STANDING WAVES
ON A STRING

The objectives of the experiment are:

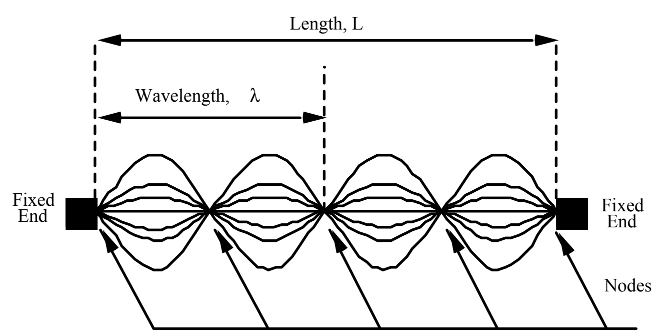
- To show that standing waves can be set up on a string.
- To determine the velocity of a standing wave.
- To understand the differences between transverse and longitudinal waves.

APPARATUS: Function generator, speaker, tube with rod, buzzer board with string, meter stick, weight holder, weights.

INTRODUCTION

A travelling 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 waves' 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: $n/2 = L/\lambda, n = 1, 2, \ldots$. 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.



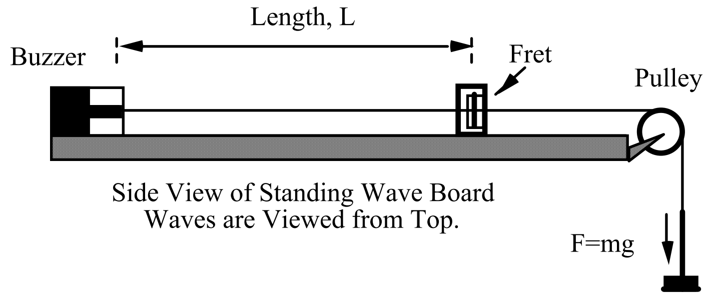
EXPERIMENT

PART A: STANDING WAVES ON A STRING

On the standing wave board shown on the next page, 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:

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

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.



Side View of Standing Wave Board
Waves are Viewed from Top.

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

$$c = \sqrt{F/\rho}, \quad (2)$$

where F is the tension produced by the suspended mass ($F = mg$), and ρ is the *linear density* of the string (mass per unit length, not volume). For a particular string (fixed ρ), changes in F by varying m enables us to verify the square root dependence of wave velocity. For a given string with linear density ρ and tension F, 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, and only when,

$$L = n\lambda/2 \quad (3)$$

Turn on the buzzer. Produce a large transverse standing wave by varying L (move fret along string). 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. Change the tension and repeat. Use at least three different tensions. The hanger alone may give a nice standing wave pattern.

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 F (do not forget the weight of the hanger) and the linear density ρ. 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.

STANDING WAVES ON A STRING

Name: ____ Date: __________

Partner: ____

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

Tension F_1_____ (F = force; f = frequency) $\lambda/2$ = L/(#of half waves)

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

Theoretical wave velocity $\sqrt{F/\rho}$ **(show calculation)** c_{th} = ______

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

Tension F_2_____

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

Theoretical wave velocity $\sqrt{F/\rho}$ **(show calculation)** c_{th} = ______

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

Tension F3_____

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

Theoretical wave velocity $\sqrt{F/\rho}$ **(show calculation)** **c_{th}** = ______

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

Question

From the above experiment what predictions can you make about the wires (strings) in a piano.

What can you say in general about the thickness of the wires for the low frequencies? Why?

What can you say in general about the tension in the strings at the high frequencies? Again, why? Justify your answers on the basis of physical principles.