LAKE FOREST COLLEGE
Department of Physics

Physics 114 Experiment 13: Standing Waves on a String-v2 Fall 2024

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Date:
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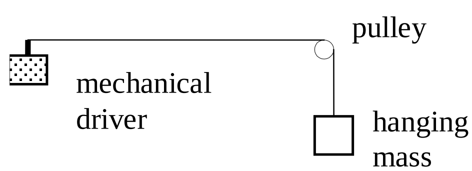
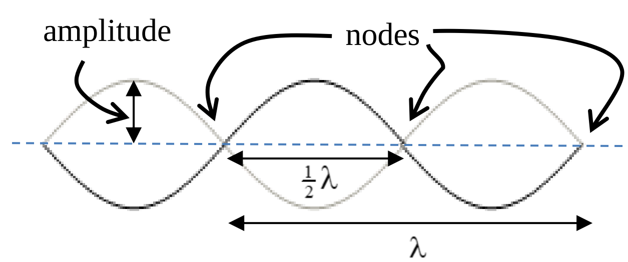
Preliminary Instructions
Create a folder for you and your lab partner. Save a copy of these instructions for each student to that folder. Include your name in the filename. Save one copy of the Excel template with both your and your partner's name included in the filename.

Experimental purpose of today's experiment
Measure the speed of transverse traveling waves on a string.

Pedagogical purpose of today's experiment
Study stationary wave patterns.

Background





Note the essential concepts of *traveling and standing waves*, *wavelength*, *nodes*, *wave velocity* (*speed*), and *amplitude*. The following relationships for the velocity (v) of the wave pattern are needed:

$v = \lambda f$ (1) wave speed v is related to the wavelength λ and frequency f

$v = \sqrt{\frac{F}{\mu}}$ (2) wave speed v on a string is also related to the tension F and the linear mass density μ, where

$\mu = \frac{m}{l}$ (3) The linear mass density is in units of kg/m and depends on the <u>total</u> mass of a sample of string, m, and its <u>total</u> length, l.

Procedure

1. Determine μ by measuring the mass and total length of the string at your station. The instructor will then help you attach the string to the connector of the mechanical oscillator, and make a loop for the hanging weight.

2. Since the acceleration of the hanging mass is negligible, the tension in the string will be equal to the hanging mass multiplied by *g*. Weigh a nominally 50 g mass for the hanging weight and use equation (2) to calculate the predicted wave speed on the string. Assume the absolute uncertainty to be 0.3 m/s.

3. Hang the mass from the string. Adjust the frequency of the shaker to find the lowest frequency (f_1) resonant standing wave pattern. As you get close to the resonant wave frequency, lower the amplitude (to about 0.3—0.4 Volt) in order to make the best possible measurement of this frequency. You should be able to find the resonant frequency to a precision of about 0.1 Hz. Record the frequency from the meter on the function generator. Measure the distance between the nodes in the standing wave pattern and calculate the wavelength. Note that there is a node at the top of the pulley and near the mechanical driver.

4. **Paste a picture of the setup here. Label the important pieces.**

Figure 1. Standing Wave Apparatus. The Pasco functional generator provides the frequency and the voltage to the pasco mechanical vibrator. One end of the string is attached to the mechanical vibrator and the other hangs off the pulley with an added weight, either 50g or 100g. The yard sticks are used to measure the distance between nodes.

5. Repeat step 3 for the next two smallest frequency (f_2 and f_3) standing wave patterns. Use the posts to locate nodes along the string. Measure the distance between adjacent nodes. Use the distance between nodes to calculate the wavelength.

6. For each trial, use equation (1) to calculate the wave speed. Calculate the average and standard deviation for the three speeds. Since all three harmonics are using the same string under the same tension, in principle the three measured speeds should be the same. Use the standard deviation for the absolute uncertainty in the speed.

7. Sketch the string patterns for the three resonant patterns found. **Paste a picture of your sketches here.**

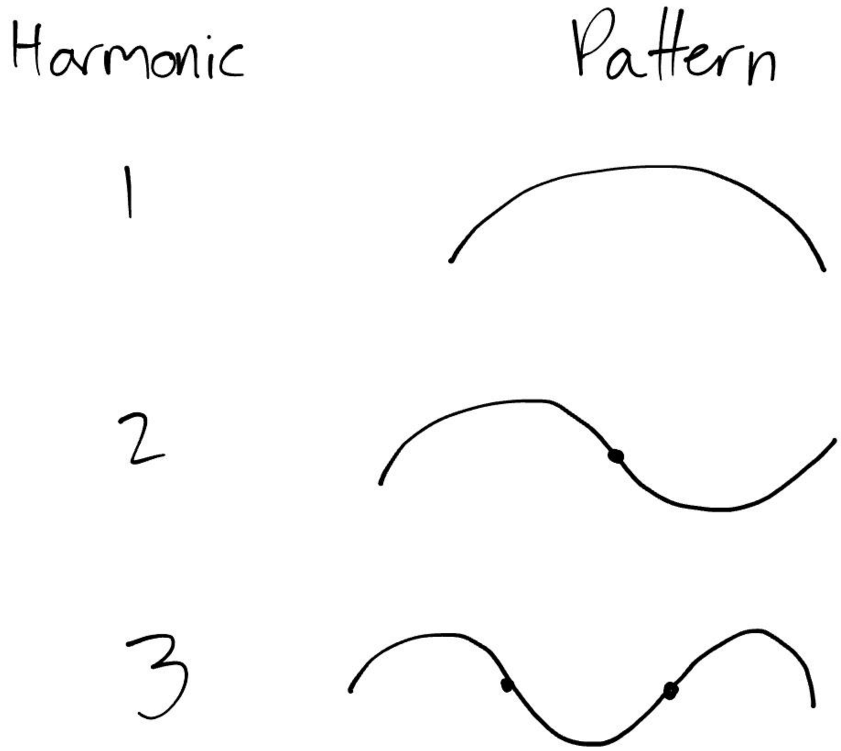


Figure 2. Wave patterns. The first harmonic has nodes at the ends of the string. The second harmonic has a node in the middle of the string. The third harmonic has two node, diving the string into thirds.

8. Compare the predicted and measured wave speeds using the ratio test.

9. Ask the instructor for help using the strobe light to observe the motion of the string for one of the standing-wave patterns. Record the observations in your report.

10. **Paste your spreadsheet here table here. Paste a picture of the equations used.**

String mass (g)	String mass (kg)	String length (m)	Linear mass density, µ (kg/m)
0.56	0.00056	1.689	0.000331557

g (m/s^2)	Hanging mass (g)	Hanging mass (kg)	String tension (N)	Predicted wave speed (m/s)	Abs. unc. in predicted wave speed (m/s)
9.803	49.98	0.04998	0.48995394	38.44133296	0.3

Harmonic	Frequency (Hz)	Distance between adjacent nodes (m)	wavelength (m)	wave speed (m/s)
1	18.269	1.072	2.144	39.168736
2	36.709	0.532	1.064	39.058376
3	56.093	0.351	0.702	39.377286
			average	39.201466
			st. dev.	0.161954737

Ratio test comparing predicted and measured wave speeds
1.645470821

Table 1. 50g Standing Wave Excel Spread Sheet. The frequencies and wave length were calculated using the apparatus above. A 50g weigh provided tension on the string. The predicted wave speed and the calculated average wave speed agree according to the ratio test.

$v = \lambda f$ $\quad$ v = speed/velocity

$v = \sqrt{\frac{F}{\mu}}$ $\quad$ λ = wavelength

$\mu = \frac{m}{\ell}$ $\quad$ f = frequency

F = tensio

μ = linear mass density

m = mass

ℓ = length

Figure 3. Standing Wave Equations. These equations were used for calculating the values in the table above. The wavelength represents the distance between peaks of the wave formed by the string. The speed is how quickly the string occelated. The mass is a hanging mass and the tension force is the mass times the gravitational constant.

11. Repeat steps 2-10 for a nominally 100 g hanging mass. Use the second tab in the Excel table to record your data. You do not need to sketch the waveforms nor use the strobe light. *Do not disturb your apparatus—you will be making one more measurement with it.*

12. **Question: For the 100 g hanging weight, how are the frequencies f_2 and f_3 mathematically related to f_1?** Predict the resonant frequency f_4. Look for this resonant pattern experimentally and measure the 4^{th} resonant frequency.

The frequencies are equal to the number of harmonics times the frequency of the first harmonic. Since the 1^{st} harmonic was approximately 25 then the 4^{th} harmonic should be around 100.

13. **Paste a picture of your Excel table data for the 100 g hanging mass portion here**.

String mass (g)	String mass (kg)	String length (m)	Linear mass density (kg/m)
0.56	0.00056	1.689	0.000331557

g (m/s²)	Hanging mass (g)	Hanging mass (kg)	String tension (N)	Predicted wave speed (m/s)	Abs. unc. in predicted wave speed (m/s)
9.803	100	0.1	0.9803	54.37513054	0.3

Harmonic	Frequency (Hz)	Distance between adjacent nodes (m)	wavelength (m)	wave speed (m/s)
1	25.963	1.055	2.11	54.78193
2	52.363	0.522	1.044	54.666972
3	78.413	0.352	0.704	55.202752
			average	54.88388467
			st. dev.	0.282065804

Ratio test comparing predicted and measured wave speeds
0.874049157

Predicted f_4	Measured f_4
103.852	104.653

Table 2. 100g Standing Wave Excel Spread Sheet. The frequencies and wavelength were observed using the apparatus above. A 100g mass provided the tesnsion on the string. The predicted and measured wave speeds agree according to the ratio test. The predicted and observed f_4 are also very similar.

14. **Write an analysis here.**

The high tension had a higher wave speed, it also took a high frequency to create each harmonic with the 100g mass. For both masses, the predicted and measured values agreed. The predicted wave speed for the 50g mass was 38.44m/s and the measured average was 39.20m/s. The predicted wave speed for the 100g mass was 54.38 m/s and the measured average was 54.88m/s.

15. **Write a brief conclusion here.**

This was a fun experiment but did not seem relevant to what we are doing in class. The salt patterns were also interesting and I wish we could have done more with those. It would have been nice to have a estimated starting frequency because I was very confused why nothing was happening when we started at the initial frequency that the function generator was set to, approximately 1000 Hz, because we needed to be all the way down at approximately 20Hz.

16. Adjust the formatting (pagination, margins, size of figures, etc.) of this report to make it easy to read. Save this report as a PDF document. Upload it to the course Moodle page.

17. Clean up your lab station. Put the equipment back where you found it. Remove any temporary files from the computer desktop. Make sure that you logout of Moodle and your email, then shut down the computers. Ensure that the laptop is plugged in.

18. Check with the lab instructor to make sure that they received your submission before you leave.