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ENGS 33
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Bridge Project Frequency Calculations

I used the following two formulas to find anticipated estimates for the frequency of the chimes based on their lengths:

Estimate 1:

$$Frequency\ (f) = \frac{22.373\sqrt{EI/_{Ml^4}}}{2\pi}$$

(Source 1)

$$Moment\ of\ Inertia = \frac{\pi}{4}({r_o}^4 - {r_i}^4)$$

($r_o = 0.5$ in | $r_i = 0.475$ in)

Estimate 2:

$$Frequency\ (f) = \frac{v}{2(L + 0.8d)}$$

(v – speed of sound | L – length of chime | d – diameter of tube)

(Source 2)

Since it was easy to apply this same formula to all of the chimes in Excel, I did so and found anticipated estimated frequencies for each chime. See the table and tabulated constants below:

Length (cm)	Length (in)	Frequency (Hz)	Note	Estimate 1 (Hz)	Estimate 2 (Hz)
9.4	3.7007894	1975	B6	640.66	1500.17
18	7.086618	3064	G7	174.72	856.13
25	9.842525	1675	G#6	90.57	634.43
30	11.81103	3030	F#7	62.90	535.40
32.4	12.7559124	2640	E7	53.93	498.08
33.3	13.1102433	2500	D#7	51.05	485.39

Inertia (in^4)
0.009105403

Mass/unit length of chimes (lb/in)
0.0239928

Brass Modulus of Elasticity (psi)
1.60E+07

(Source 3)

Frequencies found using Chromatic Tuner Lite app for Android

It is clear that the frequencies found using the piano tuner app do not exactly correspond with those anticipated by the estimates. There is one likely explanation. Although there is a fundamental frequency that is produced by the chime, as would likely be indicated by the frequencies calculated, there are also some overtones. These overtones have the potential to offset the effect of the fundamental frequency when the tuning app is looking for the frequency. If this is the case, it is possible that the tuning app is picking up one of the overtone frequencies as opposed to the fundamental one. Since the measured values are higher than our estimates, it is likely that the tuning app read a frequency of an overtone with a higher frequency than the fundamental one for that chime.

It is also worth noting that some of the frequencies appear to be off by a few octaves. An octave corresponds to a difference of 440 Hz. For the smallest two chimes, when the difference is taken between the measured and the first estimated frequency, the difference is almost an exact factor of 440 Hz or one octave (1.06 and 5.02 times 440 Hz is the difference for the smallest and second smallest chimes). Aside from noting this observation, we are unsure as to why this peculiarity may occur.

Lastly, we did look at the sound signals in Audacity and noted that there was noise in the data. This may indicate the piano tuning app would have trouble finding the correct signal. Due to this noise (as shown by the multiple peaks in the graph of our sound frequency), it would difficult to find the fundamental frequency by analyzing the sound frequency graph. Even in a quiet room, there was noise and it was difficult to obtain good measurements from the piano tuning app.

Sources:

1. Class Lecture 14.5
2. http://hedges.belmont.edu/~shawley/PHY2010/PastProjects/Brinton,%20Wilkinson,%20Zacharko%20Project%20Web%20Page/PHY2010.02ProjectWebPage.htm
3. http://www.ezlok.com/TechnicalInfo/MPBrass.html

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Bridge Project Final Reflection

Our group was happy with the final musical bridge that we produced. Our initial goal was to create a bridge in which the method for sound production was incorporated seamlessly into the design. For us, this goal meant finding a way to produce sound without requiring an external device or obstructing the design of the bridge. We achieved our initial goal. The bridge we made is modeled after an arched suspension bridge. By the way we tied chimes using knots, the lines used for the suspensions are in tension. Thus, the suspensions help to support the bridge by distributing the load through the arch. In addition, to incorporate a musical instrument, we attached a nut to each of these suspension lines. Finally, we put a chime over each of the suspended metal nuts so that when the chimes move they vibrate against the nuts, creating a musical sound.

The design that we made for the bridge worked well. We made an arch and included trusses underneath to help support the bridge. We used calculations from our individual Phase Two parts of the project to determine the ideal shape for the bridge. These calculations incorporated many of the concepts that we learned in class. For example, we did analysis of the force in the trusses to determine the best size and number of the trusses. We looked at the shear and moment in the arch and walkway to determine their shape and thickness. We considered the tension in the suspensions to determine the necessary strength of the lines. From this information, we were able to make a design that we liked and believed was structurally sound.

We had some difficulty going from our preliminary design to building the bridge. When we went to cut our bridge, we realized that some of the slots we were using to attach the pieces were going to be too small. Although this was not included in our initial calculations, we considered this new challenge and made the appropriate adjustments to accommodate it. The solution involved making some areas slightly wider to adjust for the strength of plywood. With this problem fixed, we continued building our bridge.

Our musical bridge has some clear strengths. The parabolic shape of the arch is able to distribute the load throughout this beam. Although it is not the ideal funicular form (which would be a catenary shape), it is so close that a distributed load across the bridge may be spread almost evenly through the arch. Another strength of our bridge is that the suspensions serve two purposes – carrying the load of the arch and holding the metal nut which the chimes can vibrate against. The trussed side to the bridge also provides additional support and character to the design, while not adding much weight, like having the entire side solid might.

One of the weaknesses of our musical bridge was caused by the difficulty we had tuning the chimes. We knew how to find the fundamental frequencies given the lengths of our chimes, and where to drill the holes and attach the wire to achieve these frequencies. However, when actually attaching the chimes, it became difficult to tie knots in such a way so as to avoid obstructing the frequency. Further, it was very difficult to separate out the fundamental frequency from the overtone frequencies that are also produced by the chimes. Although we did not obtain ideal frequencies, we were satisfied that we were able to play different notes in ascending and descending order using the chimes. This sound pattern made it possible to make music with the bridge.

We would not change much about our design, if we had to design and build the bridge again. The only part that we would slightly modify is the method by which the chimes are attached to the bridge. We would spend more time determining a better way to attach the chimes to the bridge, so that the lines did not obstruct the sound produced by the chimes. By doing this, it might be possible to tune the chimes to more exact frequencies, possibly even to actual notes produced by a piano. However, we were happy that we were able to change the sounds produced by the chimes enough to make different sounds for each and play simple songs. Overall, we think that our final design was successful and that we were organized enough with our time that we were able to test multiple aspects of it before arriving at the final model.