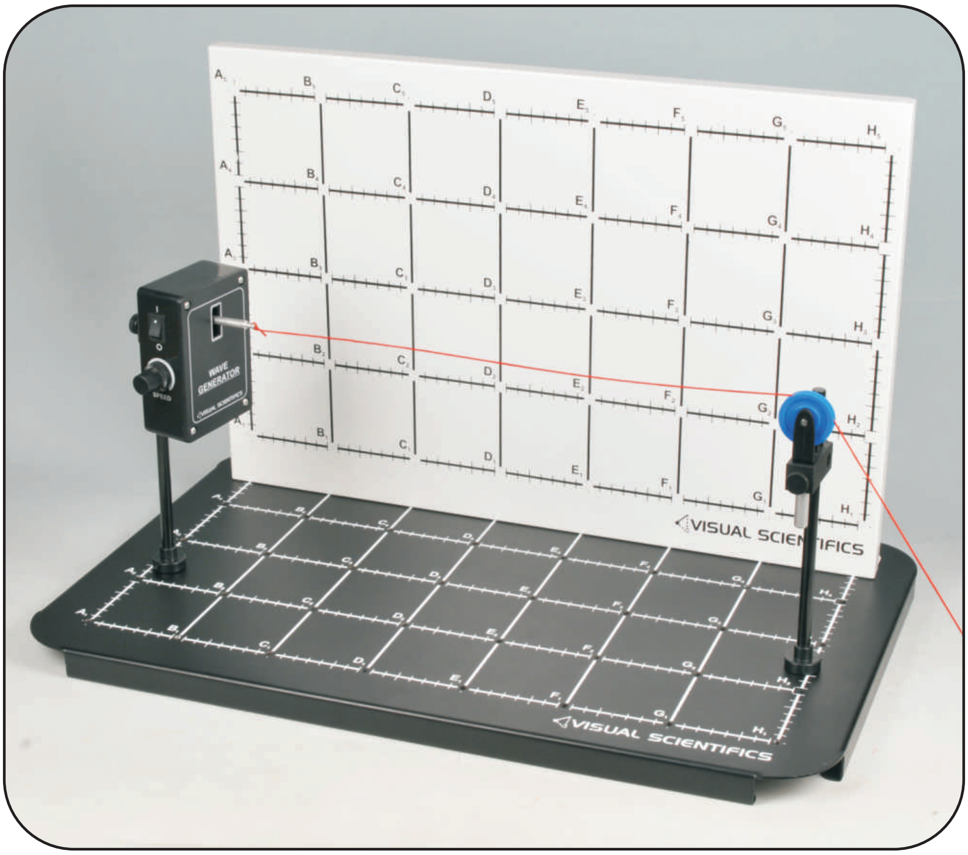
LABORATORY MANUAL & STUDENT WORKSHEET

Standing Wave Demonstrator



VISUAL SCIENTIFICS

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Product Number PTWDA

GENERAL BACK GROUND:

A wave is energy that travels from one location to another. As the energy passes by a particular point in space, it moves or jiggles the particles it is traveling through. There are two types of waves commonly studied in high school and middle school courses: transverse and longitudinal. If a particle is jiggling perpendicular to the direction that the wave is traveling this is called a transverse wave. To help students remember this, the T in transverse is the symbol for perpendicular upside down. When the particle jiggles back and forth parallel to the direction the wave travels, this is called a compression or longitudinal wave. To help remember this, the first 'l' and the last 'l' in longitudinal make the symbol for parallel lines.

Although superposition is a phenomenon that occurs in both longitudinal and transverse waves, we will concern ourselves with transverse waves for this apparatus. We will look at superposition in transverse waves as well as review some other wave terminology to help us explain what a standing wave is.

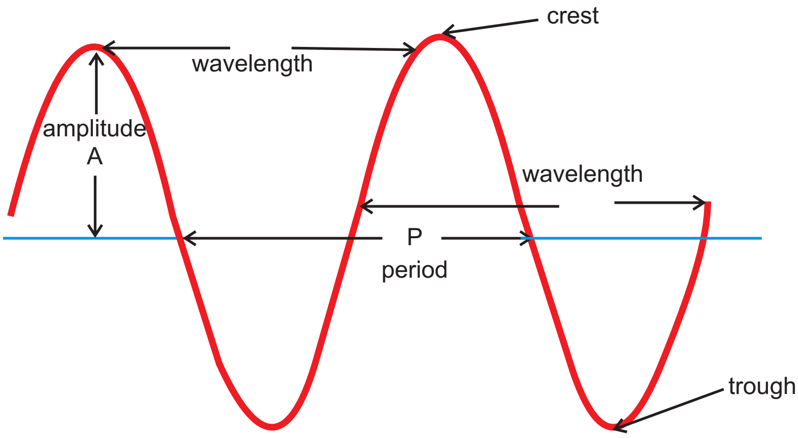


Diagram 1

The amplitude 'A' of a wave is the maximum displacement of a particle from its original rest position. The wavelength or ‘ ’ of a wave is the distance between two corresponding points of a wave. The period 'P' of the wave is the amount of time it takes for a particle to go through one complete cycle and return back to the position it was when it started. The crest is the highest point of the wave and the trough is the lowest part of the wave.

The frequency of a wave 'f' is the number of cycles a wave goes through in one second. Written as a formula,

$$f = 1/P \quad \text{or} \quad P = 1/f$$

Equation 1

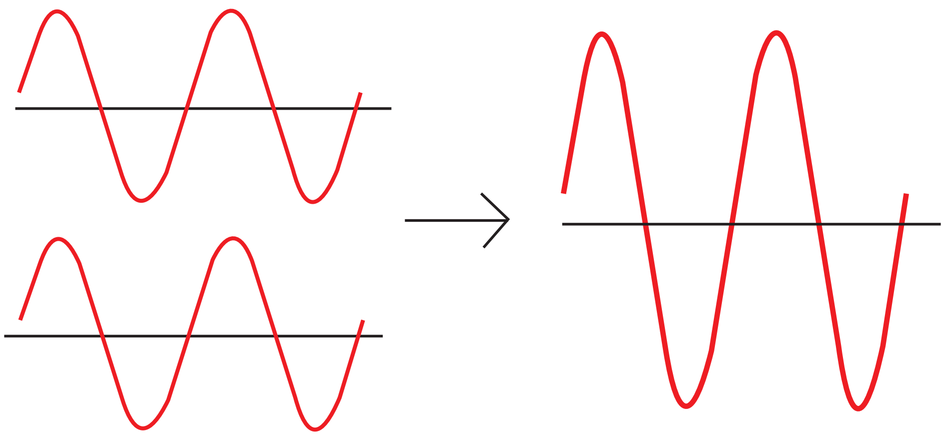
The speed of a wave 'v' is given by the formula

$$v = f$$

Equation 2

Interference is a property of waves by which two waves, when occupying the same space at the same time, will either add together (constructive interference) or cancel each other out (destructive interference). After the waves pass by each other they retain their original properties.

Constructive Interference



Destructive Interference

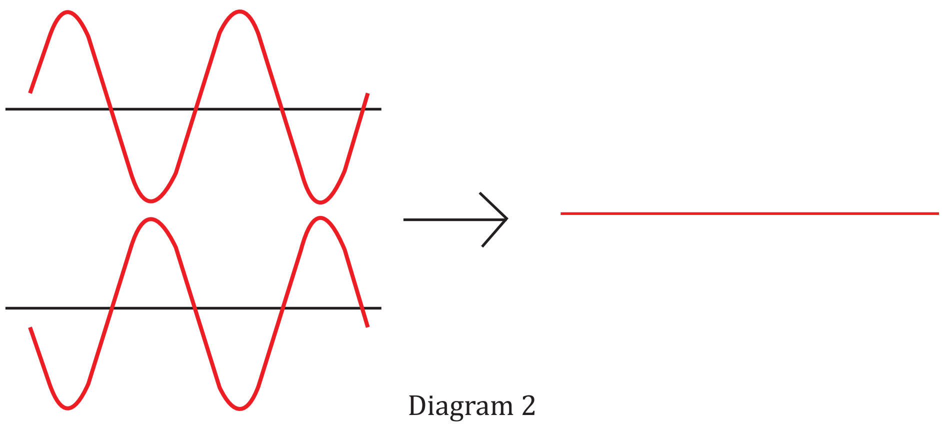


Diagram 2

Amplitudes of waves that are in phase add together to form a larger amplitude. Amplitudes of waves that are out of phase can cancel each other out to form smaller amplitudes.

A standing wave occurs when an object of finite length is vibrated so that points of complete constructive and complete destructive interference occur on the object being vibrated.

The places of complete constructive interference experience the most displacement and are called anti-nodes. The places on the object that experience destructive interference and never move are called nodes as shown in diagram.

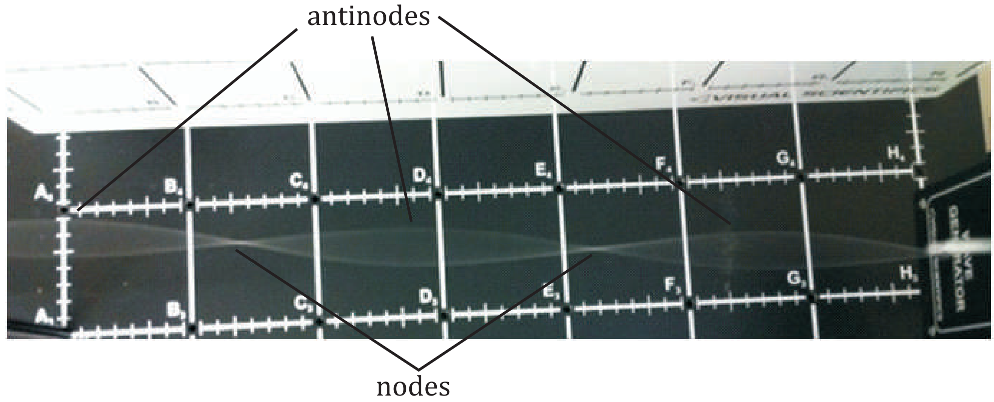


Diagram 3

For the standing waves on this apparatus, sometimes there is one “closed” end of the string (a part that does not vibrate) and one “open” end of the string. The “open” end of the string is an anti-node and exists at the metal bar where the string is being vibrated. The“closed” end, or an antinode, which is where the string meets the pulley, does not vibrate at all and is always a node.

Sometimes however, the metal vibrating bar acts as a node. This is important to keep in mind when doing the following calculations.

The velocity of a wave traveling in a string is given by the equation:

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

Equation 3

Where 'v' is the velocity of the wave, 'T' is the tension in the string, 'm' is the mass of the string being vibrated (any mass left over should not be added into the calculation), and 'L' is the length of the string used. The mass per unit length of each individual string is a constant and can vary depending on the 'T' tension on the string.

To use this apparatus we are able to change the frequency of the vibrations, the mass per unit length of the string, and the tension on the string. We therefore need equation 3 in a form we can more easily manipulate.

Setting equations 2 and 3 equal to each other yields:

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

Equation 4

The wavelength of the wave is some fraction or multiple of the length of the string. The diagrams below shows the first few possible wavelengths and then how to calculate the frequency from there by getting the wavelength in terms of the length of the string and then substituting that into equation 4.

Diagram 4- Situation 1

If your standing wave looks like the wave in diagram 4, then the wavelength of your wave is four times the length of your string. Written mathematically:

$$4L =$$

Equation 5

If we plug equation 5 into equation 4 and solve for frequency, we have a very useful formula.

$$f = \frac{\sqrt{\frac{T}{m/L}}}{4L}$$

Equation 6

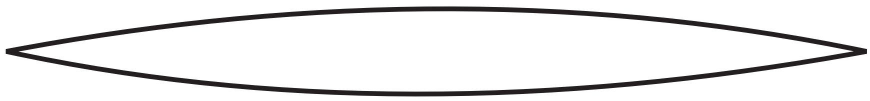


Diagram 5 – Situation 2

If your standing wave looks like the wave in diagram 5, then the wavelength of your wave is twice the length of your string. Written mathematically:

$$2L =$$

Equation 7

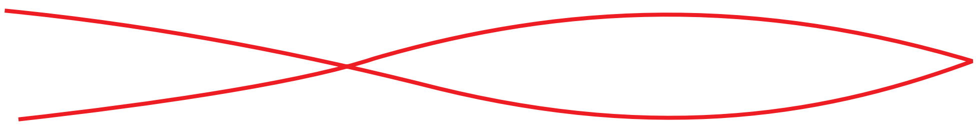


Diagram 6 – Situation 3

If your standing wave looks like the wave in diagram 6, then the wavelength of your wave is four thirds the length of your string. Written mathematically:

$$\frac{4L}{3} =$$

Equation 8

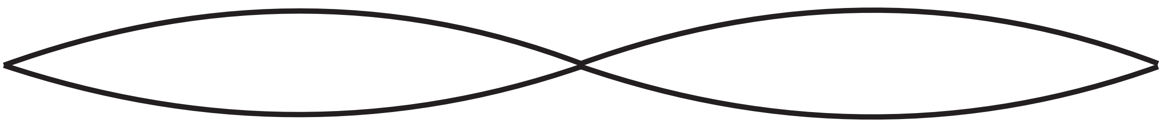


Diagram 7- Situation 4

If your standing wave looks like the wave in diagram 7, then the wavelength of your wave is the same as the length of your string. Written mathematically:

$$L =$$

Equation 9

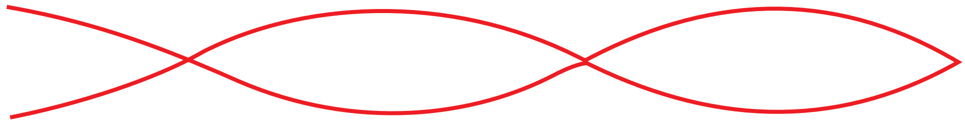


Diagram 8 – Situation 5

If your standing wave looks like the wave in diagram 8, then the wavelength of your wave is four fifths the length of your string. Written mathematically:

$$\frac{4L}{5} =$$

Equation 10

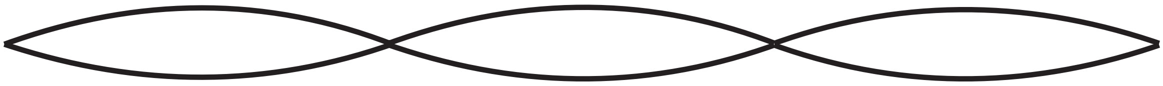


Diagram 9 –Situation 6

If your standing wave looks like the wave in diagram 9, then the wavelength of your wave is two thirds the length of your string. Written mathematically:

$$\frac{2L}{3} =$$

Equation 11

The pattern continues as more nodes and anti-nodes are added.

Warning: Photo-Induced Epilepsy

In all work with flashing lights, teachers must be aware of any student suffering from photo-induced epilepsy. This condition is very rare. However, make sensitive inquiry of any known epileptic to see whether an attack has ever been associated with flashing lights. If so, the student could be invited to leave the lab during experiments requiring the stroboscope. It is impractical to avoid the hazardous frequency range (7-15 Hz) in these experiments.

Next Generation Science Standards:

- HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Disciplinary Core Ideas

PS4-A: Wave Properties:

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.

Science and Engineering Practices

- Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.