Experiment number 5

REPORT

Standing waves in string

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Report Overview

Our report will discuss the vibrations of a string while creating several forms of waves in different frequencies (*f*), weights with different masses are attached to the string in order to change the tension (*F*), while the other end of the string is fixed to a vibration generator.

In this experiment we studied and investigated different ways by which the vibrations impact the string.

For that, we used Pasco vibration generator and the Pasco-Capstone program, as well as the various instructions and questions given to by the brief.

The objectives of this experiment were achieved. We learned about standing waves in string, investigated the relation between the wave speed and tension in a string, and we found the linear density in said string.

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Experiment Overview

The purposes of this experiment were to study the relation between the sine wave progression and the tension in the string as well as to find the linear density (μ) of the string. We made 18 different runs in various states of the system, with six different masses and three different wave patterns.

Using data we collected from the experiment, we could calculate the wave progression speed, linear density and the tension in the string. The results were used to answer the guiding questions of the experiment that were presented in the brief and helped us studying the characteristics of a standing wave.

Theoretical Explanation

The wave in the string is created by the vibration generator and could be investigated in several different ways, 3 of which will be shown here.

The stretched string will have at least one point where it is static (amplitude at zero), and another point were amplitude is at its peak. We used the point of maximal amplitude to determine the frequency at each run, this frequency was later used in other calculations, such as wavelength (λ).

The wavelength is $\lambda/2$ when the wave has a single segment, 1λ if we have 2 segments and $(n/2)\lambda$ if we have 3 or more segments (*n* represents the total number). In our experiment, we had $(3/2)\lambda$ as the maximum value.

From the wavelength and frequency, we can calculate the wave speed as we can see in the formula:

$$V = \lambda \cdot f$$

Where V is the speed, λ is the wavelength and f the frequency.

We can calculate the tension of the string using mass and gravitation:

$$F = m \cdot g$$

Using this value and the length density ($\mu = \frac{m}{l}$) we can find the speed once again:

$$V = \sqrt{\frac{F}{\mu}}$$

In this experiment, the Pasco vibration generator will vibrate the string and create amplitudes that we can adjust by changing the frequency. While the change of the total weight of the hanging masses will change the tension.

Experiment Description

In this experiment we will use the following equipment:

PASCO science workshop 750

PASCO vibration generator

A soft wool string

Variety of masses

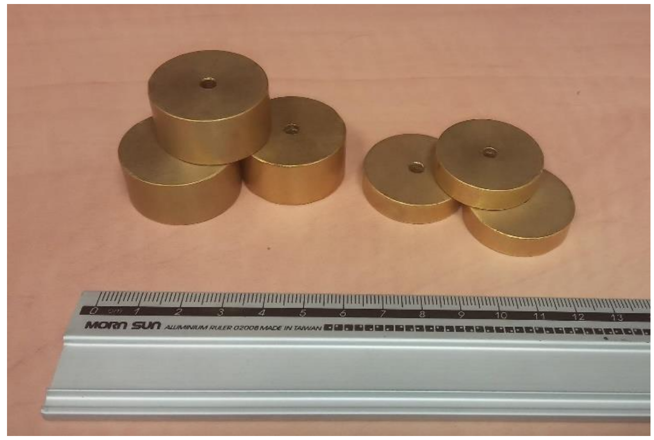
Hanger

Table clamp

PASCO ScienceWorkshop 750 – a device that connects and transfers data between the generator and the computer.

PASCO vibration generator – generates vibrations in frequencies between 0.1 to 5000 Hz and amplitudes of up to 7mm.

Metal masses – weighing 10g, 20g, 50g and 100g with an error of ±0.05g due to the limit of the weight we used. Several weights were hanged at once to achieve the desired mass.



Vibration generator (left), and various weights (right).

The weights and lengths were measured with a simple weight and a simple, 1m long ruler that were available at the lab. The error of the weight is 0.05g and of the ruler 0.005m, both errors were used in the total error calculations.

<u>Experiment procedure:</u>

1. Put the vibration generator in line with the table clamp and stretch the string by attaching the masses to it.

2. Connect the vibration generator and set the PASCO interface to read the relevant data.

3. Observe the string while alternating the frequency until a maximum amplitude is visible, write down the frequency in which it occurs, continue to adjust the frequency in intervals of 0.01Hz. Continue to do so until a 3-segment wave is created.

4. Change the mass and repeat the last section again, 3 times each mass, until the total weight reaches 150 grams.

Results

Table 1, initial results:

Weight (g) ±0.05g	Run	Frequency (Hz)	Force (N)	Speed (m/s)	λ (m) ±0.005m
50.25	1	22.512	0.49245	11.256	0.5
50.25	2	44.013	0.49245	44.013	1
50.25	3	67.013	0.49245	44.63	0.666666
70.45	1	27.513	0.69041	13.75	0.5
70.45	2	51.513	0.69041	51.513	1
70.45	3	77.013	0.69041	50.81	0.666666
90.35	1	28.21	0.88543	14.1	0.5
90.35	2	56.16	0.88543	56.16	1
90.35	3	87.06	0.88543	57.98	0.666666
105	1	29.96	1.029	14.98	0.5
105	2	60.16	1.029	60.16	1
105	3	90.06	1.029	59.98	0.666666
125	1	32.263	1.225	16.13	0.5
125	2	65.06	1.225	65.063	1
125	3	97.56	1.225	64.47	0.666666
155	1	35.56	1.519	17.78	0.5
155	2	72.06	1.519	72.06	1
155	3	111.593	1.519	74.32	0.666666

We marked each weight, or each set of runs in a different color. We can see that as the mass grows the tension grows too, and as a result we must turn up the frequency to get similar wavelengths. The speed also goes up along with all the other changing variables.

It is important to note that the speed is not a direct result but rather a calculated value. Nevertheless, we chose to show it here, for the reader to compare and understand the connection between the different parameters.

For this calculation we used the equation

$$V = \lambda \cdot f$$

<u>Error calculation for the tension (*F*):</u>

$$\Delta F = \sqrt{(g\Delta m)^2}$$

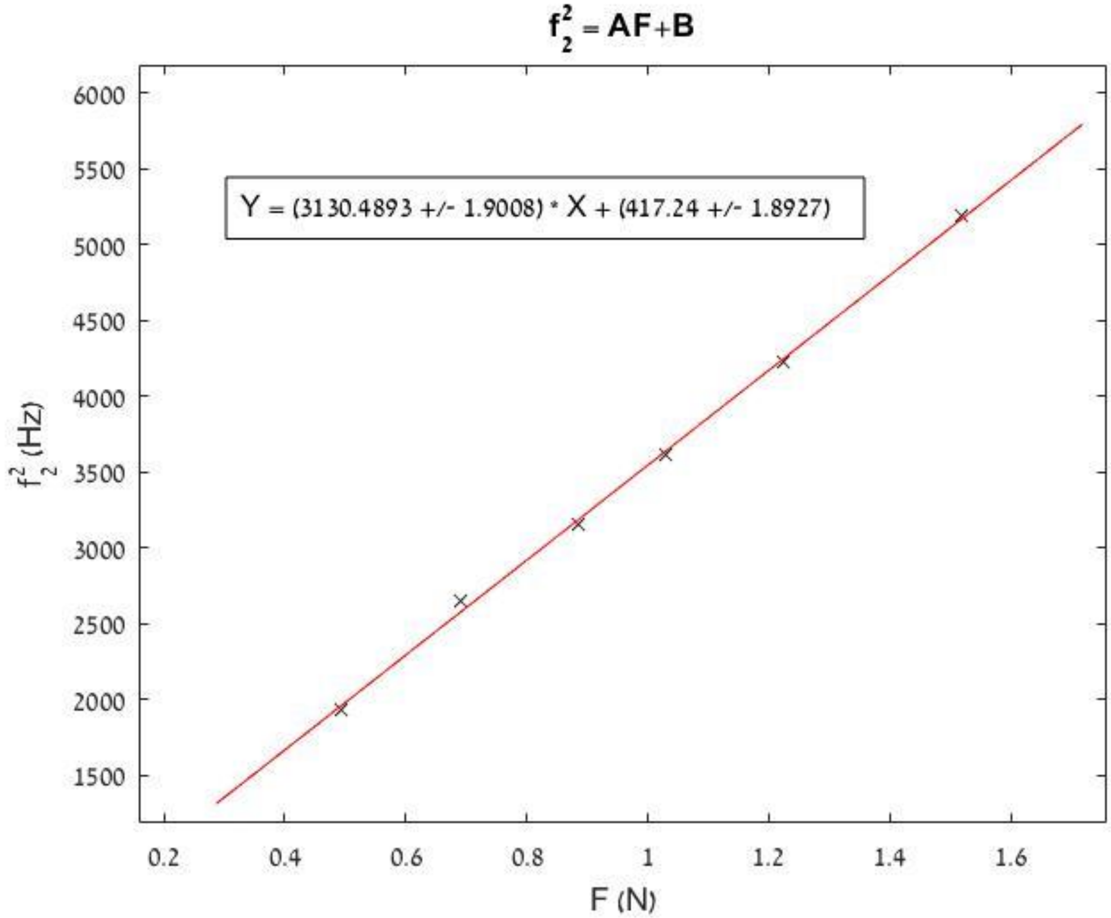
Therefore: $\Delta F = 4.9 \cdot 10^{-4}$ (N)

Data Analysis

One of the goals of this experiment was to find the relation between the frequency of a wave and the tension in the string.

Indeed, as we saw in the table above, there is a very clear connection – as we put more tension in the string, we need to generate higher frequency to achieve the same results.

It is important to note that although we assume in this report that the wave is perfect, it is not so in reality. Due to the system design, the point at which the string was knotted to the vibration generation was not still, but it moved up and down together with the device itself. Despite this fact, we still treated it as it was an ideal situation and counted it in the *n* calculations.



From the formula $f_2^2 = \frac{1}{L^2\mu}F$, which corresponds to the formula $f_2^2 = AF + B$, we see that A=3130.4893 with an error of ΔA = ±1.9008.

The linear density of the string can be calculated by the formula

$$\mu_{calc} = \frac{1}{AL^2} = 3.\cdot 10^{-4}$$

And its error is

$$\Delta\mu_{calc} = \sqrt{\left(\frac{1}{A^2L^2}\Delta A\right)^2 + \left(\frac{2}{AL^3}\Delta L\right)^2} = 3.2 \cdot 10^{-6}$$

Where L = 1m and its error is ΔL = 0.005m.

The general formula for linear density is

$$\mu_{actual} = \frac{m}{l} = 0.00025$$

And the error is

$$\Delta\mu_{actual} = \sqrt{(\frac{\Delta l}{l})^2 - (\frac{m}{l^2} \cdot \Delta m)^2} = 9.99 \cdot 10^{-5}$$

The relative error is

$$\frac{\mu_{clac} - \mu_{actual}}{\mu_{actual}} \cdot 100 = \pm 6\%$$

Conclusion

We learned about the characteristics of standing waves, and that we can influence their speed with the help of frequency and mass variations.

This experiment was very educating and enjoyable, we think that the gradual increase of mass was right on point, as otherwise we would have used much higher values and do not see the delicate changes that we achieved.

Recommendations

We can recommend using other kinds of mass or other hanger, of a kind where one can prevent them from constantly falling from the hanger (with a pin that will close the gap or something of the sort).

Except for this, we couldn't find any negative point in this experiment. Without any doubt it was the best experiment in this course so far.

Bibliography

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Bland, D. R. *Vibrating Strings: An Introduction to the Wave Equation*. Routledge and K. Paul, 1968.