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PH 142

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Lab 12: Waves, Sound, and Hearing

Introduction

Waves and oscillations are fundamental phenomena that play a central role in physics, from the smallest atomic vibrations to the vast expanses of the universe. In physics, oscillation refers to the fluctuation of a quantity around equilibrium point. Waves, on the other hand, refer to the disturbances that transfer energy from place to place. Waves are the transport of matter and can be characterized by physical properties such as wavelength, frequency, amplitude, and speed. These two concepts provide deep insight into the behavior of various physical systems such as harmonic motion and sound. The aim of this lab is to explore these concepts and gain deeper understanding of their mechanisms.

Problem 1

In this problem we looked at the fundamental frequency of a string stretched by a mass. We increased the frequency of the oscillation of the string with a signal generator attached to an oscillator.

Data and Calculations

The harmonics count the number of nodes (excluding the start and end of the string) plus one for simplicity. We estimated the linear density of the string to be around 0.055 kg/m and used this to make further calculations. Similarly, we measured the length of the string and the hanging mass. The white columns are measured, gray calculated, and dark gray used for comparisons. For each of the calculated columns, these equations were used (n is the harmonic):

$$T = \frac{1}{f} \qquad \lambda = \frac{2L}{n}$$

$$v = \lambda f \qquad f_{pred} = \frac{n}{2L}\sqrt{\frac{m}{\mu}}$$

Harmonic	Freq. (Hz)	Mass (kg)	Lin. Density (kg/m)	Length (m)	Period (s)	Wavelength (m)	Velocity (m/s)	Pred. Freq. (Hz)	Diff. Freq (Hz)
1	7.2	0.1511	0.055	0.1185	0.138888888888889	0.237	1.7064	6.993628217437	0.206371782563001
2	14.1	0.1511	0.055	0.1185	0.0709219858156028	0.1185	1.67085	13.987256434874	0.112743565126001
3	21.5	0.1511	0.055	0.1185	0.0465116279069768	0.079	1.6985	20.980884652311	0.519115347689002
4	27.8	0.1511	0.055	0.1185	0.0359712230215827	0.05925	1.64715	27.974512869748	0.174512869747996

5	34.6	0.1511	0.055	0.1185	0.0289017341040462	0.0474	1.64004	34.968141087185	0.368141087184995
6	41.26	0.1511	0.055	0.1185	0.0242365487154629	0.0395	1.62977	41.961769304622	0.701769304621998
7	47.5	0.1511	0.055	0.1185	0.0210526315789474	0.0338571428571429	1.60821428571429	48.955397522059	1.45539752205899

Analysis

At different harmonics, the values we found for the frequencies match closely with the predicted frequency, with the maximum discrepancy of around 1.4 Hz. Even if the linear density was miss measured (it was an educated guess), it can be thought of as a *parameter* for the equation of best fit. In that case, it is used to match the actual and predicted frequency very closely.

The steps in actual frequency are all around 6-7 Hz, which makes sense, since:

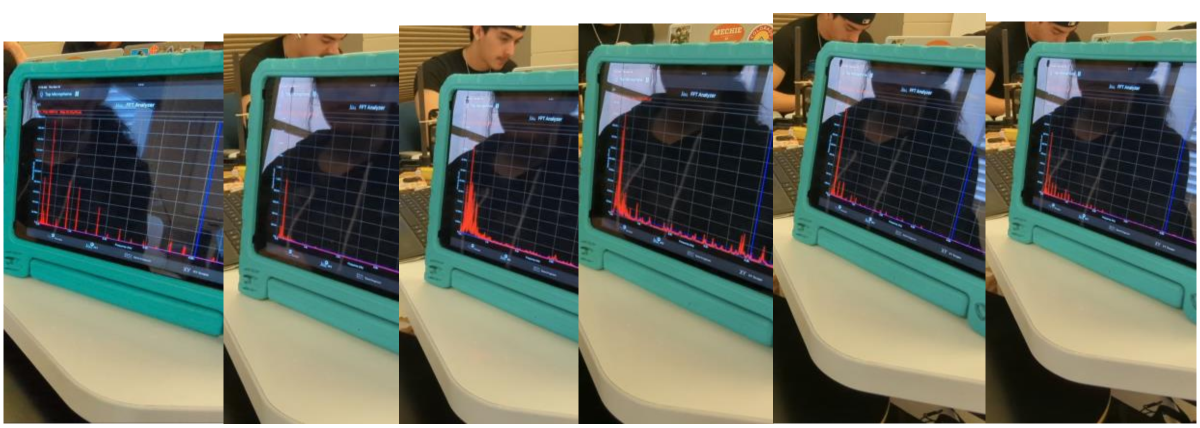
$$f = \frac{n}{2L}\sqrt{\frac{m}{\mu}} \qquad f \propto n$$

Equal steps in harmonic number correspond to equal steps in frequency. The “value” of this step is determined by all the constant terms in the equation, which reduce to one constant multiplier (a linear relationship).

Problem 2

This experiment tasked us with interpreting a wave modelling a sound and determining the impact on the model when using different strings on a guitar. To create these models, we relied on the SignalScopeBasic2020 app and played a single note into the microphone a few times. Unfortunately, due to a mix of factors, the data we gathered on the oscilloscope setting ended up being essentially unusable for analysis for the first half of this experiment.

Data



Analysis

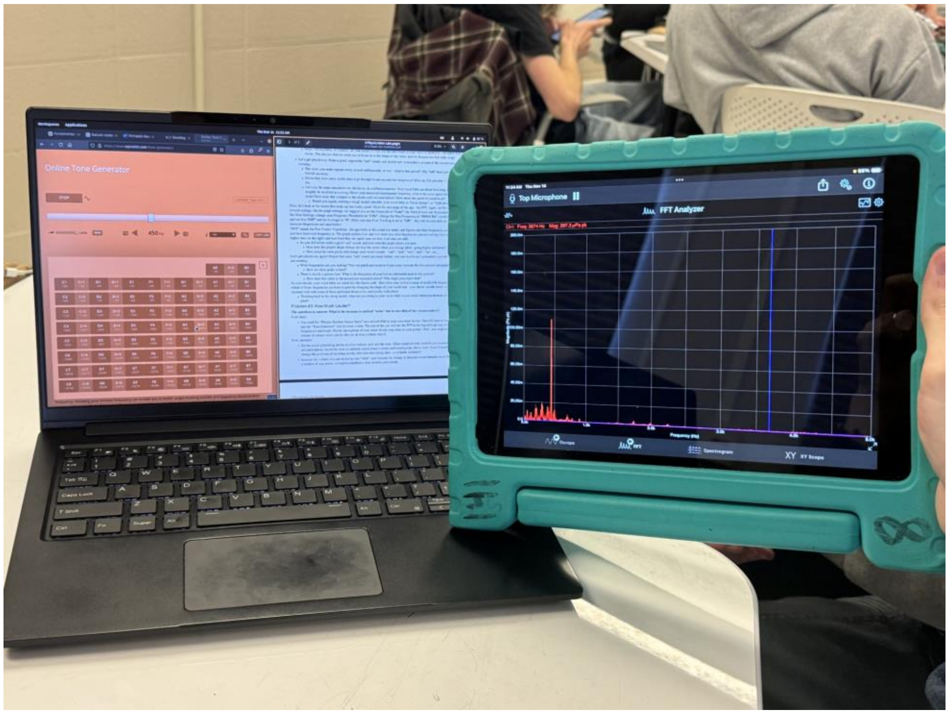
We measured frequencies that decreased with pitch and by observing the photos of the graphs we can get a rough estimate of the emitted frequencies as well as a feel for the trends. While many frequencies are created when plucking a string on the guitar, the leading frequency always remains below 500Hz, and while their amplitude seems to decrease exponentially as the frequency increases, the sub-frequencies seem to be approximately evenly spaced. Given that each string emitted a different set of frequencies either the tension or material properties of the strings must differ, likely both. A guitarist can increase the tension applied to the string to increase the frequency and consequentially the pitch of the instrument.

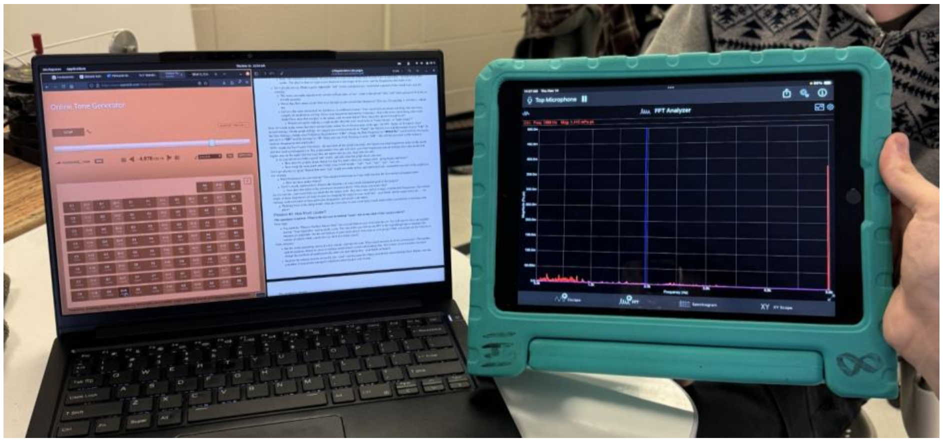
Problem 3

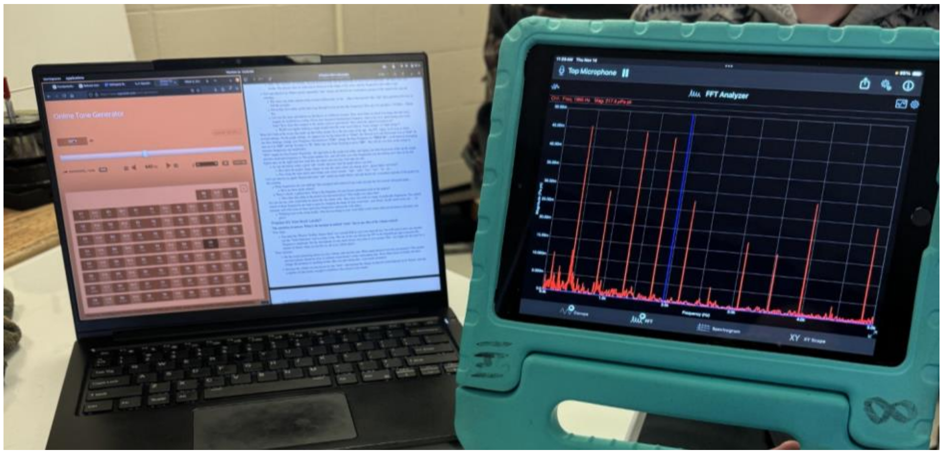
Using the SignalScope app on the iPads, we measured three different sound frequencies and their amplitude using an online tone generator. We ensured to put the iPad microphone close to the tone generator and took a picture of its intensity. We chose 3 frequencies to look at: 450 Hz, -4,978 Hz, and 440 Hz. The amplitude of the sound wavelengths was measured in Pa and the following equation was studied:

$y(t)=A\sin(2\pi ft+\phi)$

Data







Analysis

To produce a tone, a computer typically uses mathematical functions to model a sound wave. The unit for amplitude is meters and our data displays the relationship between sound and frequency: the higher the pitch, the higher the frequency and the lower the pitch, the lower the frequency. We expected there to be a slight change in frequency between 450 Hz and 440 Hz, but our data for the 440 Hz tone may have been skewed due to other voices and sounds in the room (hence the multitude of peaks).

Conclusion

This lab has provided a deeper understanding of the wave mechanics governing string vibrations, the role of tension and material properties in determining frequency, and the harmonic structure of vibrating strings. We got an intuition for the vibration of light strings, where steps of 6-7 Hz generate new harmonics. It also demonstrated the practical application of wave theory in analyzing real-world systems like musical instruments and tones, highlighting the connection between physics and the acoustics of sound production. We especially saw how different frequencies (e.g. 440 Hz), when produced by the laptop, have different amplitudes. These concepts are so important and can be applied to other outside world things like radios and seismology/earthquake detection.