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TOOLS THAT TEACH.

Instructional Guide

Transverse Wave String

Introduction to standing waves

Part# P7-1500-03

Contents:

1 ea. 7 foot elastic string
1 ea. String holder
1 ea. Hook holder
1 ea. Allen Key

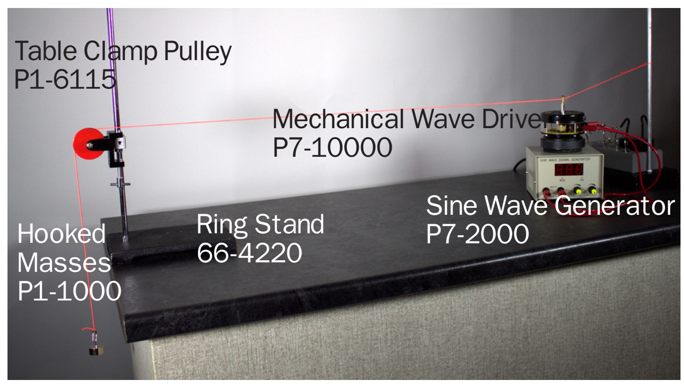
Required but not included:
Sine Wave Generator
Mechanical Wave Driver

Teacher's Background Knowledge

Wave Interference: When two longitudinal waves coming from different directions, cross and pass through each other their crests and trough can combine together increasing or decreasing the amplitude of the wave displacements. The observed overlapping appearance is called an interference pattern. For instance, when formed along a one dimensional rope or spring, this can produce a pattern called a standing wave. Tie a rope to a wall and shake it and the wave reflected from the wall will come back and interfere with the following waves moving toward the wall. At the right frequencies a standing wave forms with parts standing still along the rope called nodes. Antinodes in contrast, form in regions of maximum displacement where the waves from opposite direction cross and add together constructively.

Introduction to the Apparatus

An impressive demonstration of standing waves on a string for your students is easily produced in the classroom using the Mechanical Wave Driver along with the Sine Wave Generator. Going further, the students can directly measure the length of the waves from the standing wave pattern and confirm the wave equation $v=\lambda f$ using the frequency value from the Sine Wave Generator. With the wavelength and the frequency, the speed of the waves along the string can be calculated. Later this speed value can be compared to theoretical speed calculated from the physical properties of the medium (string).



Set up the experiment as shown above.

1. Fasten the neon red string to a fixed post or ring stand making sure it is slightly higher than the Mechanical Wave Driver.
2. Thread the string through the hole in the string holder inserted in the Wave Driver.
3. Fasten the pulley (part # P1-6115) on a ring stand approximately 2 meters from the string holder.
4. Thread the string over the pulley making sure it is clear of the table and attach a hooked mass.

Getting Familiar / Experimenting

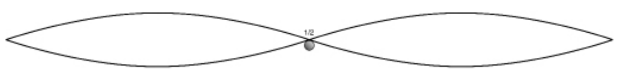
Your students will use the wave equation $v=\lambda f$ to calculate and predict the speed of the waves traveling back and forth along the string. After the apparatus is set up as shown above, the frequency and amplitude of the driver can be adjusted to produce standing waves with maximum amplitudes.

Observations and Taking Data

Measuring wave speed along the string:
Start at a low frequency and slowly increase the value through turning the frequency nob. The frequency which produces the longest standing wave is called the fundamental and has the appearance as shown in the diagram below.

Fundamental

At this lowest standing wave frequency, called the fundamental, the length of the standing wave is twice the length of the string. The fixed ends of the string are points called nodes and the center of the string, where the string moves up and down with maximum amplitude is called the antinode. Now increase the frequency until the next standing wave appears. This should occur at a frequency twice the value of the fundamental frequency and is known as the second harmonic. As shown below, there should now be two antinodes formed.



2nd Harmonic

The distance from antinode to antinode or from node to node is half a wavelength. Have the student measure and record either of both of these lengths. If both are measured, average their value and multiply it by two to get the wavelength. From the display on the Sine Wave Generator record the frequency producing this standing wave.

frequency (2nd harmonic) ___________ Hz Wave length _________________ m

Calculate the wave speed from the wave equation showing the substituted values:

v = (   ) x (   ) = _________ m/s

Now, increase the frequency of the generator to produce standing waves of higher frequency and shorter wave length. If the length of string and tension have not been changed the wave speed should remain relatively constant. Using the same procedure above, measure and calculate the wave speed again.

Within the uncertainty of measurements, how do these new values compare?

Going Further

The speed of the waves on the string in the above experiment is determined by the physical characteristics of the string. That is, the string density (m/L) in kg/m and the string tension (T) in Newtons.

The equation that relates these values is:

$$v = \sqrt{\frac{T}{m/L}}$$

The string tension (T) is produced from the weight of the hanging mass as shown in the diagram. For instance, if a 100 g mass is used, the tension represented by "mg" would be 0.98 N. For the linear string density, measure the length (L) of the string and divide it by its mass (m). Record these values below and calculate the predicted wave speed.

T = ___________ N   m = ___________ kg   L = ________________ m

Calculate the Wave Speed: (show the equation and substitution below)

v = ____________ m/s

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