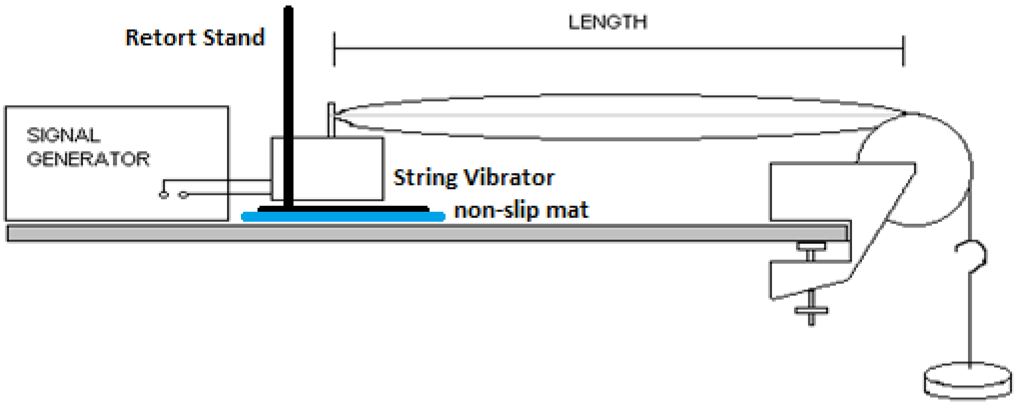
Properties of Stationary Waves on a Taut String

While conducting this experiment, you will be assessed for CPAC1: Following written instructions.
Your lab report will be assessed for CPAC5: 'y=mx+c' analysis.

Apparatus

Signal generator	Mass hanger and masses	Metre rules	String(s)
Vibration generator	Large sheets of white paper	Pulley clamp	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 investigation there are several variables. 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. Now investigate separately reducing the length (at fixed tension) and increasing the tension (at fixed maximum length) and record the corresponding frequencies for each investigation.

You should also take a single value of the frequency for a 2 loop pattern with the other thinner white string, at maximum tension and length. Use the balance to measure the mass of a length of both strings, so that *μ* may be calculated.

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.

For the investigation with tension, you will need to calculate and record a column of $T^{½}$ values.

Also record the frequency for the second string and the mass and length values for the strings.

Analysis

Frequency and length of string

- 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 tension

- Plot a graph of frequency on the y axis against $T^{½}$ 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 $f = \frac{1}{l\sqrt{\mu}} \times \sqrt{T}$

- Match this equation to that for a straight line (y = mx + c).
- What is the gradient equal to?
- 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 not can you suggest why?
- Is random error very evident in your table and on your graph?
- Is a systematic error evident in your graph?
- Calculate the expected gradient and the percentage difference between this and your measured value.
- Compare this with the percentage uncertainties in your readings of frequency and tension (mass).

Variation with mass per unit length

Try using your frequency value for the original string and the μ values for each to calculate the expected value for the frequency with the thinner string by ratio.

If you have difficulty with this, calculate the expected value for the frequency from the formula with the measured values of T, l, and μ for the white string.

How does the calculated value compare with the measured value?

Conclusion

State the relationships found between frequency and length of string and between frequency and tension.

Also comment on the gradient values obtained and the likely validity of the full theoretical expression based on the measurement with the second string.