

**Part I: Practice with Measurements**

Be sure to follow the guidelines found on the “Measurements and Uncertainty” handout!

**Problem 1.** Given the following five raw measurements for some unknown length  $\ell$ , calculate the mean of the measurements and the standard error of the mean, and report your answer in standard form  $\bar{\ell} \pm \text{s.e.}(\bar{\ell})$ , with appropriate rounding.

$i$	1	2	3	4	5
$\ell_i$ (cm)	18.5499	18.7832	18.5395	18.8291	18.5552

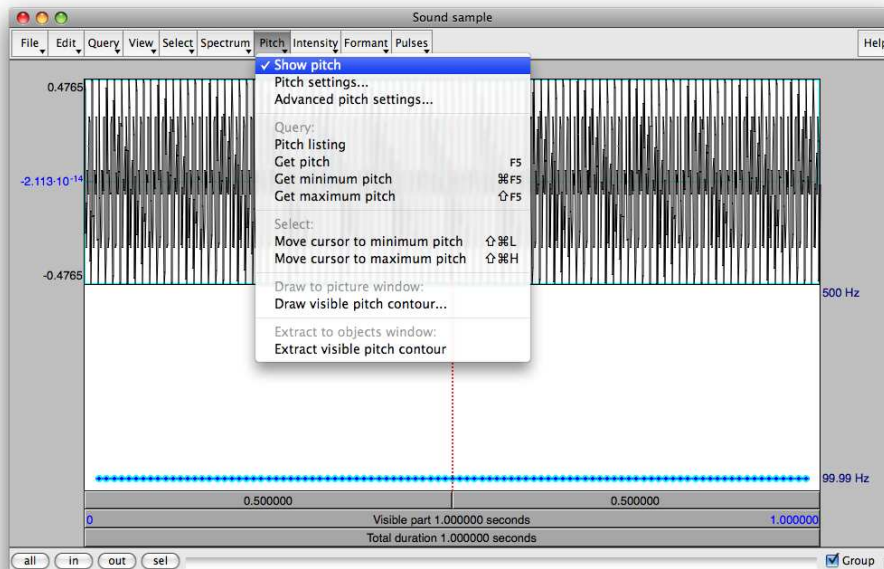
**Problem 2.** Using the formula  $(2n - 1)s/4\ell$ , with  $s = 35,000$  cm/sec, calculate the first three resonance frequencies of a half-open tube with length  $\bar{\ell} \pm \text{s.e.}(\bar{\ell})$  from Problem 1. Be sure to apply the transformations for propagating uncertainty and to report your answers in the correct format.

For Problems 3–5, you need to download the file `lab2.Collection` from the course website. This file contains four WAV files, each with a periodic sound wave (with white noise added).

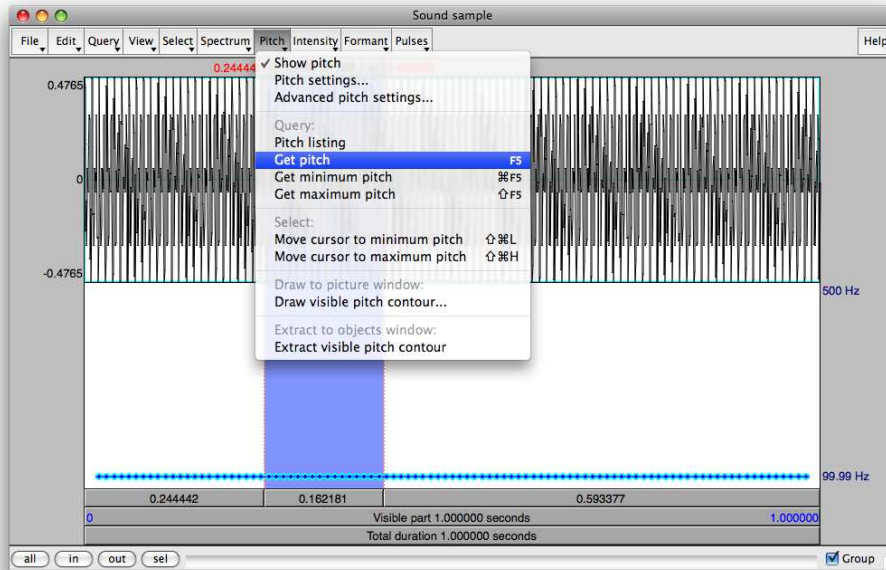
**Problem 3.** For each of the four waves in `lab2.Collection`, make at least 10 measurements of the period, and report your raw measurements, and the mean and standard error of the mean of your measurements (i.e.,  $\bar{T} \pm \text{s.e.}(\bar{T})$ ). The first wave is a simple wave, so finding where the wave repeats should be trivial. The remaining three waves are complex, so finding the repetition of these waves is a bit trickier. In addition, the fourth wave has significant white noise, so your precision is going to be worse!

**Problem 4.** Using the formula  $f = 1/T$ , calculate the frequencies of the four waves using your measured periods from Problem 3. Be sure to apply the transformations for propagating uncertainty and to report your answers in the correct format.

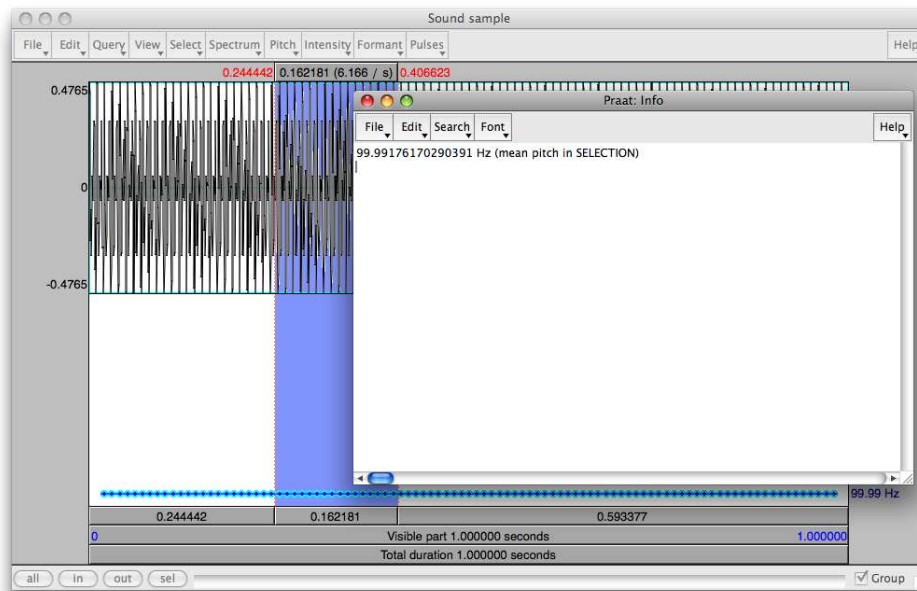
**Problem 5.** For each of the four waves, use Praat to make at least 10 measurements of the fundamental frequency (pitch), and report your raw measurements and the mean and standard error of the mean of your measurements (i.e.,  $\bar{f}_0 \pm \text{s.e.}(\bar{f}_0)$ ). In order to get the pitch in Praat, you need to ensure that `Show pitch` is checked from the `Pitch` menu from the sound's window:



Once Show pitch is checked, the pitch will show up as a blue line with dots in the bottom half of the sound's window, and you can get the pitch at a specific point or averaged over an entire range, by selecting Get pitch from the Pitch menu (keyboard shortcut: F5):



This will open up a new window containing Praat's calculated pitch (99.99176170290391 Hz here):



## Part II: Plotting the Vowels of English

For each member of your group, record them saying five different one-syllable English words containing the vowel phonemes /i u æ α/. Try to pick words that surround the vowels with voiceless sounds, because this will make it easier to see the vowels. For example, you could use the words *seat*, *feast*, *thief*, *seep*, and *quiche* for /i/.

Measure F1 and F2 over a short stretch of time from the center of the vowel in each word, and use all five measurements for each formant to get a mean and standard error of the mean for the formants of each vowel phoneme (see following chart). Using the means of F1 and F2, plot all four vowel phonemes for each speaker on the graph paper provided on the course website or a reasonable approximation (use separate graphs for each speaker).

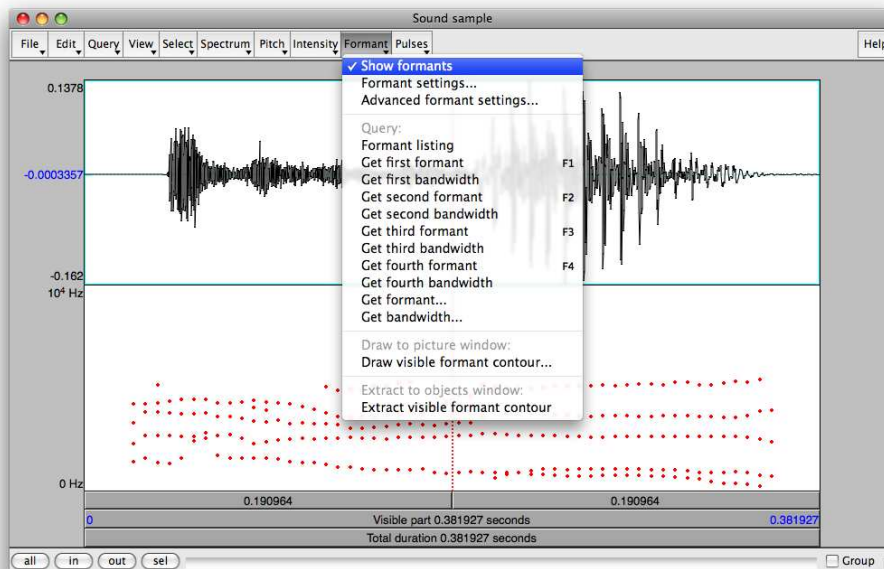
/i/	F1	F2
#1		
#2		
#3		
#4		
#5		
mean		
s.e.		

/u/	F1	F2
#1		
#2		
#3		
#4		
#5		
mean		
s.e.		

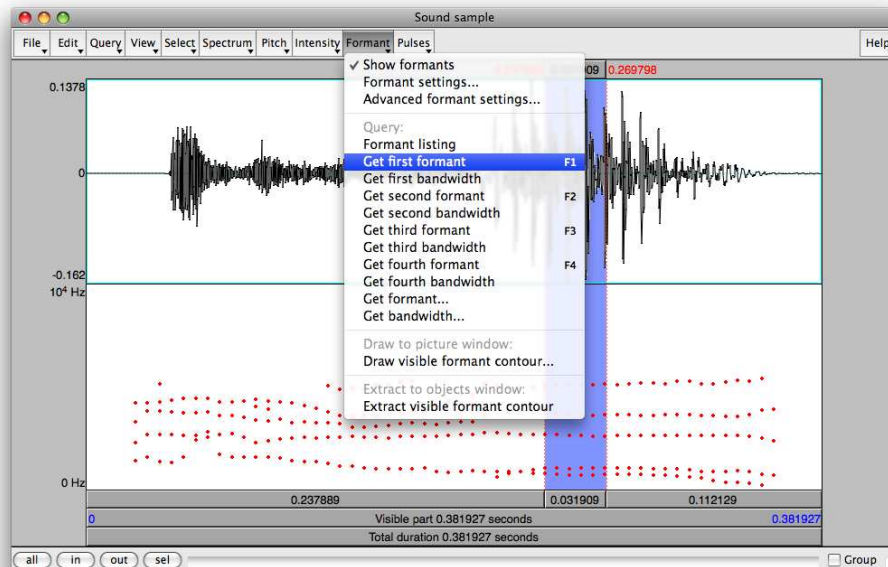
/æ/	F1	F2
#1		
#2		
#3		
#4		
#5		
mean		
s.e.		

/α/	F1	F2
#1		
#2		
#3		
#4		
#5		
mean		
s.e.		

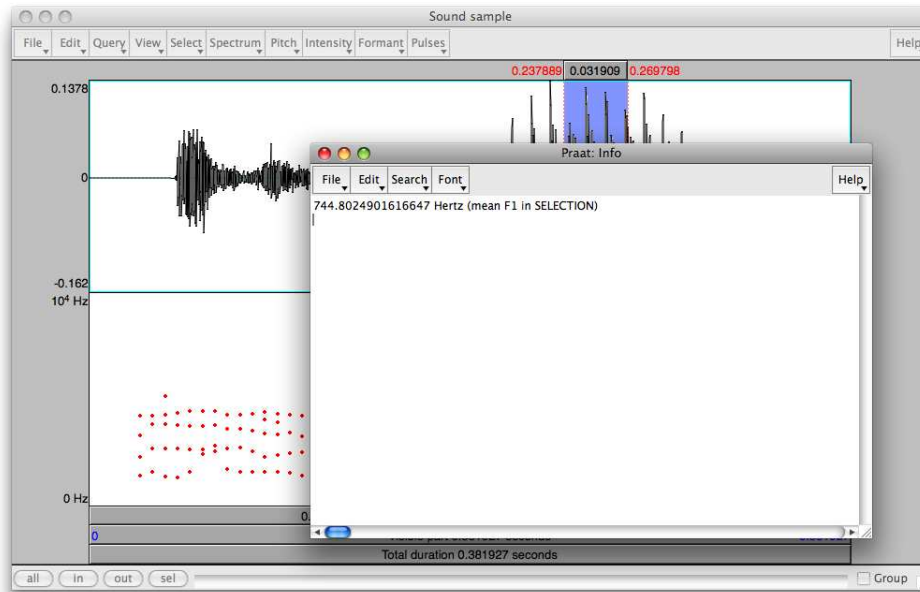
In order to get formants in Praat, you need to ensure that Show formants is checked from the Formant menu from the sound's window:



Once Show formants is checked, the formants will show up as red dots in the bottom half of the sound's window, and you can get the formants at a specific point or averaged over an entire range, by selecting Get first formant (for F1), Get second formant (for F2), etc. from the Formant menu (keyboard shortcuts: F1, F2, F3, and F4):



This will open up a new window containing Praat's calculated formant:



Finally, draw a vowel quadrangle around the four plotted vowels for each speaker so that (i) the lowest and highest recorded F1 values serve as the flat boundaries for vowel height, (ii) the lowest recorded F2 value serves as the flat boundary for vowel backness, and (iii) some diagonal line from around [i] to around [æ] finishes off the quadrangle, keeping all recorded F1 and F2 values inside. Discuss any interesting (or troubling!) aspects of each speaker's plotted vowel system.