

STANDING WAVES ON A STRING

The objectives of the experiment are:

- To show that standing waves can be set up on a string.
- To determine the velocity of a standing wave.
- To understand the differences between transverse and longitudinal waves.

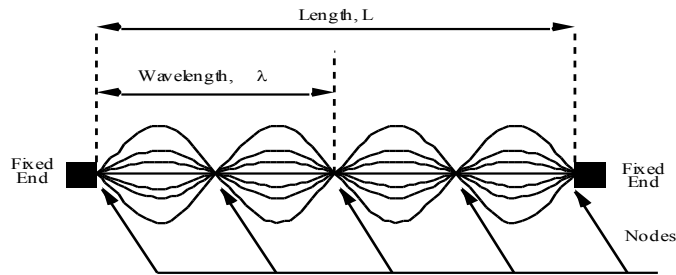
APPARATUS: Buzzer board with string, meter stick, weight holder, weights



INTRODUCTION

A traveling wave of sinusoidal shape goes a distance λ (the wavelength) in a time, T . The wave velocity c is therefore equal to λ/T . Because f (the frequency) is defined as $1/T$, we can also write $c = f\lambda$. Light and sound are examples of traveling waves, albeit very different kinds of waves.

A *standing* wave is caused by superposing two similar (same frequency and wavelength) traveling waves, moving in opposite directions. The adjacent figure shows a vibrating string. At the fixed ends the traveling waves are reflected.



If the wave's size is just right

we see nodes where there is no motion or variation at all. The "just right" condition is that the string's length is a half-multiple of the wavelength: $n\lambda/2 = L/\lambda, n=1,2,\dots$. A vibrating string is an example of a *transverse* wave: its oscillation is perpendicular to the direction of its velocity. On the other hand, a sound wave is a *longitudinal* wave: its oscillation is in the same direction as its velocity. These waves have similar properties, but they are quite different as you will see.

EXPERIMENT

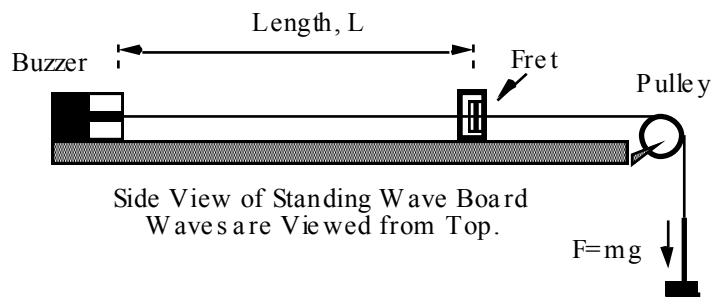
On the standing wave board shown below, a buzzer vibrates a string with a frequency of 120 Hz. Because the motion is perpendicular to the direction of propagation, these are *transverse* waves. Both ends of the string are fixed; thus, a standing wave will be set up with each end being a **node**, a location of minimum displacement. This requires that L , the length of the string, must be equal to any whole number of half-wavelengths:

$$L = n(\lambda/2) \text{ where } n=1,2,\dots \quad (1)$$

Although the buzzer end of our string is vibrating, its amplitude is so small that the end is a good approximation of a node. Standing waves will appear between the buzzer end and the moveable fret.

The wave velocity depends on the tension and material (density and diameter) of the string. Their relation is given by

$$c = \sqrt{\frac{T}{\mu}} \quad (2)$$



where T is the tension produced by the suspended mass ($T = mg$), and μ is the *linear density* of the string (mass per unit length). For a particular string (fixed μ), changing T by varying m enables us to verify the square root dependence of wave velocity. For a given string with linear density μ and tension T , the velocity c is fixed. The frequency f is given by the buzzer (120 Hz). If both ends of the string are fixed, a standing wave will be produced when

$$L = n \frac{\lambda}{2} \quad (3)$$

Turn on the buzzer. Notice how standing wave resonances develop and disappear as you move the fret through points where Eq.(3) is satisfied. Produce a large transverse standing wave by choosing an appropriate L. Using a meter stick, determine the distance between nodes by measuring the length between the most widely separated nodes and then dividing by the number of segments in that length. Find as many patterns as possible for a given tension. Ideally, you will take data for at least four different lengths, but this may not be possible for some tensions. Change the tension and repeat. Use at least three different tensions. The hanger alone may give a nice standing wave pattern.

Generally, standing waves are set up more easily if the fret is lined up with the edge of the standing wave board, but don't be afraid to move it off axis if that doesn't work. Note that the position of the node is actually the position of the pin inside the fret block. Be sure that the wire contacts the pin, not the sides of the block.

You don't want the fret to be too close to the buzzer. If you hear a loud buzzing sound this indicates the presence of harmonics. They are present because the buzzer is not driving the string with a pure sine wave, rather it resembles a square wave. These harmonics will claim some of the total energy thus reducing the amplitude of the standing wave associated with the fundamental. This may lead you to measure several times as many half-wavelengths should you confuse a harmonic standing wave for the fundamental. In this case, if you use 120 Hz as the frequency in your calculation rather than the integral multiple of 120 Hz associated with the harmonic, you will underestimate the wave velocity. It is therefore best to look for large amplitude standing waves. The use of heavier weights will result in a more sinusoidal driving force, but will also reduce the number of measurements possible.

For each tension determine $\lambda/2$ and thus your experimental value of c (for that tension). The most accurate results are obtained by using the longest length of string.

In order to calculate the theoretical value of c for each tension, record the tension T (do not forget the weight of the hanger) and the linear density μ . Use the appropriate SI units for the tension force and for the value of g . The linear density of the string is nominally 2×10^{-4} kg/m.

Compare the experimental and theoretical values of c for each tension.

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Name: _____ Section: _____

Partner: _____ Date: _____

Transverse Waves. $\mu = 2 \times 10^{-4}$ kg/m Driving frequency $f =$ _____

Tension T_1 _____ (T = force; f = frequency) $\lambda/2 = L/(\text{\#of half waves})$

L vibrating length	n # half-waves in L	λ/2 L/n	$c_{\text{exp}} = f\lambda$
$\bar{c}_{\text{exp}} :$			

Theoretical wave velocity $\sqrt{\frac{T}{\mu}}$ (show calculation) $c_{\text{th}} =$ _____

Ratio $R = \bar{c}_{\text{exp}} / c_{\text{th}} =$ _____

Tension T_2 _____

L vibrating length	n # half-waves in L	λ/2 L/n	$c_{\text{exp}} = f\lambda$
$\bar{c}_{\text{exp}} :$			

Theoretical wave velocity $\sqrt{\frac{T}{\mu}}$ (show calculation) $c_{\text{th}} =$ _____

Ratio $R = \bar{c}_{\text{exp}} / c_{\text{th}} =$ _____

Tension T_3 _____

