Lab Name : Sinusoidal waves

Subject Area: Mathematics

Grade: 11

Course: Pre-Calculus

Topic: Trigonometry

Experiment Title:Analyzing Sinusoidal waves through music.

Hardware: PC

Software: GNU radio companion

Number of Sessions to teach the topics: 1 - 3 sessions at 55 minute classes

Educational standards to be addressed:

Cosmos concepts to be used for the lab:

K12 Educational Goals (How the educational goals are achieved through teaching using the experiment, how the topic is connected to the COSMOS concepts used)

Short Description and Walk-through of the experiment

Testbed mapping of the experiment

Day 1: [Worksheet #1 for students](https://drive.google.com/open?id=1oxmpv7THax6Gc7-5tOWkou3AO6JupTV4nVOL2J0Ynb4)

Lesson thoughts: Discussion for Part 1 and Part 2. No technology needed for these parts.

Part 1:

# ***So if Beethoven was completely deaf, how did he compose?***

# **Discuss with your table:**

1. Where do we observe waves in the real world?

2. What is sound?

3. If you were to smile, what music describes you.

3. So...if a tree falls in the forest, and no one is around to hear it....does it still make a sound?

Part 2:

**Introduction; Vocabulary**



## **Looking at the picture above:**

1. The sine wave with the highest frequency is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ , and the sine wave with the lowest frequency is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ .

2. The sine wave with the longest period is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ , and the sine wave with the shortest period is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ .

3. The sine wave with the shortest wavelength is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ , and the sine wave with the longest wavelength is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ .

4. What relationship exists between frequency and wavelength?

Technology is needed which includes computer and/or cell phone.

Part 3:

***Elements of a sinusoidal wave.***

Students will discover all the elements of a sinusoidal wave through discovery using a program (CAN THE PROGRAM BE USED ON THE IPHONE OR FROM A WEBSITE). The program will allow students to alter the frequency, change volume, change balance, play/stop the sounds see the graph of time versus frequency.

1. The students can fine tune different hertz with a slider.
2. A visual graph will accompany the different frequency.
3. Words students will define: Frequency, **Period**, Amplitude, Midline and phase shift.

[See the bottom of the web page](https://www.mathsisfun.com/algebra/amplitude-period-frequency-phase-shift.html)

1. Raise/lower the amplitude?
2. After students will start a DESMOS.com activity lesson. [Transformation of Sinusoidal waves introduction](https://teacher.desmos.com/activitybuilder/custom/56b3e682b884dbd81be6ed09)

**Class will come together to discuss their findings.**

Part 4:

***The Chromatic Scale — A Geometric Series***

Musical pitches (notes) are determined by their frequency, which is measured in vibrations per second, or Hertz (Hz). The notes on a piano keyboard form a *chromatic scale*.

A chromatic scale divides the octave into its semitones. There are twelve semitones, or half steps, to an octave in the chromatic scale.

The white keys on a keyboard are A, B, C, D, E, F, and G. The black keys are named relative to their adjacent white keys. For example, the black key between the C and D keys is known as either *C sharp* (C#) or *D flat* (Db).

* The A note below middle C on a keyboard has a frequency of 220 Hz. Using this value, calculate the frequencies of the terms that generate a two-octave chromatic scale. Calculate each value using the original value of *a* = 220 and the formula $ar^{n}$, where *r* =$2^{\frac{1}{12}}$ . Round each frequency to the nearest whole number.

|  |  |  |  |
| --- | --- | --- | --- |
| Lower Octave | Frequency (Hz) | Higher Octave | Frequency (Hz) |
| A | 220 Hz | A |  |
| A# |  | A# |  |
| B |  | B |  |
| C (middle c-key) |  | C |  |
| C# |  | C# |  |
| D |  | D |  |
| D# |  | D# |  |
| E |  | E |  |
| F |  | F |  |
| F# |  | F# |  |
| G |  | G |  |
| G# |  | G# |  |

* In the table above, compare the frequencies of notes that are one octave apart. For instance, compare A in the lower octave (left column) with A in the higher octave (right column), compare A# in the lower octave with A# in the higher octave, and so forth. How do frequencies an octave apart appear to be related?

The sine wave related to a musical pitch has the following form, where *A* is the *amplitude* of the sound (or the volume, measured in decibels) and *B* is the frequency of the note (measured in Hz):

$f(x)=Asin(Bx)$

* Based on the frequencies in the above table, write the sine functions to represent both the low and high octaves for the C notes. (The value of *A* represents the volume of the note, so any value can be used. For the remainder of this activity sheet, let *A* = 2.)
* Then, graph the sine function for each note on *Desmos.com*. You will have to modify the viewing window by changing the *x* & *y* minimum and maximum values to see the curve. Graph the sine waves for notes in both octaves in the same viewing window. Write a statement about what you have observed.
* Draw each graph, and record the viewing window, frequency and period.

$xmin=$ $xmax=$ $$$ymin=$ $ymax=$ $Period=$ $Frequency=$



$xmin=$ $xmax=$ $$$ymin=$ $ymax=$ $Period=$ $Frequency=$



* Based on your observations above, describe where the graphs meet. With the use of DESMOS describe in your own words how the notes compare.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Let’s try to add on an additional note from the C-major scale to observe simultaneously.

|  |  |  |  |
| --- | --- | --- | --- |
| Note: | Frequency | Sine Function | Period of Sine Wave |
| 1st middle C-note | 262 |  |  |
| 3rd note after middle C | 327.5 |  |  |
| 5th note after middle C | 393 |  |  |

Based on the C major scale identified above, identify the notes of the C major chord, the frequencies of those notes, the associated sine function with *A* = 2, and the period of the sine wave.

* When all three of the above sine waves are graphed, they intersect at the point (0, 0).
* What are the coordinates of the second point where all three sine waves intersect? ( \_\_\_\_\_\_ , \_\_\_\_\_\_ )
* From the origin to the next point of intersection, record the number of cycles for each of the sine waves.

|  |  |
| --- | --- |
| Note of the Chord | Number of Cycles |
| 1st note of the scale |  |
| 3rd note of the scale |  |
| 5th note of the scale |  |

Part 5

***Can you match the musical note with your voice?***

Students will use the microphone to match the frequency with their voice.

Students will take notes on their observations. What is the lowest and highest frequencies that you can match? What is the domain of frequencies that most people can cover? Is this different for a male to a female?

Part 6

***Song Analysis - Students will analyze a song***

1. Each group will get a different time frame of a specific song.
2. Student will freeze the song and take a screenshot.
3. Students will apply elements associated with sinusoidal waves to find an equation to match.
4. Using Desmos, students will overlay the equation with the screen shot.
5. What type of song was played? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. Sketch a diagram of the wave produced by the song over the full twenty seconds.



1. Label the highest frequency, the lowest frequency, the largest amplitude, and the smallest amplitude.
2. What affected the frequency throughout the recording? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. What affected the amplitude? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Part 7

***Create your own wave from music***

Students will record a 20 second sound clip. Make your own music that is associated with a sinusoidal wave and their functions.

1. What did you record for your sound? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Sketch a diagram of the wave produced by your sound over the full twenty seconds.
3. Label the highest frequency, the lowest frequency, the largest amplitude, and the smallest amplitude.
4. What affected the frequency throughout your recording? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. What affected the amplitude? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Part 8

Quiz on topics learned through this project. Or having the students do the following options.

Option A - Cymatic - Making visual sound waves with change in frequency.

THOUGHT: Can we adjust the frequency and make the spectrum into an art piece? Cymatics: Turning Sound into Art

Example: Using a violin bow to rub against a plate with sand producing a frequency wave that makes an art piece. A flat plate. Instead of sand you can use foam pieces.

Example: What does your voice look like? Having a saying and transforming it to a wavelength.

Example: Tone generator with sand or salt. Building it <https://www.instructables.com/id/Easy-Chladni-Plate/>

You could keep the picture it makes by pressing a sticky sheet of paper over the image and pressing in. The salt/sand should stick to the sticky adhesive.

Option B - Visual picture associated with a student voice. Students will connect a picture with there sound.