Created by Jason van Tol

The Physics of Music – Lesson 4

Materials:

- Calculator	- Laptop with speakers & power cord
- Slinky	- Review Sheets
- Whiteboard + Markers (x3)	- Kalimba
- Guitar + TUNER	- Clarinet
- Piano (keyboard)	- Didgeridoo

Introduction / Review of Lesson 1

If new st., get others to explain core ideas from last lesson. If not, get them to explain to the group what they recall: What are: Frequency, Amplitude, Notes? What musical characteristic do they determine? How are they measured?
(5 min)

Overview of Topic

In the first half of this lesson we're going to again build on the ideas we learned in the last lesson. Based on your questions from last week we're going to look at musical temperament, and consider two particular temperaments that are important in Western music. This will involve some math so bring a calculator! We'll start the second half of the lesson with your presentations about your sound / music topic you chose last week. After each presentation your mates will have time to ask questions about your topic. To end off, I'll give out a summary sheet of the concepts, principles, and vocabulary we learned to quiz each other informally to see what we have retained. Finally, we can have a little jam and I'd like to spend a few minutes getting feedback from all of you about this unit. See you Thursday!

Notes on Notes:

All class activity Some instruments are tuned to completely different frequencies, and pitches, than those of western musical instruments. **DEMO KALIMBA WITH TUNER.**
Question: How could we tune the kalimba to align its notes with those in Western music? Why would this adjustment work
(5 min)

Intervals

The difference between two notes is called an interval. Musical instruments are designed to play specific notes with specific intervals. That is, to sound notes that are a particular 'distance' apart. More specifically, in Western music, the smallest interval – that is, the frequency ratio between any two successive notes, is given by $\sqrt[12]{2} \approx 1.059$ ... and is called a semitone. However, the most important interval is called the octave, which is a doubling of the frequency of a note. In fact, octaves are so important, that the notes they generate have the same name. (i.e. one octave above middle C is still a C!).

ActivityIn pairs/alone:

- See if you can come up with the frequency of the notes one, two, and three octaves above middle C. Middle A.

- See if you can come up with the frequency of the notes one, two, and three octaves ***below*** middle C. Middle A.
- See if you can come up with the frequency of the notes one semitone above middle C. One semitone below middle C. One semitone above and below middle A. (You might need a calculator for this).

<u>Any questions about this topic??</u>
(10 min)

<u>Musical Temperament / Pythagoras:</u>
Pythagoras was the first to realise that consonance was produced by strings whose lengths were in low, whole number ratios. We already talked about the **Octave** which is considered the most consonant interval. Its ratio is 2:1 – for every one cycle of the lower note, there are exactly two cycles of the higher note. Another such ratio is 3:2 and is called a **Perfect Fifth**; that is, for every 2 cycles of the lower note, there are exactly 3 cycles of the higher note. Pythagorean temperament, or tuning, is based on stacks of perfect fifths to generate all the notes in a scale. It is customary to multiply or divide the resultant frequency by a power of 2 to bring it within the same octave. Refer to table below:
Pair / Share Activity: Given a few of the entries below, see if you can fill in the rest.

Note	Formula	Frequency Ratio	Decimal (to 3 places)
Ab	$\left(\frac{2}{3}\right)^6 \times 2^4$	$\frac{1024}{729}$	1.404
Eb	$\left(\frac{2}{3}\right)^5 \times 2^3$	$\frac{256}{243}$	1.053
Bb	$\left(\frac{2}{3}\right)^4 \times 2^3$	$\frac{128}{81}$	1.580
F	$\left(\frac{2}{3}\right)^3 \times 2^2$	$\frac{32}{27}$	1.185
C	$\left(\frac{2}{3}\right)^2 \times 2^2$	$\frac{16}{9}$	1.778
G	$\frac{2}{3} \times 2$	$\frac{4}{3}$	1.333
D	1	1	1
A	$\frac{3}{2}$	$\frac{3}{2}$	1.5
E	$\left(\frac{3}{2}\right)^2 \times \frac{1}{2}$	$\frac{9}{8}$	1.125
B	$\left(\frac{3}{2}\right)^3 \times \frac{1}{2}$	$\frac{27}{16}$	1.688
F#	$\left(\frac{3}{2}\right)^4 \times \left(\frac{1}{2}\right)^2$	$\frac{81}{64}$	1.266
C#	$\left(\frac{3}{2}\right)^5 \times \left(\frac{1}{2}\right)^2$	$\frac{243}{128}$	1.898
G#	$\left(\frac{3}{2}\right)^6 \times \left(\frac{1}{2}\right)^3$	$\frac{729}{512}$	1.424

Pair / Share Activity:

- Now put the above notes in order of increasing decimal places. What do you find?
- By looking at the frequency ratios which notes would be the most consonant? Dissonant?
- CHALLENGE QUESTION: How many perfect fifths would we need to reach the octave (i.e. decimal place of 2)? Try solving $\left(\frac{3}{2}\right)^m = 2^n$ where *m* & *n* are whole numbers representing the number of keys, or intervals, in the octave.
- MORAL OF THE STORY: The above cannot be done. In the table above Ab and G# are held to be the same note but clearly have different frequency ratios; including this interval in a composition would lead to those notes sounding badly out of tune: called the **Pythagorean Comma**, or a **Wolf Interval**.

(20 min)

Modern 12 TET:

Modern 12 tone equal temperament gets around the Pythagorean Comma by treating all successive intervals, called semitones, as the same: $\sqrt[12]{2} \approx 1.059$ ....

Pair / Share Activity:

- Why do you think this number was chosen?
- How does this improve upon the Pythagorean Temperament / Comma?
- **Compare this smallest interval to that in the table above: What do you notice?**
- What do you think are the drawbacks of this modern 12TET are? Tell about professional Sitar player. Bach's Well-Tempered Clavier.

(10 min)

Challenge Problem:

Given that middle A is 440Hz, choose a random note on the keyboard and see if you can determine its frequency using the fact that $\sqrt[12]{2} \approx 1.059$ ...

Can you see how middle C is ~262Hz?

(10 min)

BREAK TIME:

(5 min)

Research Presentations:

All Class Activity: Allow question time at the end of each one.

(20 min)

Review Sheet:

Pairs or all Group Use the review sheet to check all the vocabulary and concepts that we covered. Make up some questions and quiz one another.

(15 min)

Jam Time:

Pairs or all Group Pick up an instrument and let's have a jam!

(10 min) (110 min to here)

Evelyn Glenni:

Although you can use your ears to hear the sounds of the clarinet, piano, guitar and everything else, Evelyn Glenni is deaf. Watch the video of her performing.
Question: How do you think she's able to play along with the rest of the orchestra? Hint: She always performs barefoot.
(5 min)

Summary + Feedback:
What did you like / dislike about this unit? Suggestions for how to improve it? **ANY QUESTIONS** about anything we did that you're still not sure about?
(5 min)

mou NI-HYAKU Do-ru ka na?

Other ideas:
Daniel Kish