Riverside Community College

Physics 4C

LABORATORY REPORT 2

Messing around with a rope

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1 Introduction

In this lab we explore the linear mass density (μ) of a rope by analyzing the relationship between the tension force and wave speed.

2 Methodology

The lab is fairly straightforward, and can be preformed by the following steps.

2.1 Setup

We began the experiment by measuring the length of our string, which was 2.45 meters, and its mass, which was 4 grams. On a long table, we installed clamps at both ends: one clamp held the vibrator unit, and the other supported a pulley system. One end of the rope was secured to the vibrator unit, while the opposite end was attached to a mass and stretched taut over the pulley.

2.2 Procedure

Five experiments are needed for different masses;30g, 50g, 100g, 150g, and 200g. Which cause varied tension forces on the rope.

1. For each mass,the frequency of the vibrator unit was adjusted to form five distinct standing wave patterns. It is crucial that each frequency chosen results in a different number of nodes.[1]

2. The wavelength of the waves was determined by measuring the distance between two nodes in series using a meter stick. With this measured distance multiply it by two to get a full wavelength.

3. For each standing wave pattern observed, the frequency was converted to the period.

4. After each experiment was conducted the tension force in the string was calculated by multiplying the mass attached to the end of the string by the acceleration due to gravity (9.81 m/s^2).

[1]Nodes are points along the wave where no motion occurs.

3 Data

3.1 Change of Frequency for various masses.

Frequency (Hz)	Period (s)	λ (m)
12.0	0.083	1.16
16.2	0.062	0.82
19.7	0.051	0.68
24.5	0.041	0.56
27.9	0.036	0.48

Table 1: 30 g mass attached to rope

Frequency (Hz)	Period (s)	λ (m)
14.5	0.069	1.20
19.5	0.051	0.90
25.0	0.04	0.68
29.0	0.034	0.59
35.0	0.029	0.50

Table 2: 50 g mass attached to rope

Frequency (Hz)	Period (s)	λ (m)
20.3	0.049	1.2
27.5	0.036	0.88
34.0	0.029	0.68
41.5	0.024	0.54
49.0	0.020	0.48

Table 3: 100 g mass attached to rope

Frequency (Hz)	Period (s)	λ (m)
25.0	0.040	1.24
35.0	0.028	0.82
45.0	0.022	0.62
50.0	0.020	0.58
55.0	0.018	0.50

Table 4: 150 g mass attached to rope

Frequency (Hz)	Period (s)	λ (m)
30.0	0.033	1.16
35.0	0.029	0.96
42.5	0.023	0.78
52.5	0.019	0.64
65.0	0.015	0.50

Table 5: 200 g mass attached to rope

3.2 Expected Linear Density

- Our mass density expected, μ, was achieved by dividing the mass by the length. Giving us the expected μ of 1.6325 g/m.

4 Analysis

4.1 Calculations

To analyze the data, we employed a series of equations to calculate the wave speed (c) and the linear mass density (μ). The process involved the following steps:

1. Initially, we used the equation $\lambda = c \times t$, representing a linear relationship where c is the slope. This equation allowed us to determine the wave speed (c) directly from the slope of the plot of wavelength (λ) against the period (t). This was done for the five experiments. 1

2. With our varied wave speeds and tension forces , we tabulated 1 the wave speeds squared c^2, for the five different masses as well as their tension force, in order to find the experimental linear mass density (μ).

3. To find μ, we applied the equation $c_{\text{wave speed}} = \sqrt{\frac{F_t}{\mu}}$, leading us to another linear relationship expressed as $c^2 = \frac{1}{\mu} \times F_{\text{tension}}$. In this equation, $1/\mu$ serves as the slope for our recorded data points.

4. Finally, the reciprocal of the slope from the plot of c^2 against F_{tension} provides the value of μ.

m (g)	F_t (mN)	c (m/s)	c^2 (m^2/s^2)
30	294.3	14.115	199.2332
50	490.5	17.578	308.9861
100	981	25.569	653.7738
150	1471.5	32.486	1055.3400
200	1962	36.134	1305.6660

Table 6: Measurements of mass (m), force tension (F_t), wave speed (c), and wave speed squared (c^2)

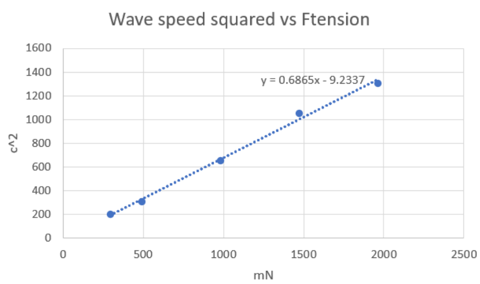

Figure 1: c^2 vs miliNewtons

Finding the wave speed of our different masses.

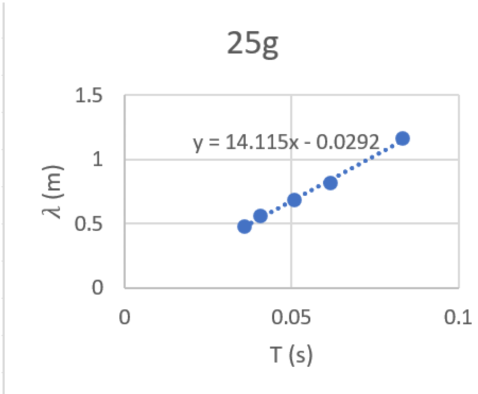

Figure 2: 25g T vs λ

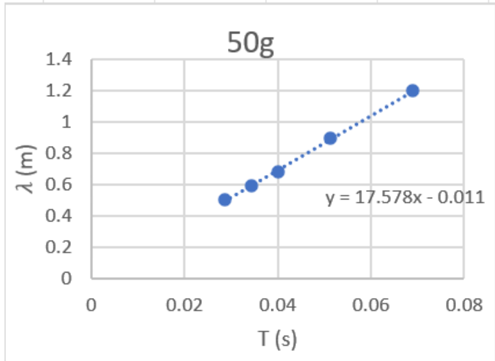

Figure 3: 50g T vs λ

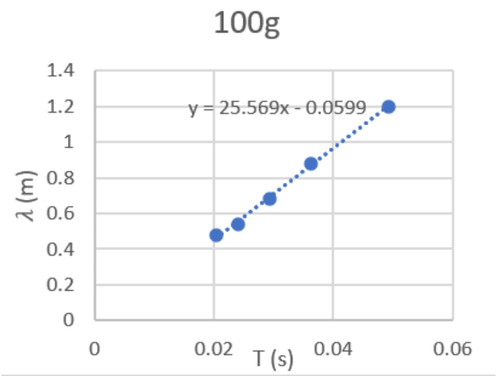

Figure 4: 100g T vs λ

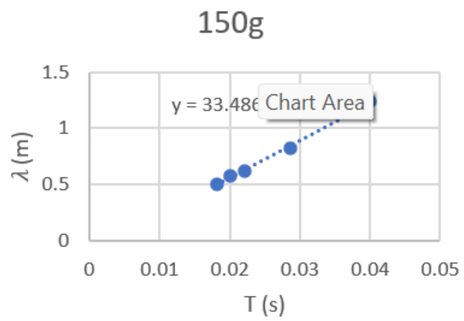

Figure 5: 150g T vs λ

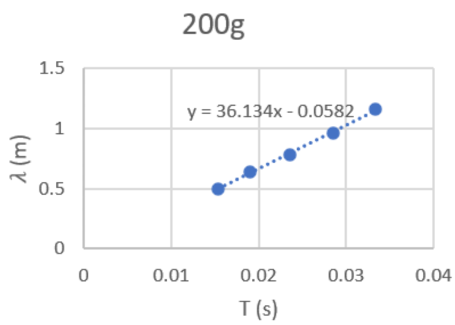

Figure 6: 200g T vs λ

5 Result

Our expected μ value was measured to be $1.63\frac{g}{m}$.1 A linear relationship between c^2 and F_t was observed, where we got μ experimental from the slope of the c^2 vs F_t graph to be $1.46\frac{g}{m}$.

6 Conclusion

With this experiment we explored the relationship between wave speed and tension to produce the linear mass density on a rope.

One caveat to consider, is the measurement of the wavelengths with the meter stick may be affected by human error, as we held the meter stick elevated which may have caused some error.

7 References

[1] Dr. Russel's Lecture 2/26/24, Riverside Community College.

Special thanks to Marlon, and my professor Dr. Russel