

## Resonant Pipes & Harmonic Series:

### INTRODUCTION:

We are going to study different resonant systems, and try to model them as either **open** or **closed** resonant pipes. Of course, real systems are not quite so simple, so we will be studying how closely such a real system matches the theoretical ideal.

### EXPERIMENT:

#### Step 1: Practice:

You will be given a resonant pipe. Spend a few minutes experimenting with it to discover how to efficiently generate as many resonant frequencies as possible. When you have mastered your instrument and are ready for performance, proceed to a tuner and we will measure the frequencies of these resonances.

#### Step 2: Performance:

*(You may find it useful to examine the example table shown below to understand how to fill in the data.)*

Measure the frequencies of as many resonances as possible. Have one person play the instrument and center the tone without looking at the meter, and have a second person take a reading. Fill in the notes in the following table starting from the highest resonance you can play, and working downward.

Most of you will be using musical chromatic tuners to determine your frequency. The tuner will tell you the note (e.g., F#), and the cents above/below this note (e.g., +40).

Record the notes as follows: F<sub>5</sub># +40, would be 40 cents an F<sub>5</sub>-sharp. You must figure out the octave. There will be a piano available to assist you.

#### Step 3: Frequencies:

Once you have determined the note (e.g., F<sub>5</sub># +40), use the table to compute your frequency. 3 digits accuracy should be plenty. Then compute the difference between the two frequencies. *(Note, if you made an error, or are missing a resonance, it will show up here in the difference. If you find an anomaly, go back and cross check for errors.)*

#### Step 4: Fundamental Frequency:

You may or may not have measured the fundamental (lowest) frequency. Assuming you did not, you can estimate what this should be by stepping down in frequency. First, compute the average difference, and then use this to step down to obtain the fundamental frequency.

In the example table, I measured down to the 700Hz resonance. Using the average difference of 200Hz, I was able to determine the fundamental frequency was 100Hz. I indicate that the values below 700Hz are theory not measurement using the last column.

### **Step 5: Harmonic Series:**

Do the resonant notes from your instrument appear to be all multiples of the fundamental frequency (e.g.,  $1f_0$ ,  $2f_0$ ,  $3f_0$ ,  $4f_0$ ,  $5f_0$ , ...) or only the odd multiples (e.g.,  $1f_0$ ,  $3f_0$ ,  $5f_0$ ,...). Does your instrument appear to be harmonic, or odd-harmonic?

### **Step 6: Length of Instrument:**

Measure the length of your instrument in meters. Compute the expected fundamental if this were both an open and closed pipe. How does this compare with what you found in Step 5? *Be sure to use the real value for the speed of sound ( $c=331\pm 0.6/C$ ), not my fake 400m/s.*

### **Repeat:**

Repeat the above steps so that you perform this experiment for a total of 3 resonant systems. I prefer that you try and use at least one closed, and one open system.

### **QUESTIONS:**

How closely did real instruments match ideal theoretical models? What elements would make the real instruments differ from the models?

Other general conclusions and observations?

---

### **EXAMPLE CALCULATION:**

Note:	Frequency	Difference	Measured Y/N
F <sub>6</sub> # +20	1500		Y
E <sub>6</sub> -20	1300	200	Y
C <sub>6</sub> # -10	1100	200	Y
A <sub>5</sub> +40	900	200	Y
F <sub>5</sub> +00	700	200	Y
	500		N
	300		N
	100		N
	-100		N

$$f_{\text{closed}} = \frac{c}{4L} = 100\text{Hz}$$

$$f_{\text{open}} = \frac{c}{2L} = 200\text{Hz}$$

## CALCULATION WORKSHEET:

---

Note:	Frequency	Difference	Measured Y/N

$$f_{\text{closed}} = \frac{c}{4L} =$$

$$f_{\text{open}} = \frac{c}{2L} =$$

---

## CALCULATION WORKSHEET:

Note:	Frequency	Difference	Measured Y/N

$$f_{\text{closed}} = \frac{c}{4L} =$$

$$f_{\text{open}} = \frac{c}{2L} =$$

---

## CALCULATION WORKSHEET:

Note:	Frequency	Difference	Measured Y/N

$$f_{\text{closed}} = \frac{c}{4L} =$$

$$f_{\text{open}} = \frac{c}{2L} =$$

