Lab-02:
29-Jan-24

Objective:

Clarify the objective:

Think: The sound created by the tension of the string changes depending on how tight the string is. A higher tension results in a higher note while a lower tension results in a lower tension. Tension is how much force is being acted upon the wire in both directions uniformly.

Pair: A higher note means a higher tension which in other words means a higher frequency.

Share: Force in the string. Force is acting on both ends and it is exactly the same at any point along the wire.

Edit1: We will use the PhyPhox app to measure the frequency of the string

Explore Tools:

Tool	Physical Parameter	Resolution	Range	Usage
Ruler	Length	1mm	1m	Used to measure the length of the string to figure out wavelength
Caliper	Length	0.05mm	155mm	Diameter of wire to figure out cross sectional area
PhyPhox App	Frequency	~~0.01hz~~ 24hz (2048 samples on Fourier transform)	20hz-20,000hz	Measures the frequency of the string

Data:

Fundamental Frequency in Hz	Length of String	Diameter of String
164Hz $\pm$ 12hz (half of resolution)	~~100cm ± 0.5cm~~ $1.00m \pm 0.005m$	~~0.50mm ± 0.05mm~~ $5 \cdot 10^{-4}m \pm 5 \cdot 10^{-5}m$

<u>TPS 2.1: Why are there many peaks in the spectrum of the string:</u>
Think: Since this is an oscillating string I think the peaks are sound waves with smaller and smaller amplitudes.

Pair: Called it damped harmonic motion

Share: $\lambda = 2L/n$ relationship for standing waves on a clamped vibrating string

<u>Related Quantities:</u>

Think: To determine the wave velocity in a string, we employ the formula $\lambda = 2L/n$, where L is the string's length, measured with a ruler. Given that velocity v equals frequency f times wavelength λ, we can find the wave velocity ($v = f\lambda$). The wavelength is derived from our initial formula, while the frequency is ascertainable through the Audio Spectrum feature in the PhyPhox app. It's important to note that this wave velocity in the string is distinct from sound speed in air, as wave velocity depends on the medium's properties. In this case, the medium is the steel string, not air. The velocity in a string is influenced by factors intrinsic to the material, such as tension and mass per unit length, rather than by frequency or wavelength. Altering frequency or wavelength leads to a compensatory change in the other, maintaining constant velocity. This principle is illustrated in the equation $v = \sqrt{\frac{T}{\mu}}$, where T is tension and μ is mass per unit length. To calculate the mass per unit length μ, we first determine the string's mass by utilizing its volume and density. The density of our steel string is given as 7920 kg/m³. The mass, obtained by multiplying the string's volume by its density, is then divided by its length to find μ ($\mu = \frac{AL\rho}{L} = A\rho$). With the values of velocity v and mass per unit length μ computed, we can deduce the string's tension using the formula $T = v^2\mu$.

Pair: Also need equation of area of circle $A = \pi r^2$ and radius = $\frac{diameter}{2}$

Share: Were given methods and formulas to figure out linear mass density. Can be calculated without cutting string, therefore must use density and volume calculations to figure out. We are given the density of steel is 7920 $\frac{kg}{m^3}$

Approach to measure data:

Think: I think we will use the frequency and peaks we find from the PhyPhox app and correspond that with the harmonics. Then we can plot these points in matlab and it will give us a line of best fit as well as the uncertainty.

Pair: Me and my partner had very similar ideas for this aspect of the lab

Share: We can create a fitting equation that results in a equation that takes the general shape $y = mx + b$ so in our case $Fn = n(v/2L)$ $where\ the\ slope\ acts\ as\ v/2L$

Method 2: The other way to calculate this is to estimate the fundamental frequency using just the PhyPhox app

Calculations:

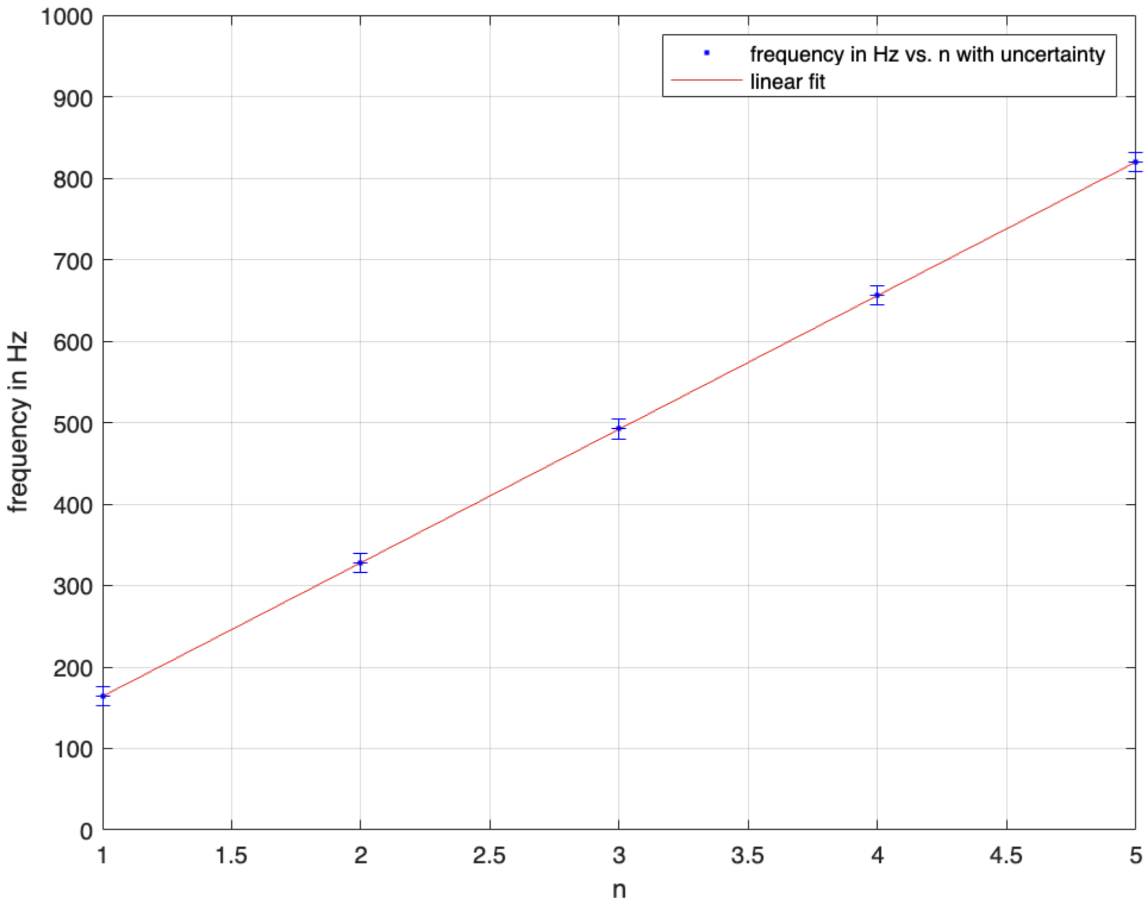
slope is

```
m=result(1,2)
```

```
m = 164.0000
```

with uncertainity

```
del_m=abs(m-ci(2,2))/gof.rmse
```



Fundamental Frequency in Hz	Length of String	Diameter of String
164Hz $\pm$ 12hz (half of resolution)	~~100cm ± 0.5cm~~ $1.00m \pm\ 0.005m$	~~0.50mm ± 0.05mm~~ $5 \cdot 10^{-4}m \pm 5 \cdot 10^{-5}m$

Now that we have slope we can begin calculations.

$\frac{V}{2L} = 164$

$V = 328m/s$

Which is the speed of the wave

$A\rho = \mu$

$\pi(\frac{5 \cdot 10^{-4}}{2})^2(7920) = \mu$

$\mu = 1.55 \cdot 10^{-3}\frac{kg}{m}$

$T = v^2\mu$

$T = 166.7552$

Therefore final tension is 167 N

<u>Propagation of Uncertainty:</u>

$\delta V = V\sqrt{(\frac{\delta r}{r})^2 + (\frac{\delta h}{h})^2}$ $\delta T = T\sqrt{(\frac{\delta \mu}{\mu})^2 + (\frac{\delta v}{v})^2}$ $\delta\mu = \sqrt{C1(\delta\rho)^2 + C2(\delta d)^2}$ $\delta\mu = \sqrt{C2(\delta d)^2}$ $\delta m = \rho\delta V$ $V = \pi r^2 h$

When determining the uncertainty in the mass per unit length, it is observed that the coefficient C1 is extremely small, being 0.000…1, whereas C2 is significantly larger. As a result, the contribution of the C1 term becomes negligible and can be effectively considered as zero. This simplifies the calculation to primarily focus on the uncertainty associated with the diameter, which directly corresponds to the uncertainty in the mass per unit length.

- Volume: 0.020 cubic centimeters
- Mass: 0.156 grams
- Mass per unit length: 1.56 x 10^-4 kilograms per meter

Using MATLAB, the uncertainty in frequency was determined to be 15.437. Consequently, the overall speed (v) is calculated as the square root of twice the frequency uncertainty, equating to approximately 21.8 meters per second.

Finally, the uncertainty can be computed as follows:
- Tension (Force): 27.8 Newtons

This approach simplifies the initial complex calculations by focusing on the more significant terms, leading to an efficient determination of the mass per unit length's uncertainty.

Reflection

Due to time constraints we were unable to carry out methodology 2. From comparing to groups around us we found that we had similar uncertainties and our overall final answer for tension was correct.

Procedure:

1. Employ a pair of calipers to determine the diameter of the string. Note this value in meters, and then calculate the radius by halving the diameter.
2. Utilize a ruler to ascertain the string's length. Document this measurement in meters.
3. Install the PhyPhox application on your smartphone and navigate to the 'Audio Spectrum' feature.
4. Initiate the recording by tapping the play icon in the upper right corner. Immediately after, pluck the string. Once the sound diminishes significantly, halt the recording by pressing the play button again.
5. Examine the spectrum results in the app to identify the frequency. Record the frequency corresponding to the most prominent peak, which represents the fundamental frequency.
6. Prepare a spreadsheet in Excel, organizing it into columns for harmonics (n), frequencies (f), and frequency uncertainty (del_f). Calculate the uncertainty by dividing the PhyPhox app's resolution by two.
7. Populate the harmonics column with sequential integers, enter the frequencies as per the app's data, and include the predetermined constant uncertainty.
8. Import these values into a Matlab script as column vectors. Analyze these vectors to derive the slope and its uncertainty, representing the fundamental frequency and its error margin.
9. Apply Equation 1 to compute the wavelength, using the total length of the string.
10. Combine the frequency data (slope) from Matlab with the calculated wavelength in Equation 2 to determine the wave's velocity.
11. Calculate the cross-sectional area of the string using its radius.
12. Insert the values of the string's area, its length, and its density into Equation 3 to ascertain the mass per unit length.
13. Calculate Final tension