Science of Music: Problem Set 3

Due Monday Sept 18; Joseph Sepich (jps6444)

Directions: Save this worksheet with the filename SOMProblemSet3-(lastname). Be completely sure that you have used the number 3 in the filename. Enter your answers directly into the document and save, then upload it into Canvas. Clearly show your work. If you are using an equation, write the equation down, then plug in values you are using on the next line. When you are finished with a problem, draw a box around your final result or highlight it. Leave at least a couple of spaces on the paper before starting your next problem. Every answer should include the appropriate units. Remember to submit your homework by 10pm Monday. No homework will be accepted late, so get it done early.

1 Problem 1

It's pretty obvious that if you walked into class and saw a small trumpet and a large tuba sitting next to each other, and the musicians came in to play them, the tuba's various notes (and the fundamental frequency produced by its length) would generally be lower¦octave(s) lower. Why? What is it about the tuba's construction that causes lower notes? Be more specific than because it's longer.

A tuba and a trumpet are both essentially long vibrating pipes that have been wrapped up, so they're not ridiculously long. As we know from the past two lectures the frequency of a pipe depends on the wavelength. In this case both are open-open pipes, whose fundamental frequency follows the equation $f_1 = \frac{V_{air}}{2L}$. You can see from this equation that as the length (L) of the pipe gets larger, the frequency gets lower. Logically this makes sense, because the instrument is creating vibrations, and the bigger instrument will be able to create a wave with a longer wavelength, which correlates to the frequency.

2 Problem 2

An uncoiled French horn would be about 13 feet long. Treated as an open-open pipe, what would its fundamental wavelength (in meters) be? What frequency (in Hertz (Hz)) would that be? And, what frequency would the second harmonic be? And, the third?

$$\lambda = 2 * length = 2 * 13 = 26ft$$

The speed of sound in air V_{air} is approximately 343 m/s and the conversion of **26 feet** to meters is 26 / 3.281 = 7.9248 meters.

$$f_1 = \frac{343}{7.9248} = 43.28Hz$$

The fundamental frequency of a french horn is **43.28 Hz**. This makes the second harmonic 2x greater or **86.56 Hz**. The third harmonic would then be 3x greater than the fundamental or **129.85 Hz**. This seems rather low for the actual range the French Horn likes to play in. I am guessing that this means the fundamental is the bottom of the range of the instrument.

3 Problem 3

By contrast, a piccolo is about 32 cm long. Treated as an open-open pipe, what would its fundamental wavelength (in meters) be? What frequency (in Hertz (Hz)) would that be? And, what frequency would the second haermonic be? And, the third?

The fundamental wavelegth of an open open pipe is about double the length of the instrument, so a piccolo would be $\lambda = 2 * L = 2 * 32 = 64$ cm. In other words the wavelength is **0.64m**. With a sound speed of 343 m/s this makes the fundamental frequency $f_1 = \frac{343}{0.64} = 535.94Hz$. This fundamental frequency of **535.94Hz** is much higher than the French Horn. This fundamental has a second harmonic of **1071.88Hz** and third harmonic of **1607.81Hz**.

4 Problem 4

A bass clarinet (length, approx. 40 inches) behaves acoustically as an open-closed pipe. What is its fundamental wavelength (in meters), and its fundamental frequency?

The fundamental wavelength in an open-close pipe is 4 times thelength of the pipe: $\lambda = 4 * 40 = 160$. The fundamental wavelegnth is 160 inches or **4.064m** (by multiplying by 39.37). Assuming a speed of sound of 343 m/s we can then calculate the fundamental frequency to be $f_1 = \frac{343}{4.064} = 84.40$, **84.40 Hz**.

5 Problem 5

What frequency is an octave above a fundamental frequency of 262 Hz? (Hint: What is the ratio that resuilts in an octave?)

An octave is 2:1 ratio, so an octave about the fundamental of 262 Hz is **524Hz**, which would be the second harmonic of an open-open pipe or string.

6 Problem 6

What frequency is a perfect fifth above 300 Hz?

A fifth is a 3:2 ratio, and would be the third haromic if 300 Hz was the second in an open-open pipe. This makes the perfect fifth from 300Hz, **450Hz**.

7 Problem 7

The speed of sound in Helium at 0 degrees Celsius is 970 m/sec. When played using helium, the fundamental frequency of a clarinet, approx. 150 Hz., would sound much higher since helium's speed of sound is faster than air at that temperature (only 331 m/sec). What would the new fundamental frequency be?

The fundamental frequency in air would follow the formula used for a closed-open pipe of $f_1 = \frac{V_{air}}{4L}$. This means that the frequency is directly correlated to the speed of sound. Since 970/331 = 2.93, we can divide the frequency by 2.93 to get the new fundamental. This value would be 150 / 2.93 = **51.19Hz**.

Figure 1:

8 Problem 8

If you pluck a string and hear an A (110 Hz), what are the frequencies of the first four harmonics (the first three overtones) including the fundamental?

The fundamental frequency is **110Hz** as stated. The second harmonic would be 2 times greater or **220Hz**. The third harmonic would be 3 times greater than the fundamental, which is **330Hz**. The fourth harmonic would be 4 times greater than the first harmonic or **440Hz** (2 octaves).

9 Problem 9

Find videos of two of these instruments: Hurdy-Gurdy, Sackbut, Erhu, and Shawm. Describe their timbre using the musical adjectives sheet found in our Canvas files page.

10 Problem 10

On the musical grand staff below, write the name of each pitch. Then, find and circle the three adjacent notes that best represent an open-open pipe's fundamental first overtone second overtone relationship.