Introduction:

The objective of this lab was to utilize Audacity to explore constructive and destructive sound waves, and the graphs of combined waves.

Theory/Pre-lab:

a) $P_1(t) = A\cos(2\pi f_1 t)$

$P_2(t) = A\cos(2\pi f_2 t)$

$\Delta P_T = P_1(t) + P_2(t)$

$= A\cos(2\pi f_1 t) + A\cos(2\pi f_2 t)$

$= A[\cos(2\pi f_1 t) + \cos(2\pi f_2 t)]$

$= A[2\cos(\frac{a-b}{2})\cos(\frac{a+b}{2})]$

$= A[2\cos(\frac{2\pi f_1 t - 2\pi f_2 t}{2})\cos(\frac{2\pi f_1 t + 2\pi f_2 t}{2})]$

$= A[2\cos(\frac{2\pi t(f_1 - f_2)}{2})\cos(\frac{2\pi t(f_1 + f_2)}{2})]$

$= A[2\cos(\pi t(f_1 - f_2))\cos(\pi t(f_1 + f_2))]$

b) $\Delta P_1(t) = A\cos(2\pi f_1 t)$

$\frac{P_1(t)}{A} = \cos(2\pi f_1 t)$

$\cos^{-1}\left(\frac{P_1(t)}{A}\right) = 2\pi f_1 t$

$f_1 = \frac{\cos^{-1}\left(\frac{P_1(t)}{A}\right)}{2\pi t}$

$f_{fast} = \frac{\cos^{-1}\left(\frac{\Delta P_1(t)}{A}\right)}{2\pi t}$

$\Delta P_2(t) = A\cos(2\pi f_2 t)$

$\frac{P_2(t)}{A} = \cos(2\pi f_2 t)$

$\cos^{-1}\left(\frac{P_2(t)}{A}\right) = 2\pi f_2 t$

$f_2 = \frac{\cos^{-1}\left(\frac{P_2(t)}{A}\right)}{2\pi t}$

$f_{slow} = \frac{\cos^{-1}\left(\frac{\Delta P_2(t)}{A}\right)}{2\pi t}$

c) $f_1 = 19\text{ Hz}$ $f_2 = 21\text{ Hz}$

$f_{slow} = 0$?

$\Delta P_2(t) = A\cos(2\pi f_2 t)$

$\frac{0}{A} = \frac{A\cos(2\pi(21)t)}{A}$

$0 = \cos(42\pi t)$

$\cos^{-1}(0) = 42\pi t$

$t = \frac{\cos^{-1}(0)}{42\pi}$

$= \frac{\frac{\pi}{2}}{42\pi}$

$= \frac{\pi}{2 \cdot 42\pi}$

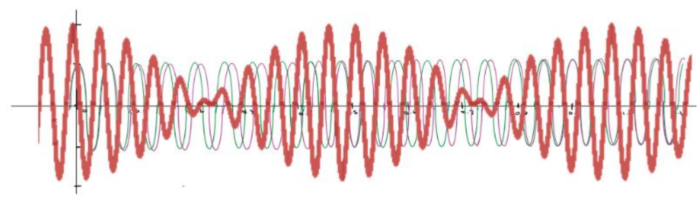
$t = \frac{1}{84}(2n+1)$ ← for cos graph, odd x value = 0.

$n=0$ $\quad t = \frac{1}{84}$

$n=1$ $\quad \frac{1}{84}(2+1)$ $\quad t = \frac{3}{84}$

Sound intensity is min at $t = \frac{1}{84}, \frac{3}{84}, \ldots$

d)



$A = \frac{\text{Max} - \text{min}}{2}$

$= \frac{0.2332 - (-0.2326)}{2}$

$A = 0.2329$

$T = \frac{t \text{ taken}}{\# \text{ oscillations}}$

$= \frac{0.007863 - 0.00092}{5}$

$= \frac{0.00693}{5}$

$T = 0.0013886 \text{ s}$

$f_2 = \frac{1}{T}$

$= 720.14971$

$f_2 = 720 \text{ Hz}$

According to the calculations above, the resultant wave is a function of the two waves, which means that if (f1-f2) can be found, the two frequencies that create the resultant can be calculated as well. (f1-f2) can be calculated by multiplying the average wave by 2, since the formula of the average is (f1-f2)/2.

Procedure:

For all parts of the lab, Audacity was used to manipulate and create audio files.

Part 1:

1. Obtain an audio recording of a resonating wine glass via the internet or by recording a tone
2. Open the file using Audacity, and export the data into a plain text file
3. Imported into a spreadsheet program to plot the data.

Part 2:

1. Generate a tone between 220 and 600 hz, with an amplitude value less than 0.5.
2. Generate a new tone 10-50 hz higher than the previous tone, and an amplitude value equal to the previous tone.
3. Next, combine the tones to generate a combination of the previous tones by recording an audio file of both tones playing at once, or by using the mix function under the tracks tab.
4. Once the tracks are combined into one, export the combination audio into a simple text file. Ensure the sample rate is appropriate, the measurement scale is linear, to exclude headers, choose L-R on same line as the channel layout.
5. Import the data into a spreadsheet, and generate a graph based on the data.

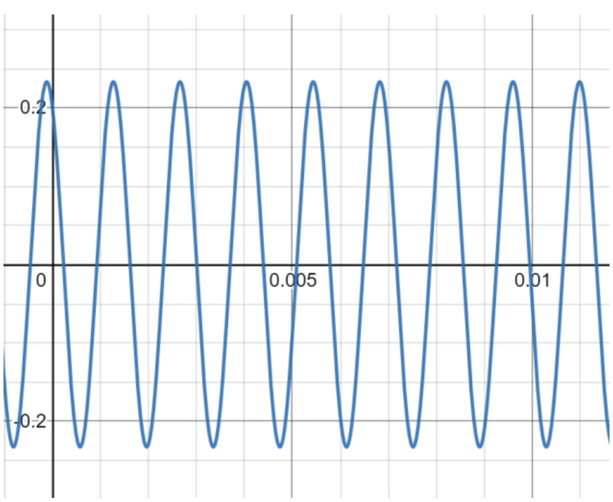
Part 3:

1. Obtain a csv audio file from the directory provided from the d2l shell
2. Select a file, and use spreadsheet programs to interpret the data into a wave graph
3. Calculate the frequency of the two tones

Results and Calculations:

Part 1:

Analysis 1:



Calculated values:

$$A = \frac{Max - min}{2}$$

$$= \frac{0.2332 - (-0.2326)}{2}$$

$$A = 0.2329$$

$$T = \frac{t \text{ taken}}{\# \text{ oscillations}}$$

$$= \frac{0.007863 - 0.00092}{5}$$

$$= \frac{0.006943}{5}$$

$$T = 0.0013886 \text{ s}$$

$$f_z = \frac{1}{T}$$

$$= 720.14979$$

$$f_z = 720 \text{ Hz}$$

Values from the graph:

$$y_1 \sim A \cos\left(Bx_1 + C\right) + D$$

STATISTICS

$R^2 = 0.9984$

RESIDUALS

e_1 plot

PARAMETERS

$A = 0.232909$

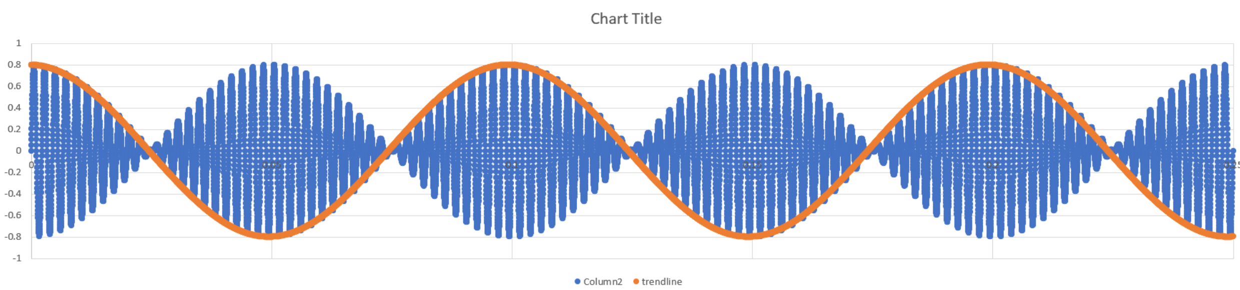
$B = 4524.64$

$C = 0.548549$

$D = 0.000264053$

Part 2:

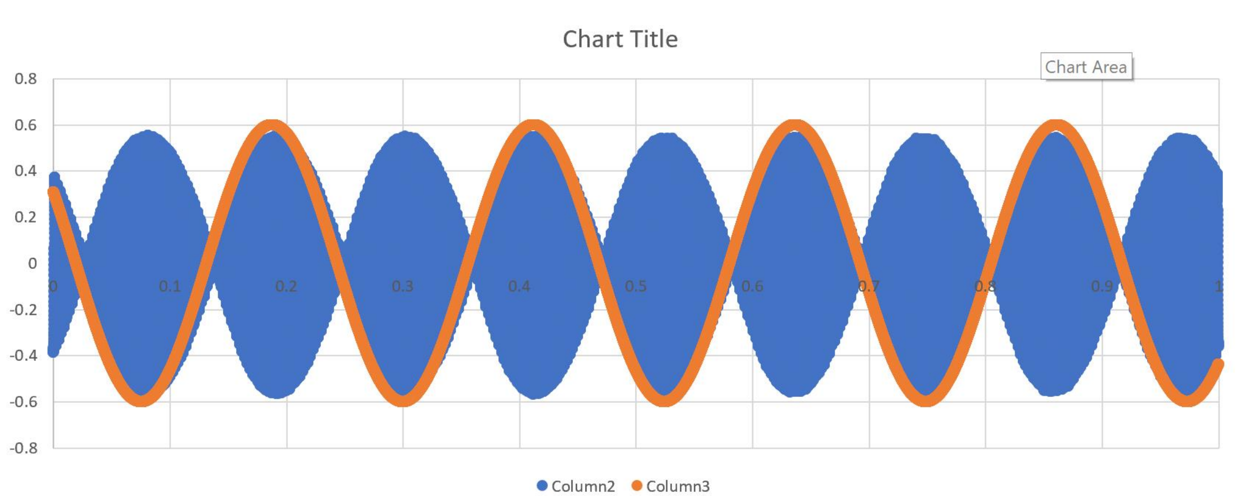
The first tone generated had a frequency of 440 hz, and an amplitude value of 0.4. The second tone generated had a frequency of 460 hz, and an amplitude value of 0.4 as well. These beats had a difference of 20 hz.



A	B	C	D
0.8	63	0	1.6

The beat frequency calculated from the tones is 20 hz. The B value is 63, with a calculated frequency of 10.02 hz.

Part 3:



A	B	C	D
0.6	28	0.3	2.3

Using the formula for the combined wave obtained from the prelab, the frequencies were calculated by calculating the value of f1 – f2, then substituting a point from the data sheet into the equation to solve for (f1+f2), and therefore f1 and f2. The frequencies are: 13.4 hz and 3.5 hz. The calculations are as followed:

3.

$w = 28 = 2\pi f$ $\qquad f_1 - f_2 = 8.91267$

$\qquad\qquad\qquad f_1 = 8.91267 + f_2$

$f = 4.4563$ hz

Avg $fz = 4.456$ hz

$\frac{f_1 - f_2}{2} = 4.456$ $\qquad\qquad$ Point = (0.031, 0.02)

$f_1 - f_2 = 8.91267$

$$S(t) = A\left[2\cos(\pi t(f_1 - f_2)\cos(\pi t(f_1 + f_2))\right]$$

$$0.02 = 0.55\left[2\cos(\pi t(f_1 - f_2))\cos(\pi t(f_1 + f_2))\right]$$

$$\frac{0.02}{0.55} = 2\cos(\pi t(4.456))\cos(\pi t(f_1 + f_2))$$

$$\frac{0.02}{2 \cdot 0.55} = \cos\left[\pi(0.031)(8.192767)\right] \cdot \cos\left[\pi(0.031)(f_1 + f_2)\right]$$

$$\frac{0.01}{0.55} = 0.698219\cos\left[0.031\pi(f_1 + f_2)\right]$$

$$\frac{0.01}{0.384} = \cos\left[0.031\pi(f_1 + f_2)\right]$$

$$\cos^{-1}\left(\frac{0.01}{0.384}\right) = 0.031\pi(f_1 + f_2)$$

$$\frac{\cos^{-1}\left(\frac{0.01}{0.384}\right)}{0.031\pi} = f_1 + f_2$$

$$= 8.91267 + 2f_2$$

$$\frac{\cos^{-1}\left(\frac{0.01}{0.384}\right)}{0.031\pi} - 8.91267 = 2f_2$$

$$= 2f_2$$

$f_2 = 3.47447$

$= 3.47$ hz

$f_2 = 3.5$ hz

$f_1 = 8.91267 + 3.47447$

$= 12.3857$

$f_1 = 12.39$ hz

$f_2 = 12.4$ hz

Discussion and Conclusion:

Part 1:

It appears that there was no difference between calculating by hand or calculator, as the value of the amplitude is the same between human and graphical calculations, however there is a difference of ~0.3 between the frequency values, likely due to rounding differences.

Part 2:

Upon further examination, the beat frequency is approximately twice the value of the envelope frequency. This is further confirmed by the graph, where there appears to be two envelope waves inside one beat frequency wave.

Part 3:

In conclusion, the frequencies were able to be calculated from the combined graph.

References:

ryersonphysicsvids, 2020. Wine Glass Resonance - Sound Waves!. [video] Available at: <https://youtu.be/oSlmYtuYKzU> [Accessed 1 March 2022].

Pxy