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

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Problem Set 8 *11/30/04*

Problem 1

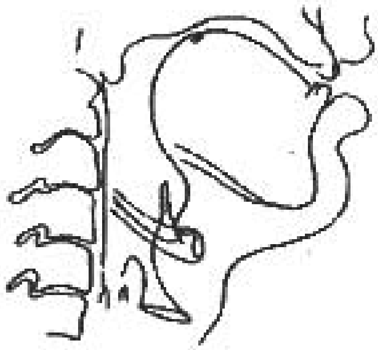


Fig. 1.1

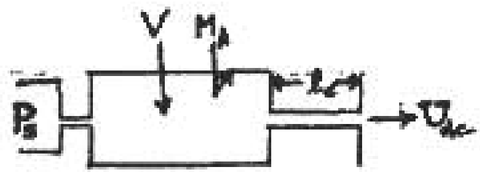


Fig. 1.2

The midsagittal vocal tract shape for the high vowel /i/ is shown in Fig. 1.1. For purposes of estimating the first formant frequency, this shape can be approximated by a Helmholtz resonator like that in Fig. 1.2. The wall surfaces have an effective acoustic mass M_A. Values of the parameters are: Volume $V = 50\ cm^3$; $M_A = 0.01\ gm/cm^4$; $\ell_c = 4$ cm.

(a) The subglottal pressure P_s is 8 cm H_2O during production of the vowel. The peak airflow U_{dc} through the glottis during a glottal cycle is 400 cm^3/s. Assume this same peak airflow occurs at the constriction with area A_c. What is the minimum value of A_c such that the pressure drop across the constriction is no greater than 1 cm H_2O. (Recall the approximate relation between the pressure drop ΔP, the airflow U and the cross-sectional area A_c:

$$\Delta P = \frac{\rho U^2}{2 A_c^2} \quad)$$

(b) Draw an equivalent acoustic circuit for the configuration in Fig. 1.2, including the acoustic mass M_A. Using this equivalent circuit, calculate the frequency F1 corresponding to the value of A_c in (a). (A smaller A_c would lead to increased pressure drop across the constriction, and would compromise the "vowelness" of the configuration.)

Note: A distinction should be made between the airflow behavior in (a), which is essentially a *dc* behavior, and the acoustic behavior in (b). For the acoustic calculations, assume the opening at the glottis (to the left of Fig. 1.2) has infinite acoustic impedance.

Problem 2

Make up three different sentences, each containing 5-7 words. The following criteria apply to each sentence:

(a) Sentence 1: Every vowel should be a front vowel.

(b) Sentence 2: Every vowel should be a back vowel.

(c) Sentence 3: Every vowel should be a lax vowel.

(d) Sentence 4: Every consonant should be a sonorant consonant (i.e., there is no pressure buildup in the mouth).

(Note: The sentences might contain schwa vowels as in words like th**e**, or the first vowel in **a**bout. Don't count these vowels.)

Problem 3

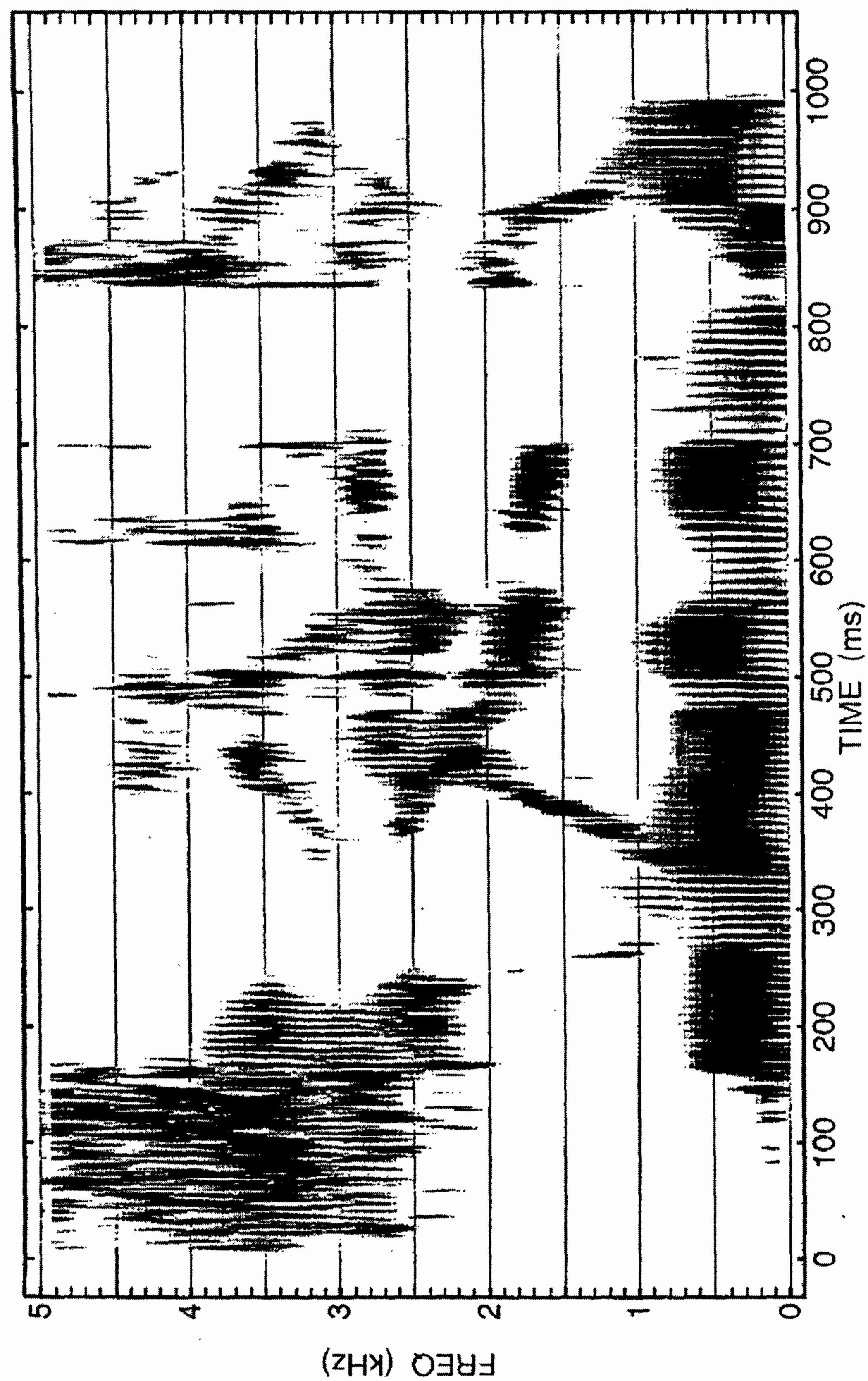
A spectrogram of a sentence is attached. Answer the following questions about events or regions in this sentence. Briefly explain the reasoning that leads to your answer.

1. Identify a region in time where there is evidence for a back vowel.
2. What is the approximate speaking rate for this sentence, in syllables per second?
3. Identify at least two regions where there is complete closure of the lips.
4. Identify at least one region where the velopharyngeal port is open (i.e., there is a lowering of the soft palate).
5. There is a time interval of about 100 milliseconds where the tongue body moves from a backed to a fronted position. Identify this time interval.
6. Identify a region where turbulence noise is generated by blowing air against the lower incisors.
7. Roughly what is the vocal-tract length of the speaker? (Hint: find the average frequency of the third formant.)
8. Identify a region where the principal source of sound is aspiration noise in the vicinity of the glottis.

9. Locate a time when there is evidence for a segment with the following combination of features: [+vowel, +high, -back].

10. What is the fundamental frequency of vocal-fold vibration in the vicinity of 1800 milliseconds?

11. Estimate where in the sentence the tongue body is in a maximally low position.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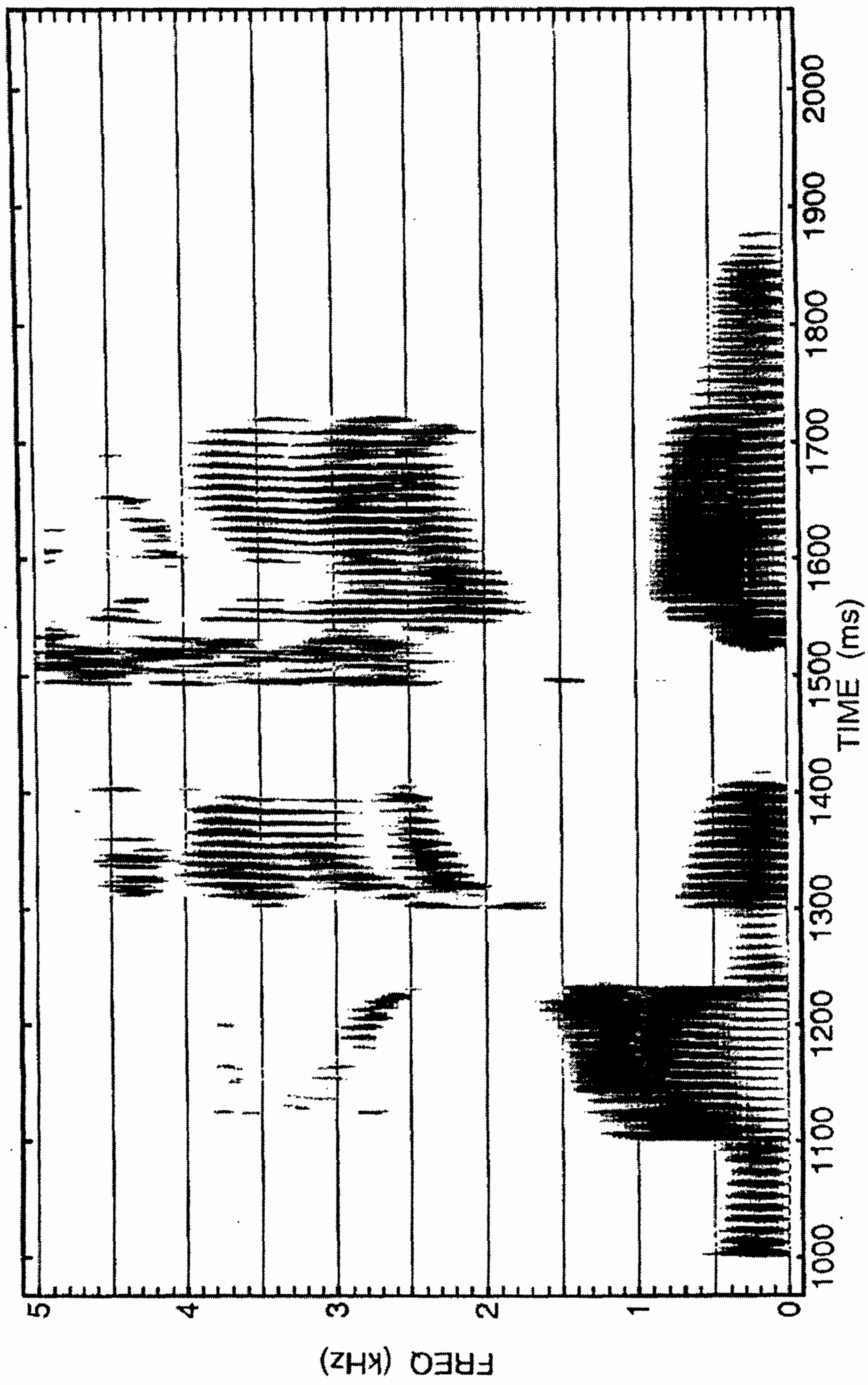
2
3
4
5
0
100
200
300
400
500
600
700
800
900
1000


FREQ (kHz)
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TIME (ms)
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2000