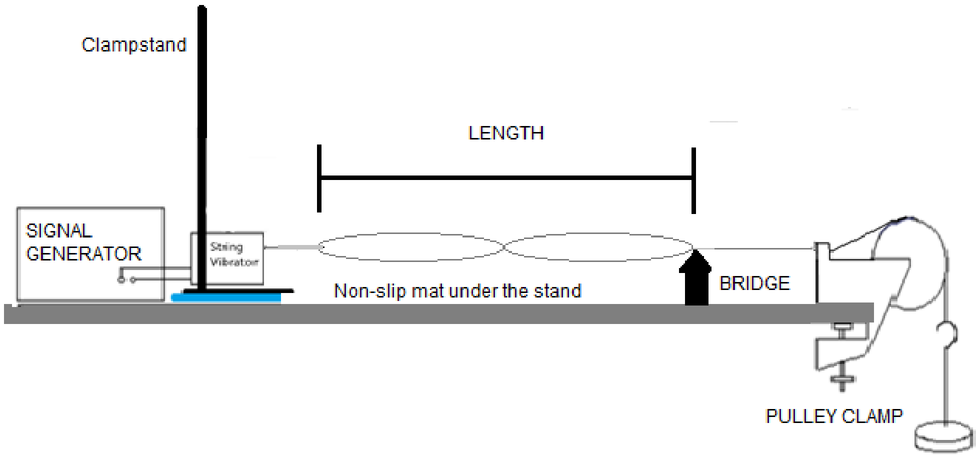
Properties of Stationary Waves on a Taut String – Part 1

Apparatus

Signal generator
Vibration generator
Mass hanger and masses
Large sheets of white paper
Metre rules
Pulley clamp
String
Balance

Diagram



Theory

For a stationary wave, each 'loop' is a half wavelength. Let the length of the string be ***l*** and the number of 'loops' be n, then if the wavelength is λ,

$$l = n\lambda/2$$

Now, if the velocity of the wave is c, then c = fλ, where f is the frequency. Hence $f = \frac{nc}{2l}$

The speed of waves on a taut string is given by: $c = \sqrt{\frac{T}{\mu}}$ where *T* is the tension in the string (*mg*, where *m* is mass of load) and *μ* is the mass per unit length of the string.

Hence the frequency is given by: $f = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$

Method

Set up the apparatus as indicated in the diagram using the red string. Firstly, use a mass of about 200/300 g to supply the tension. Arrange the paper under the string so you can see the string more clearly. Set the length to be at least 1.5 m.

For this first part of the investigation, you should keep the number of loops constant at 2 throughout. Adjust the frequency of the signal generator until a clear 2 loop pattern is seen on the string. Then reducing the length (at fixed tension) record the corresponding frequencies. Adjustment of the length is by moving the position of the bridge.
For the second part of the investigation, find the frequency of the first 8 harmonics for the red string. Create a suitable table to record your results.

Results

You should record the results for each of the 2 main parts of the investigation in a separate table.

For the investigation with length, you will need to calculate and record a column of 1/***l*** values.

Analysis

<u>Frequency and length of string</u>

- What is the dependant, independent and control variables?
- Plot a graph of frequency on the y axis against 1/***l*** on the x axis.
- Determine the gradient of the graph.
- The gradient has units – what are they?

The equation is $f = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$ or $f = \frac{1}{l}\sqrt{\frac{T}{\mu}}$ for n = 2

This can be written as $f = \sqrt{\frac{T}{\mu}} \times \frac{1}{l}$

- Match this equation to that for a straight line (y = mx + c).
  What corresponds to y?
  What corresponds to x?
  What corresponds to m?
  What is the intercept on the y axis?
- State what shape you expected the graph to be.
- Is your graph the shape you expected?
- Is the intercept the expected value?
  (If you used a false origin then calculate the intercept as follows:
  c = y – mx
  Select a point ON THE LINE NOT IN THE TABLE.
  Substitute in the values of y, m and x in the equation).
- If the shape is not as expected can you suggest why?
- Is random error very evident in your table and on your graph?
  HINT: are the points very close to the line of best fit?
  If you repeated the readings are they identical?
- Is a systematic error evident in your graph?
  HINT: is the intercept the one expected?

- Calculate the mass per unit length of the string and use this with the fixed tension value to calculate a theoretical gradient.
- Calculate the percentage difference between your measured gradient and the expected value.
- Compare this with the percentage uncertainties in your readings of frequency and length (use a middle value in the table)

Frequency and number of loops

- What is the dependant, independent and control variables?
- Plot a graph of frequency on the y axis against n on the x axis.
- Determine the gradient of the graph.
- The gradient has units – what are they?

The equation is $f = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$

This can be written as $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \times n$

- Match this equation to that for a straight line (y = mx + c).
  What corresponds to y?
  What corresponds to x?
  What corresponds to m?
  What is the intercept on the y axis?
- State what shape you expected the graph to be.
- Is your graph the shape you expected?
- Is the intercept the expected value?
  (If you used a false origin then calculate the intercept as follows:
  c = y – mx
  Select a point ON THE LINE NOT IN THE TABLE.
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- If the shape is not as expected can you suggest why?
- Is random error very evident in your table and on your graph?
  HINT: *are the points very close to the line of best fit?*
  If you repeated the readings are they identical?
- Is a systematic error evident in your graph?
  HINT: is the intercept the one expected?

Planning (CPAC2)

There are 2 other variables that effect the frequency in the equation is $f = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$

Plan an investigation to show this relationship.

- What equipment do you need?
- What procedure will you follow?
- What are the dependant, independent and control variables?

Conclusion

State the relationships found between frequency and length of string and between frequency and number of loops.