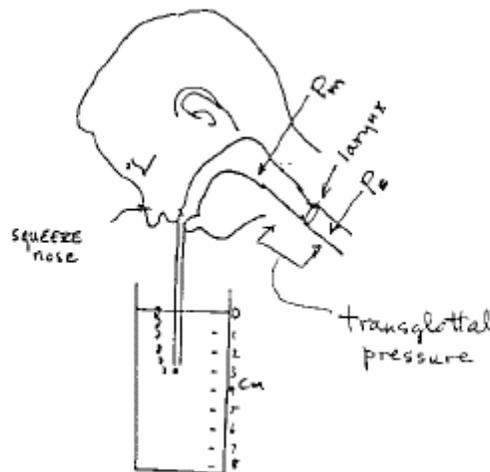


Fig. 3.1

Problem 4

In our discussion of the acoustics of speech, we will be using phonetic symbols to refer to the sounds of speech. It will be useful for you to learn these symbols. They are listed below.

i	<i>beet</i>	p	<i>put</i>	č	<i>chin</i>
ɪ	<i>bit</i>	t	<i>tap</i>	j	<i>judge</i>
ɛ	<i>bet</i>	k	<i>cat</i>	m	<i>map</i>
e or eɪ	<i>bait</i>	b	<i>bit</i>	n	<i>nap</i>
æ	<i>bat</i>	d	<i>dill</i>	ŋ	<i>sing</i>
ɑ	<i>father</i>	g	<i>get</i>	r	<i>ring</i>
ɔ	<i>bought</i>	f	<i>fain</i>	l	<i>lip</i>
ʌ	<i>but</i>	θ	<i>thin</i>	w	<i>will</i>
o or ou	<i>boat</i>	s	<i>sit</i>	j	<i>yell</i>
ʊ	<i>foot</i>	ʃ	<i>shoe</i>	h	<i>head</i>
u	<i>boot</i>	v	<i>veal</i>		
	<i>bird</i>	ð	<i>then</i>		
aɪ	<i>bite</i>	z	<i>zeal</i>		
ɔɪ	<i>boy</i>	ʒ	<i>azure</i>		
aʊ	<i>bout</i>				
ə	<i>about,</i> <i>famous</i> (unstressed)				

(a) Find the errors in the transcription of the following words. In each word there is one error, indicating an impossible pronunciation of that word for a native speaker of English. Circle this error, and write the correct symbol. (The error may be among the consonants, vowels, or the stress marks.) Note the convention of placing a “ˈ” just ahead of the syllable where there is main stress in a word.

- length [ˈleŋθ]
- claim [ˈclem]
- them [ˈθm]
- strives [ˈstraɪvs]
- fishing [ˈfɪʃɪŋ]
- enjoy [ənˈjɔɪ]

7. bellow ['bɛllo]
8. damage ['dæməj]
9. depreciate [də'pre ʃiət]
10. avoid [æ'vɔid]
11. recall [ri'kol]
12. contain [kən'taɪn]
13. pleasure ['plɛzər]
14. exemption [ɛx 'ɛmpʃən]
15. thorough ['θɔ]
16. protrude [pro'trʊd]
17. inhumane [ɪnhu'men]
18. understanding [und 'stændɪŋ]
19. insight ['ɪnsɪt]
20. tiptoe ['tɪptə]
21. doomsday ['domzde]

(b) Stored on the Athena terminal are several utterances which you can listen to. (Instructions on how to access these are attached.)

Transcribe the two sentences in file **rainbow.wav** into phonetic symbols.

(c) Transcribe the following phrase into phonetic symbols:

My name is pronounced “

Hint: Be careful in transcribing the vowels, particularly the reduced vowels, and don't confuse the transcription with the spelling. Thus the word **phonetic** would normally be transcribed as [fə 'nɛ tək], or sometimes [fə 'nɛ tɪk], but **phonetician** would be transcribed as [fə'nɛ tɪʃən]. ** Note the convention that a “'” is placed just ahead of the syllable where there is main stress in a word.