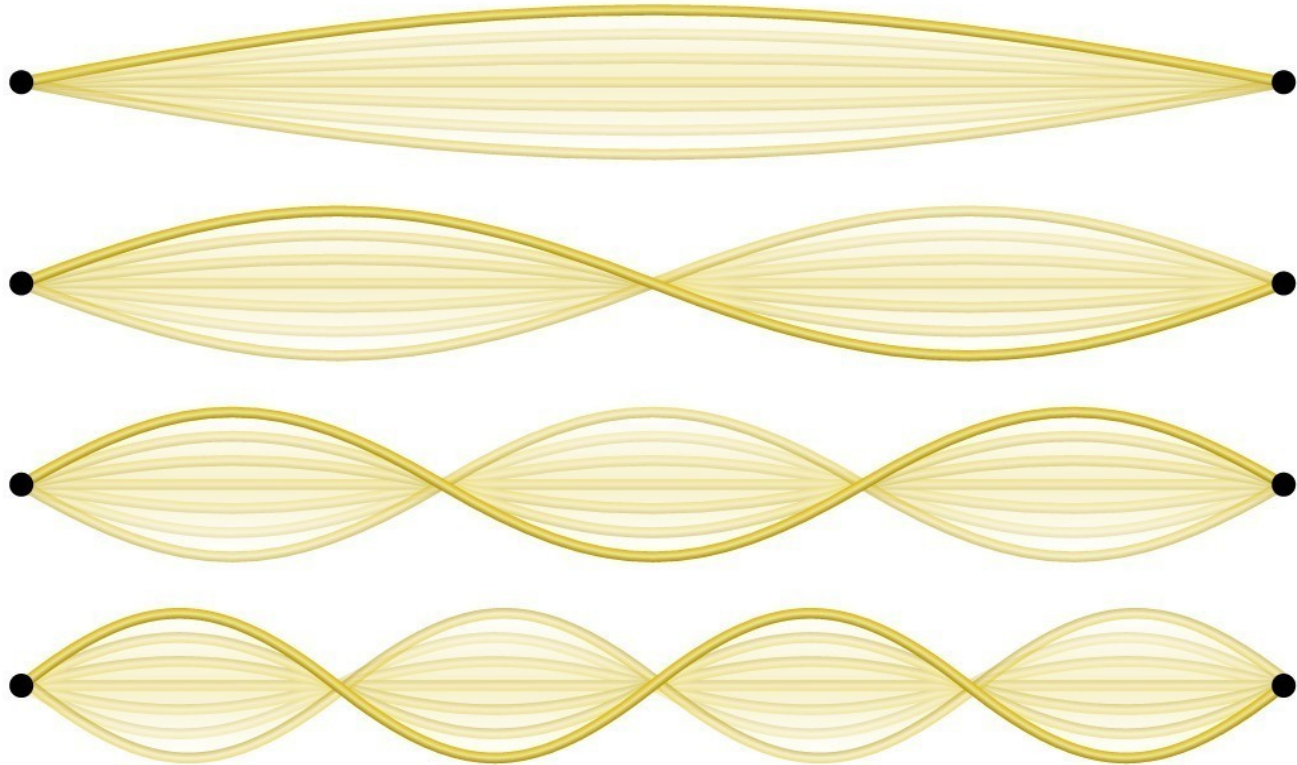# Standing Waves

Prelab

LR Write experiment title, your name and student number at top of the page.

LR **Prelab 1:** Write the objective of this experiment.

LR **Prelab 2:** Write the relevant theory of this experiment.

LR **Prelab 3:** List the apparatus and sketch the setup.

! Have these ready to be checked by lab staff
at the door on the day of your lab.

Introduction

Standing waves are a type of resonance that occurs when waves interfere and produce a pattern which appears to stand still with time. This occurs as incident waves constructively interfere with reflected waves producing a fixed pattern. Resonance refers to when waves interfere producing a resulting wave that is greatly increased in amplitude at a specific frequency.

Standing waves are visualized in this experiment by sending waves along a string under tension, where incident waves travel the length, get reflected back and these waves constructively interfere. This interference pattern will help in understanding the properties of wave interference and help understand the idea of resonance.

In this experiment, we'll look at a standing wave resonance on a string and study some of its properties.

Standing waves

Waves on strings are transverse waves. When a string is vibrating at its fundamental frequency, the wave pattern looks like the one shown below.

$$L = \frac{\lambda}{2}$$
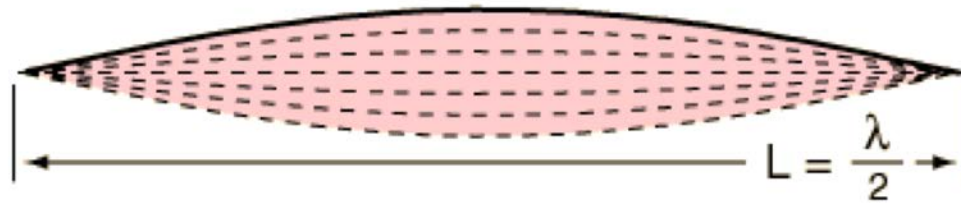
Standing waves are created by an interference pattern of waves whereby there are fixed points of constructive and destructive interactions.

At points where there is constructive interference, there is a relative maximum amplitude which is referred to as an **antinode**. Above, this would be in the middle of the image. Where destructive interference occurs, amplitude is a minimum and a **node** is created. In the case above, the nodes would be the ends.

Wave speed on a string

The **wave speed** v can be determined using the **frequency** f and the **wavelength** λ by the expression

$$v = f\lambda \ .$$

The wave speed on a string is also given by

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

where T is the **tension** in the string and μ is the **linear mass density.**

The mass density μ is calculated by the mass per unit length of the string, namely
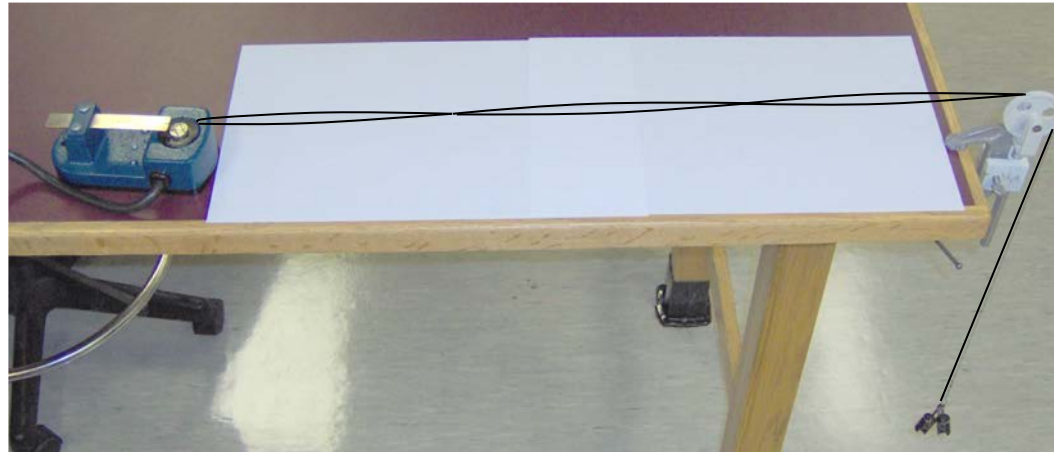
$$\mu = \frac{m_s}{L} \ .$$

Apparatus

You will use the following equipment in your experiment:

– Fixed frequency vibrator (either blue **or** black: both are shown at right)
– String
– Hooked masses
– Pulley with clamp
– Paper
– Tape
– Orange triangular rulers
– Meter stick

Experimental Setup

The string vibrator will generate waves at a fixed frequency. These incident waves travel the length of the string to the pulley at the end of the bench where the waves will be reflected back towards the vibrator. At certain distances between the vibrator and the pulley, the incident and reflected waves will begin to interfere and create a standing wave pattern. This standing wave pattern is an example of **resonance**, where an external force or boundary condition can produce an increase in amplitude at specific frequencies.

Wavelength Prediction
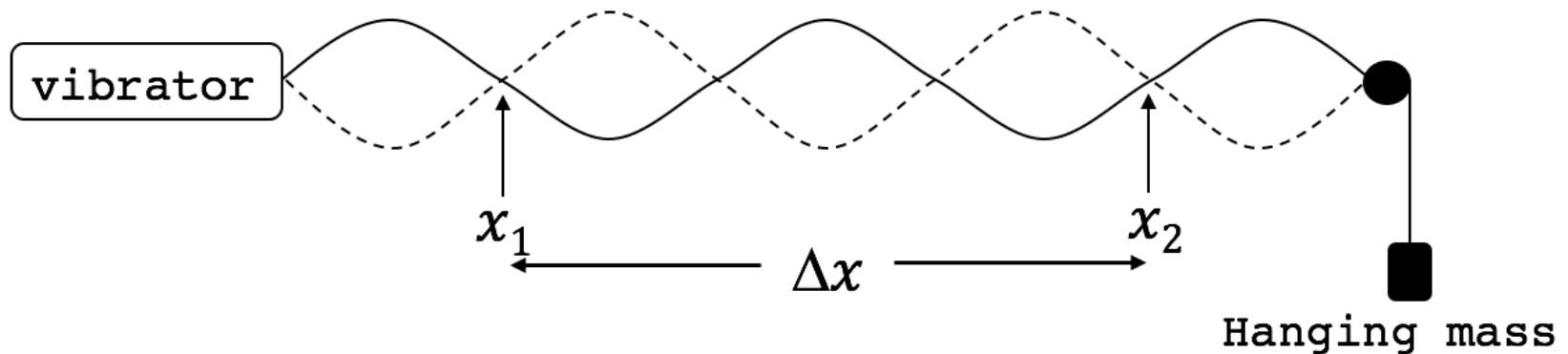
In order to produce a standing wave pattern, the distance from the string vibrator to the pulley needs to be a multiple of <u>half a wavelength</u>.

We'll use the wavelength to guide the placement of the string vibrator to create a standing wave pattern. Using the wavelength, and the understanding that the vibrator must be placed near a node, we should be able to easily produce a good standing wave pattern.

Choosing a Mass

To provide the tension in the string, masses are hung over a pulley. If we assume that the pulley is massless and frictionless, than the tension in the string will be equal to the weight W of the hanging mass.

- If you have the metal type vibrator with black string:
  - The frequency is 120 Hz.
  - Suggested to use masses between 70-100 grams.

- If you have the black plastic type vibrator with yellow string:
  - The frequency is 60 Hz.
  - Suggested to use a masses between 150-200 grams.

Take the uncertainty in the mass sets to be $\delta m = \pm 0.1g$.

Wavelength Prediction

The linear densities of the strings

$$\mu_{black} = 1.42 \times 10^{-4} kg/m \qquad \mu_{yellow} = 1.50 \times 10^{-3} kg/m$$

$$\frac{\delta\mu}{\mu} = 0.03$$

(LW) **Lab Report 1:** Indicate your string vibrator frequency and string colour in your lab workbook. We take the uncertainty in frequency to be zero, $\delta f = 0$.

(LW) **Lab Report 2:** Write the linear density of your string in the form $\mu \pm \delta\mu$.

(LW) **Lab Report 3:** Choose a mass to provide the tension in the string, based on information on previous slide, and record this mass. Calculate the tension. Include uncertainty.

Wavelength Prediction

LW

Lab Report 4: Using f and μ, and your chosen tension, determine the wavelength of your wave with uncertainty. Write in the form $\lambda \pm \delta\lambda$.

We can use this wavelength value to construct our experimental setup. In the example to the right, the setup has a total of 2.5 wavelengths from the vibrator to pulley.
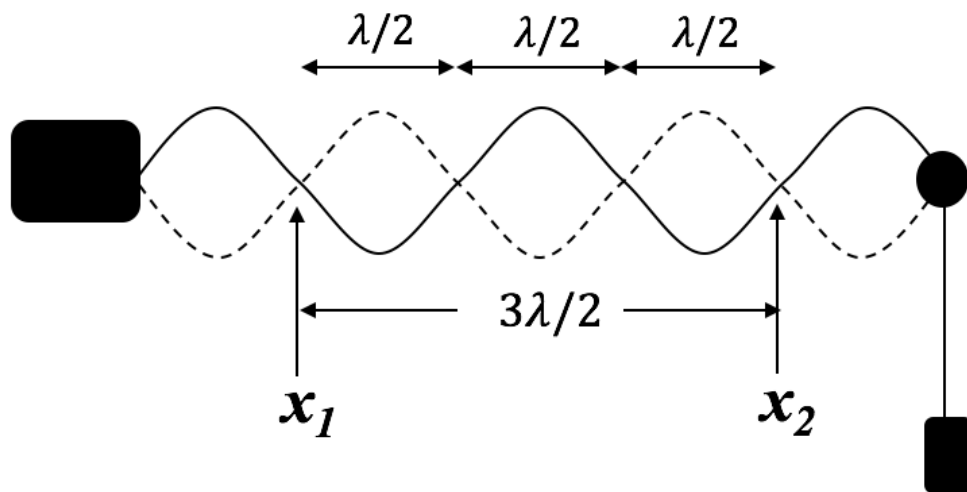
Use this information and the following slide to set up your apparatus similarly.

As the nodes at the vibrator and pulley are difficult to measure, the setup works best by keeping the total length at least 1.5 wavelengths.

Experimental Setup

Assemble your apparatus as shown:

- – Clamp the pulley to the desktop.

- – Hang the string over the pulley.

- – Tape paper to the benchtop below the string's path.

- – Hang your chosen mass from the end of the string to provide the tension. Make sure the pulley wheel turns freely.

- – Level the string to avoid a systematic uncertainty.

- – Plug in the vibrator.
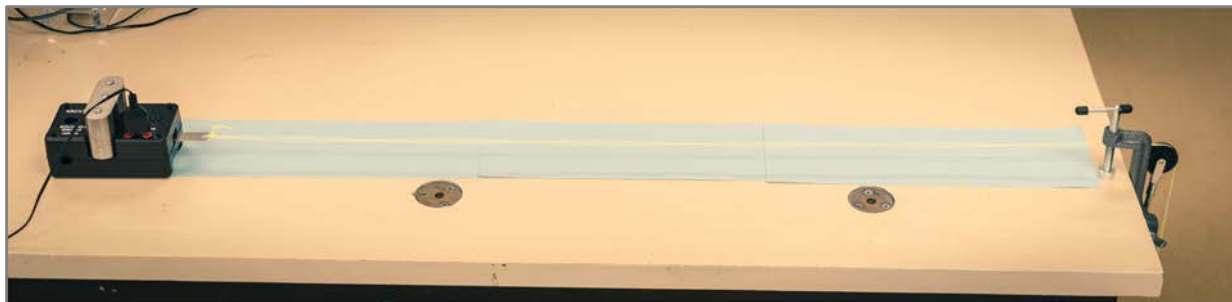
Equipment Warning.

The string vibrators should only be plugged in while collecting data, and should not be running continuously.
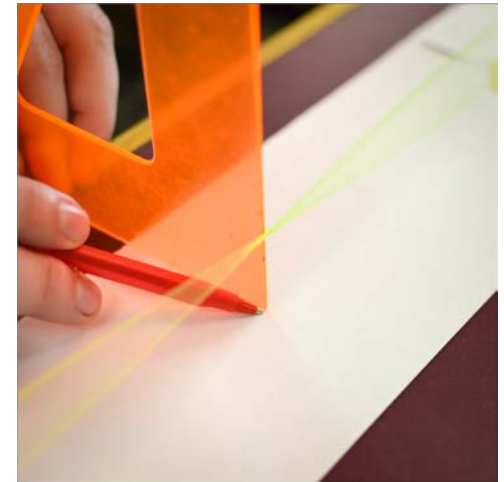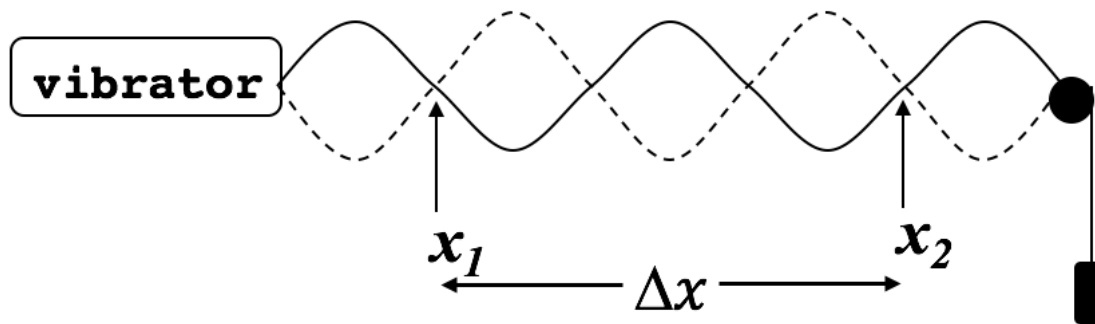
The devices get **HOT** and as they do, the frequency may shift and disrupt your data collection, or can cause burns.

DO NOT leave string vibrator running for more than a few minutes.

Wavelength Measurement

Use your chosen mass in which you calculated tension and create a standing wave pattern.

Measure the wavelength by using the orange triangle to mark the positions of the nodes x_1 and x_2, as shown above, on the paper. Using a meter stick, we can measure Δx and, knowing the number of wavelengths between x_1 and x_2, we can measure λ.

CP

Have an instructor check your setup and initial your lab report.

Wavelength Measurement

LW **Lab Report 5:** Record your value of wavelength and estimate your uncertainty. Write in the form $\lambda \pm \delta\lambda$.

LW **Lab Report 6:** If we increase the value of tension, by increasing the mass, how would the wavelength change? Provide an explanation. Would you need to move the string vibrator closer, or farther from the pulley to create a standing wave?

Test your prediction by altering the hanging mass and creating a new standing wave pattern. Comment on your findings.

LW **Lab Report 7:** If a plot of T vs λ^2 were created, what would you expect for the fit parameters? E.g. If plot is linear, what you expect for the slope and intercept? Use equations to support your answer.

Summary & Conclusion

LR   **Lab Report 8**: Briefly summarize your experiment, in a paragraph or two, and include any experimental results.

LR   **Lab Report 9:** List any sources of experimental uncertainty and classify them as random or systematic.

Include your prelab and all data analysis with your report.