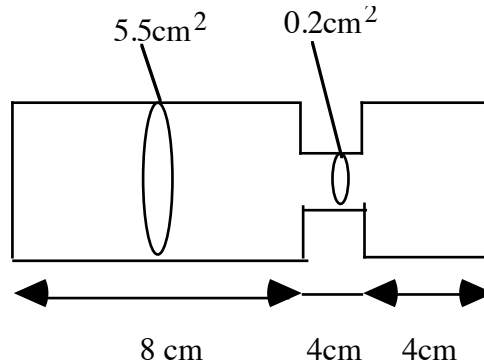


**Acoustics Assignment 4: Due 11/3**

1. The figure below shows a simple tube model for the high front vowel [i]. Ignoring the effects of acoustic coupling, F3 is the first resonance of the front cavity, F2 is the first resonance of the back cavity, and F1 is the helmholtz resonance of the back cavity and constriction.



The dimensions of this vocal tract are appropriate for an adult male. A typical female vocal tract might be about 90% of this size.

- (i) What are the proportional changes in F2 and F3 if the dimensions of this vocal tract shape are shortened by this amount? (You shouldn't need to calculate the actual formant frequencies to work this out).
- (ii) What is the proportional change in F1 if all dimensions are reduced by this amount (including constriction length and tube widths - NB cross-sectional areas will be reduced in two dimensions)

Peterson and Barney (1952) measured average formant frequencies for English vowels spoken by women and men. Average values for [i] are as follows, together with the ratio female/male formant frequency, for each formant:

		F1	F2	F3
[i]	Males	270	2290	3010
	Females	310	2790	3310
	Ratio	1.15	1.22	1.10

- (iii) How do the relative magnitudes of the ratios for each formant compare with the predicted results of shortening the vocal tract, calculated in (ii)? (I.e. don't worry too much about the absolute values of the ratios because we could change our predictions of those by choosing a scaling factor other than 90%. We are more concerned about the predicted relationships between ratios for different formants: How do the observed values of the ratios for each formant compare to each other? How do your calculated values of the ratios for each formant compare to each other? Any difference?)

(iv) Physiological data indicates that the female vocal tract is not uniformly smaller than the male vocal tract. Generally the pharynx is smaller relative to the mouth cavity in females, so the difference in pharynx size between males and females is bigger than the difference in mouth size (Chiba and Kajiyama 1941). Explain how this fact can help explain the discrepancy between observed and predicted female:male ratios for F2 and F3. (The story on F1 is different).

2. For students in 24.963 (optional extra credit question for students in 24.915): Analyze the form of locus equations for F2 in [b]-vowel sequences using simple tube models of the vocal tract. The figure shows the locus equation for bilabial stop [b] from Fowler (1994). Full data are at the end of the handout. Similar patterns have been found across languages.

a.

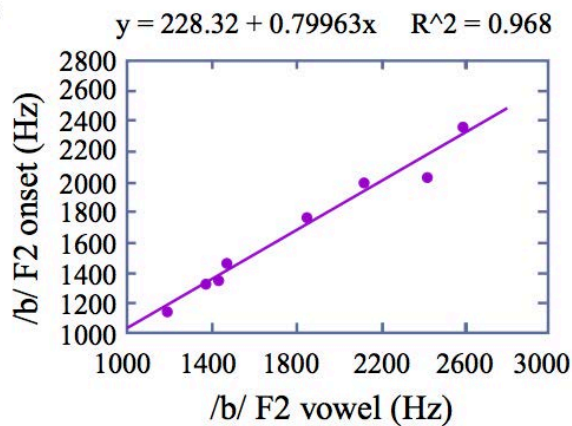


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$$F2_c = 228 + 0.80 F2_v$$

Try to model the behavior of labial stops by assuming that they involve the same vocal tract shape as the following vowel, but with a constriction at the lips. The effect of this constriction can be modeled as equivalent to lengthening the front cavity. How well does this model account for the observed locus equation? Does it predict a precisely linear relationship between F2 onset and vowel F2? Does it account for the observed slope and intercept? Explore explanations for any gaps between predictions and observations.

Image removed due to copyright restrictions. Please refer to Appendix for Values of F2 at Onset and F2 at Midpoint averaged over 10 subjects, found in: Fowler, C. A. (1994). Invariants, specifiers, cues: An investigation of locus equations as information for place of articulation. *Perception & Psychophysics*, 55(6), 597-610.

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