Maths in Music: Workshop 2

What you will do in this workshop

In this workshop you will conduct three different experiments using the container you brought, rubber bands and some pencils. You are going to make a one string 'guitar' and will try to make some music!

1. In the first experiment you will make your own standing waves.
2. In the second experiment you will use the formula shown in the lectures to investigate the relationship between the frequency of a wave, the length of the string and tension of the string.
3. In the third experiment you will start making music notes. Using the ratios you have seen in the lectures, you will find octaves and perfect fifths of notes.

What you will need for this workshop:

- A ruler
- 2 pencils
- Elastic Bands
- A box
- A guitar tuner app: we recommend Pano Tuner (free for Android and iOS) as this app gives the frequency of the note being played.

Experiment Setups

Figure 3: Experiment 1 Setup

Figure 1: Experiment 2 and 3 Setup

Figure 2: Experiment 2 and 3 Setup (for small box)

Experiment 1: Standing Wave

1. Set up the box as show in Figure 1. Pluck the string by pushing down on the middle of the string and letting go. Do you see a standing wave?

Experiment 2: Frequency, Length, Tension, String Thickness

In this experiment, you will be investigating the relationships between the length, tension and thickness of a string, and the frequency of the corresponding sound that is produced. Recall the formula that was shown in the lecture

$$F = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

where f is the frequency of the wave, L is the length of the string, T is the tension, and mu is the density of the string. Set up the box as shown in Figure 2 or 3.

1. Increase the length of the string, while holding the tension constant. What do you notice about the frequency?
2. Decrease the length of the string, while holding the tension constant. What do you notice about the frequency?
3. Increase the tension of the string, while holding the length constant. What do you notice about the frequency?
4. Measure the frequency of the wave at a particular length. Half this length and then measure the frequency again. What do you notice about the frequency?

Experiment 3: Notes, Octaves and Perfect Fifths

In this experiment, you will be making some music notes using your new guitar!

Step 1: Octaves

1. Place the pencils at the very edge of the box, making the string as long as it can be. Pluck the string and measure the frequency of the note. Write down this value. Go to Table 1 in the accompanying document. Find which octave this frequency lies in. This is the octave you will work in.
2. Pick a note in this octave that you want to tune on your guitar string. We will call this the base note. We recommend A, but it is up to you what you would like! How about you and your neighbour pick different notes?
3. Tune your string to this base note using the tuner. Measure the length of the string.
4. Recall from the lecture that the frequency of a note in a higher octave is twice that in the octave below, e.g. A5 = 880 Hz = 2(440 Hz) = 2(A4). Also recall that you can double the frequency of the wave by halving the length of the string. Change the length of the string to be half its length.
5. Measure the frequency at this length. It should be close to the frequency for the base note in the octave above, but may not be exactly correct due to experimental error (more on that later).
6. Now calculate the ratio of the base note to the measured note in the higher octave, in the form of 1:n. Remember, theory says this should be 1:2. Your answer should be close to this.
7. Calculate how far your answer was from the theory using the formula: Error = 2-n.

Step 2: Perfect Fifths

1. Go back to your original base note from the beginning.
2. Look at table 2 which gives a list of a base note and its corresponding perfect fifth. Identify which perfect fifth goes with the base note you've chosen. For example, if you have chosen an A, your perfect fifth will be an E.
3. Recall from the lecture that in a perfect fifth, the ratio between the two notes is 2:3, e.g. A:E = 2:3. Using this ratio, and the relationship between frequency and length, find the length that the perfect fifth should occur at.
4. Change the string to this length, and measure the frequency of the corresponding note.
5. Now calculate the ratio of the base note to the measured perfect fifth note. Try get it in the form 2:m. Remember, theory says this should be 2:3, so your m should be close to 3.
6. Calculate how far your answer was from the theory using the formula: Error = 3-m.

Discussion Question: Why do you think your measurements differ from the theory?