

EXAMPLE OF A WELL WRITTEN LAB REPORT FOR PHYSICS 183/184

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STANDING WAVES ON A STRING

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Objective: To find the relationship between the velocity and wave length of standing waves on a string as well as to find the relationship between string tension, velocity and wave length and the number of standing waves formed.

Apparatus: 120Hz vibrator, an aluminum rod and 90° clamp, string, mass hanger, a pulley clamp, various masses, a 2-meterstick, and a triple-beam balance.

THEORY: Consider a string fixed at one end and tied to a vibrator. The waves produced by the vibrator travel down the string, are inverted by reflection at the fixed end, and travel back to the vibrator. If the vibrator amplitude is small, it acts essentially as a fixed end as far as reflection is concerned. The condition for constructive interference between the reflected wave and the wave produced from the vibrator is $L = n\lambda/2$, where L is the length of the string and n is any integer.

Standing wave

A standing wave, also known as a stationary wave, is a wave that remains in a constant position. This phenomenon can occur because the medium is moving in the opposite direction to the wave, or it can arise in a stationary medium as a result of interference between two waves traveling in opposite directions.

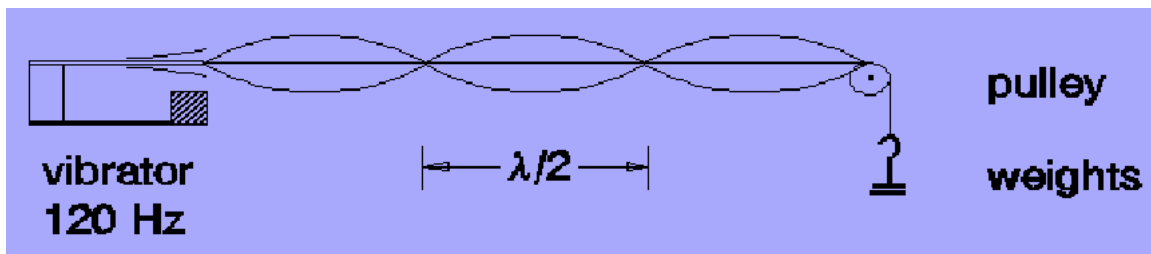
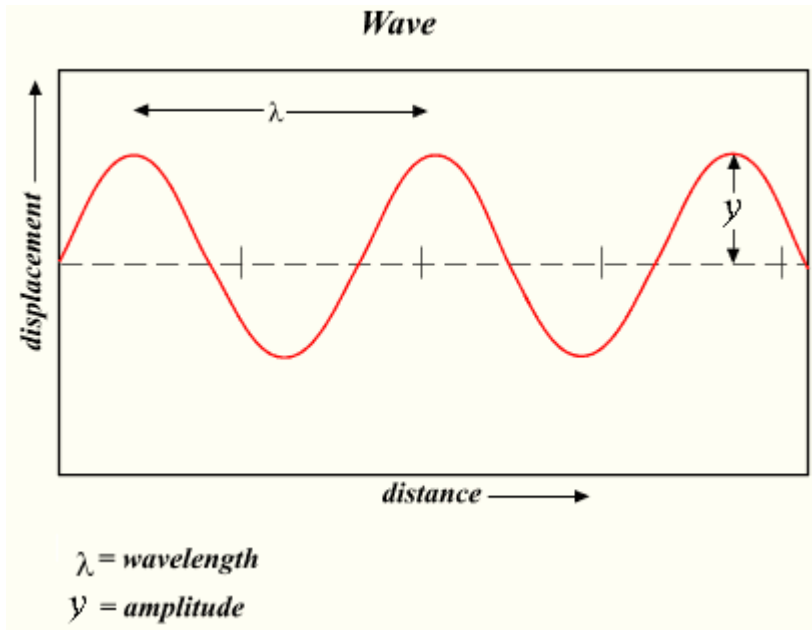
The *sum* of two counter-propagating waves (of equal amplitude and frequency) creates a *standing wave*. Standing waves commonly arise when a boundary blocks further propagation of the wave, thus causing wave reflection, and therefore introducing a counter-propagating wave. For example when a violin string is displaced, longitudinal waves propagate out to where the string is held in place at the bridge and the "nut", where upon the waves are reflected back. At the bridge and nut, the two opposed waves are in antiphase and cancel each other, producing a node. Halfway between two nodes there is an antinode, where the two counter-propagating waves *enhance* each other maximally. There is on average no net propagation of energy.

Also see: Acoustic resonance, Resonance Tube Experiment, Helmholtz resonator, and organ pipe

Propagation through strings

The speed of a wave traveling along a vibrating string (v) is directly proportional to the square root of the tension (T) over the linear density (μ):

$$v = \sqrt{\frac{T}{\mu}}$$



Procedure:

- 1. Place the aluminum rod in the hole in the surface of the lab table. Put it at the end of the table next to the wall.**
- 2. Attach the 90° clamp to the rod and then insert the metal rod attached to the vibrator to the clamp.**
- 3. Attach the pulley clamp to the other end of the table. Take the string attached to the vibrator and run it over the pulley.**

4. Hang the mass hanger from the loop at the end of the string. (Note the mass hanger has a mass of 50g so you must add this mass to any additional mass you hang from it.)

5. Add additional masses to the mass hanger until you get a series of standing waves. (See illustration below)

6. You will add different amounts of mass to get 3,4,5,6,7,and 8 loops. The standing waves will only form when discrete masses are added. They are not continuous. Measure and record the total mass for each number of standing waves using the triple-beam balance.

7. Measure the length of the string L from the end of the vibrator to the center of the pulley. Record this value in meters in your original data

8. For each set of standing waves formed, record the number of loops n .

9. Calculate the wavelength λ of the standing waves. Use the following formula.

$$\lambda = 2L/n \quad (1)$$

10. Record λ for each of the 5 masses that give you a standing wave.

11. Calculate and record the velocity of each set of standing waves. Use the following formula.

$$V = f \lambda \quad (f = 120 \text{ Hz}) \quad (2)$$

12. Calculate the tension in the string. Use the following formula.

$$T = mg \quad (3)$$

13. Calculate the velocity of the standing wave using the following formula.

$$V = (T/\mu)^{1/2} \quad (4)$$

14. Compare the velocities found using formula (2) and (3).

15. From the data taken in part one, plot a graph showing the relationship between the tension $T(N)$ and the square of the wavelength $\lambda^2(m^2)$ (experimental points). Add regression line to your graph.

16. Calculate the frequency of the vibrator f from the slope of the regression line.

Does this seem reasonable based on what you know about alternating voltage from the power company? Place this value for f in the results section of your report. The slope of the line is:

$$\text{Regression line slope} = T / \lambda^2$$

$$f = ((T / \lambda^2) / \mu)^{1/2} = (\text{slope} / \mu)^{1/2}$$

17. Calculate a percent difference for f experimental and f given and place in result of this calculation the Results Section of your report.

18. Discuss the possible types and sources of error in your conclusions section.

See questions below.

Some possible reasons for errors are listed below. Pick up 4 most important ones and explain why they are the most important ones. State whether they are systematic or random and explain.

1. Temperature expansion/contraction of ruler and thread.
2. Wooden ruler is not precise enough? - Should steel one be used instead?
3. Air resistance.
4. Vibrations are in x and y direction.
5. Position of node is not clear.
6. Weighing error - scale is not precise enough.
7. Linear density of the string is non uniform
8. Tension is not constant.
9. Linear density is a function of tension (Hooks law) How does linear density of the string change wit increasing or decreasing tension.
10. Reading the position of nodes (parallax).
11. Frequency of vibration is not constant.
12. Amplitude of vibrations not at maximum
13. Thread is not horizontal.
14. Ruler was not parallel to thread when reading the node positions.
15. Some other errors.

Note the previous sections are to be written in long hand on your pre-lab sheets.

Original Data:

$L = 1.54\text{m}$ $\mu = 5.56 \times 10^{-4} \text{ Kg/m}$ $f_{\text{given}} = 120\text{Hz}$

Number of Loops n	Mass (kg)	Tension (N)	λ Wave length (m)	λ^2 (m^2)	Velocity m/s from eqn. (2)	Velocity m/s from eqn. (4)
3	0.943	9.25	1.026	1.054	129.12	129.91
4	0.485	4.76	0.770	0.5921	92.40	92.50
5	0.353	3.43	0.616	0.3795	79.92	78.58
6	0.217	2.13	0.513	0.2635	61.60	61.89
7	0.159	1.56	0.440	0.1936	52.80	52.96
8	0.120	1.17	0.395	0.1482	46.20	46.01

Sample Calculations and Graph

1. $T = mg = 0.943\text{Kg} \times 9.81 \text{ m/s}^2 = 9.25 \text{ N}$

2. $\lambda = 2L/n = (2 \times 1.54\text{m}) / 3 = 1.026\text{m}$

3. $\lambda^2 = (1.026\text{m})^2 = 1.054\text{m}^2$

4. $V = (\mu / T)^{1/2} = (9.25\text{N} / 5.56 \times 10^{-4} \text{ Kg/m})^{1/2} = 129.12\text{m/s}$

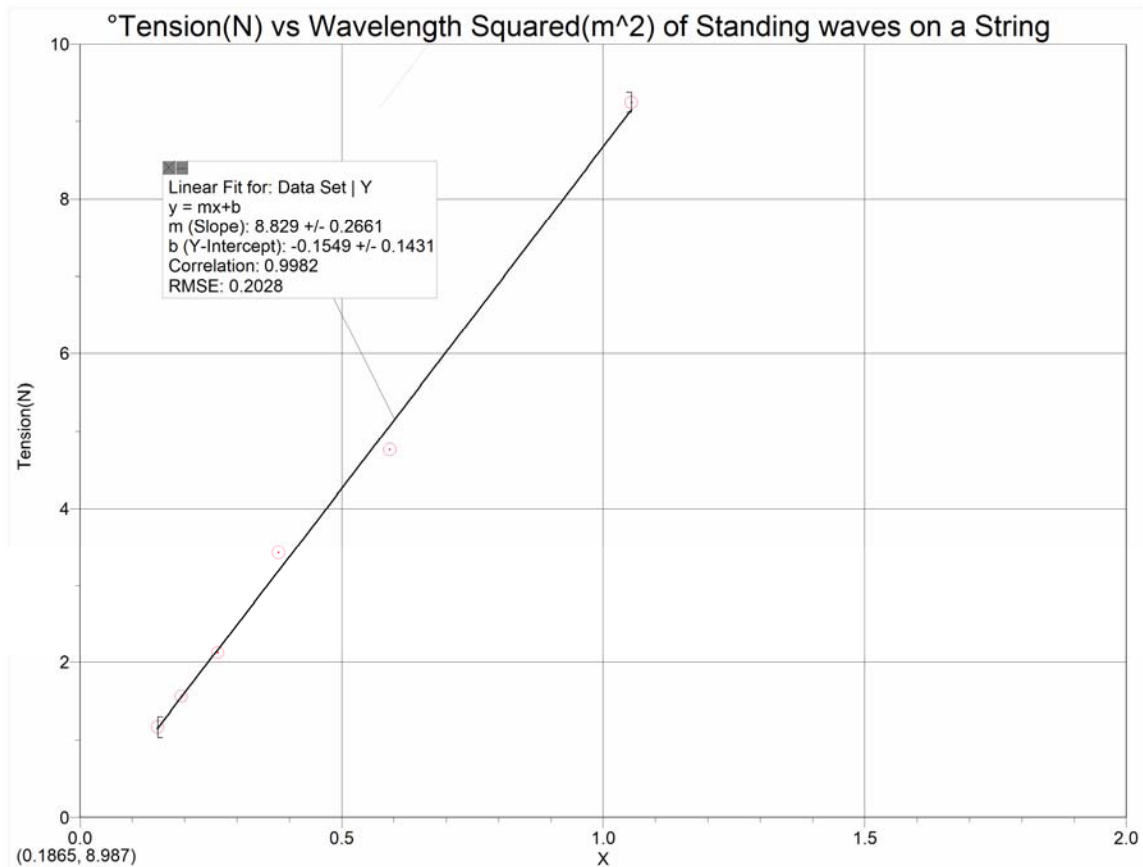
5. $V = f \lambda = 120 \text{ Hz} \times 1.026 \text{ m} = 129.91 \text{ m/s}$

6. Slope of straight line through T vs. λ^2 :

Slope = $(9.25 - 1.17) \text{ N} / (1.054 - 0.1482) \text{ m}^2 = 8.92 \text{ N/m}^2$

7. $f = (\text{slope}/\mu)^{1/2} = (8.92 \text{ N/m}^2 / 5.56 \times 10^{-4} \text{ Kg/m})^{1/2} = 126.66 \text{ Hz}$

8. % error f = $[(120.0 \text{ Hz} - 126.66 \text{ Hz})/120.0 \text{ Hz}] \times 100\% = 5.55\%$



Results:

f experimental 126.66 Hz

f given 120.00 Hz

slope 8.92 N/m²

% error f 5.55%

Conclusions: Answer question is step 18 of the procedure.

This is the section of the report where you give example of possible sources of errors in the experiment. You must give an example of the error your are talking about as well as it's type.