Waves and Sound-1

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Items:

1. Types of Waves
2. Periodic Waves
3. Wave Equation

Waves

We live surrounded by waves.

Some are visible such as water waves.

Some are invisible such as sound and radio waves.

Visible and invisible waves have some characteristics in common.

All waves originate from a vibrating source.

Definition

A wave is a transfer of energy through a medium in the form of a disturbance.

A wave is a traveling **disturbance**.

A wave carries **energy** from place to place.

Types:

Waves are usually described as **periodic waves**, where the motions are repeated at regular time interval in a simple harmonic motion.

There are two types of wave: longitudinal waves and transverse waves.

But a wave can also consist of a single disturbance called a **pulse**, or shock wave.

A Pulse.

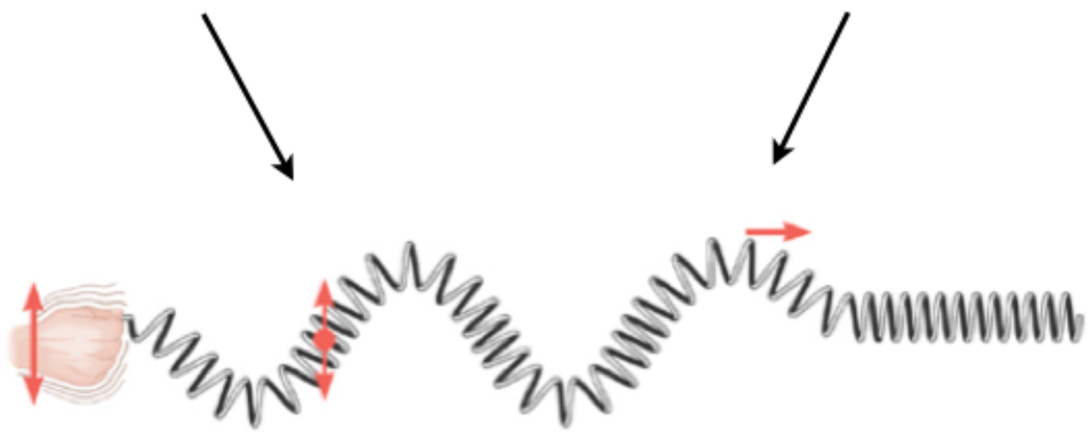
If you hold one end of the Slinky with your hand and move your hand up and down, you can create a pulse or a single wave that will travel along the Slinky, away from you as illustrated below:

Transverse Wave -

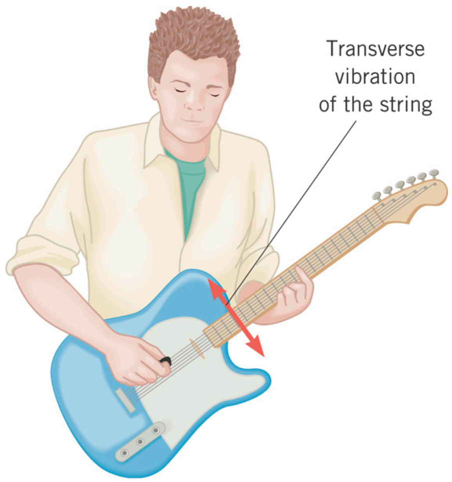
the “disturbance” caused by the wave moves **perpendicular to** the direction that the wave propagate. Below is a pulse representation of a transverse wave.

The particle of the medium (disturbance) moves up and down.

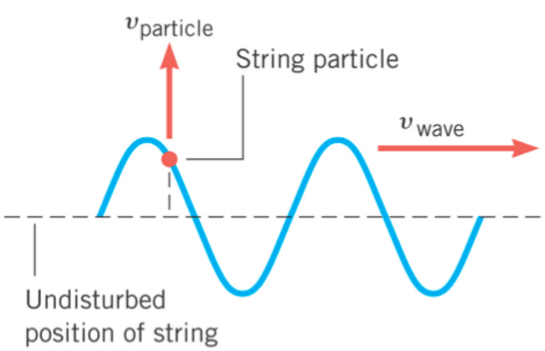
The wave travels in a straight line to the right.



Example of Transverse Wave: Transverse waves travel on each string of an electric guitar after the string is plucked.



The speed of the particle v_{particle} changes from moment to moment as the wave passes.



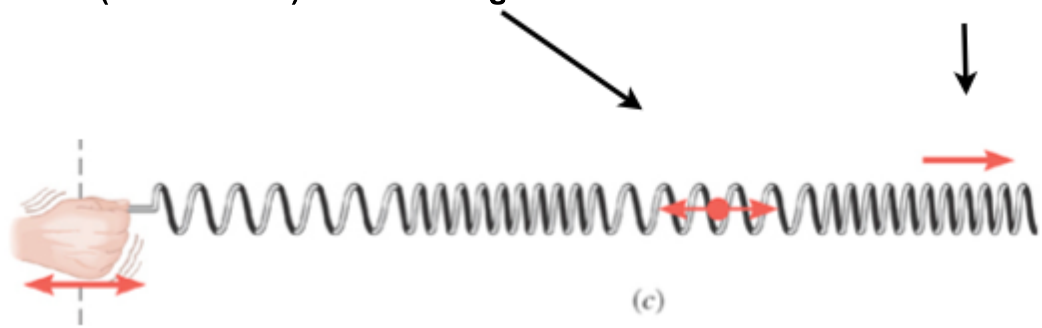
Longitudinal Wave -

The “disturbance” caused by the wave moves **along** the direction that the wave propagates, e.g., sound waves, “compressed slinky waves”....

Below is a pulse representation of a longitudinal wave.

The particle of the medium (disturbance) moves straight.

The wave travels in a straight line to the right.

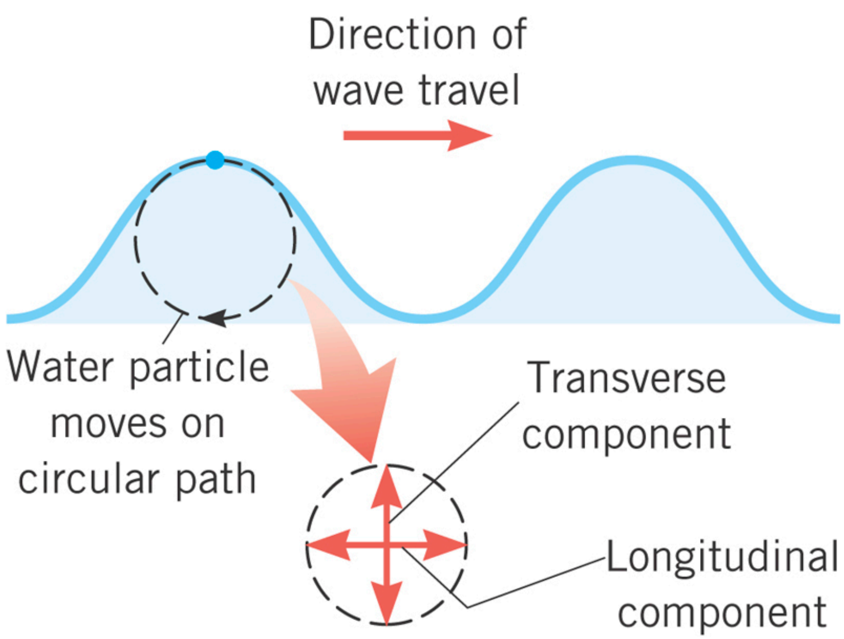


(c)

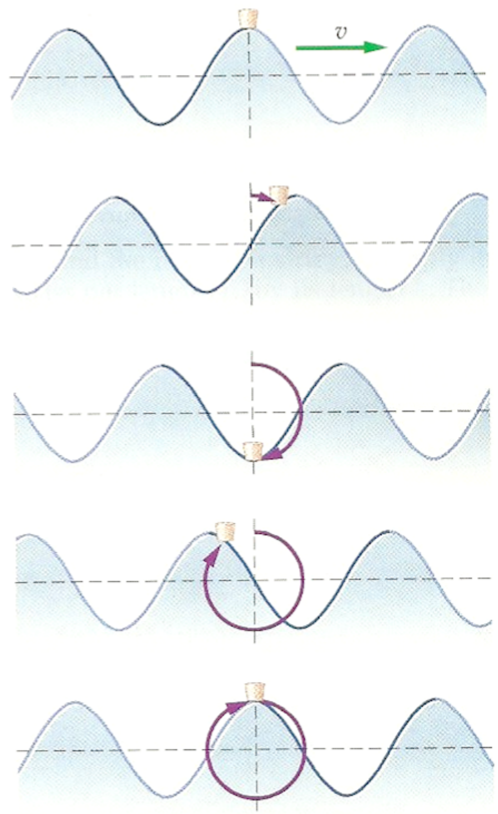
Water Waves

Water waves are partially transverse and partially longitudinal.

The water particles at the surface move clockwise on nearly circular path as the wave moves from left to right.



Visualizing the movement of water wave travel.



The cork moves in a roughly circular path, returning approximately ti its starting point.

Terminology of Periodic Waves:

The terminologies used to describe periodic waves are :

1- cycle,

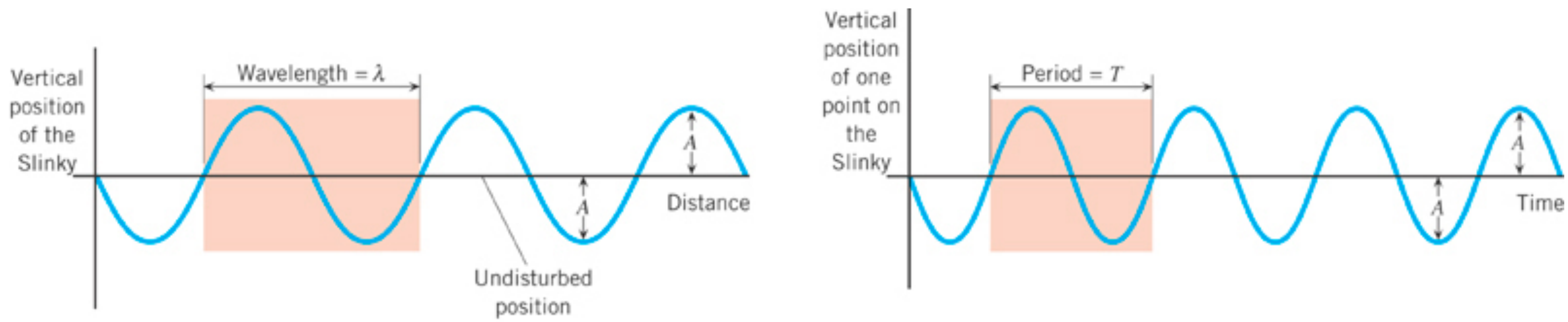
2- amplitude *(A)*

3- wavelength (λ)

4- period (T *)* and

5- frequency *(f)*

Figures (a) and (b) below, are graphical representations of a transverse wave on a slinky.



(a) At a particular time

(b) At a particular location

Figure (a) shows a graph in which distance is plotted on the horizontal axis. Figure (b) shows a graph in which time is plotted on the horizontal axis.

In figures (a) and (b) the ***amplitude*** (A) is the maximum excursion of a particle of the medium from the particles undisturbed position.

In the drawings (a) and (b), one ***cycle*** is shaded in color.

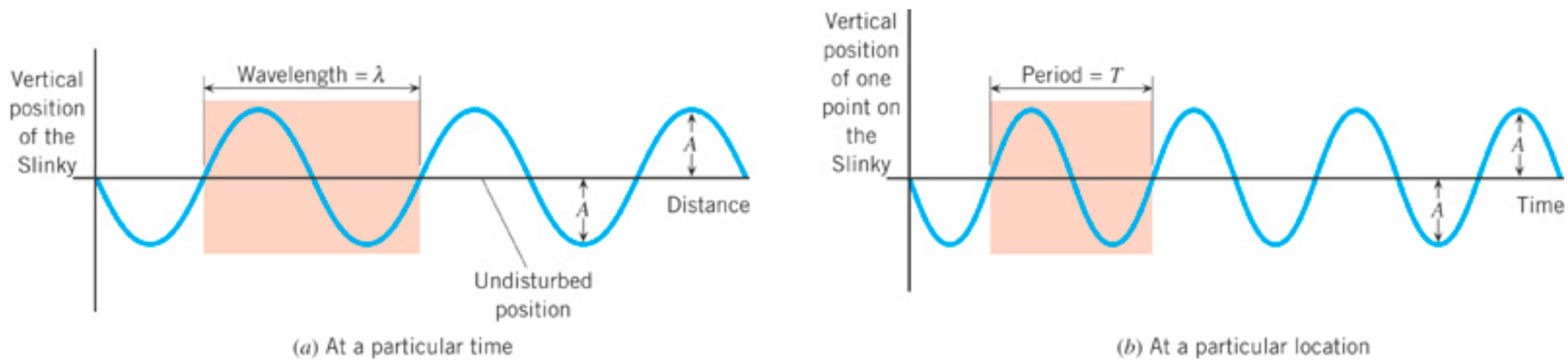


Figure (a): The distance is plotted on the horizontal axis.
The ***wavelength*** (λ) is the horizontal length of one cycle of the wave. It is the distance between two successive equivalent points.

Figure (b:The time is plotted on the horizontal axis.
The ***period*** (T) is the time required for one complete cycle. It is the time required for the wave to travel a distance of one wavelength. The unit of period is second (s)
The ***frequency*** (f) is the number of wave cycles per second that pass an observer. It is the reciprocal of the period (T). The unit of frequency is Hz or s^{-1}.

Frequency (f)	**Period (T)**
Frequency = cycles / time $f = 1/T$	Period = time / cycles $T = 1/f$

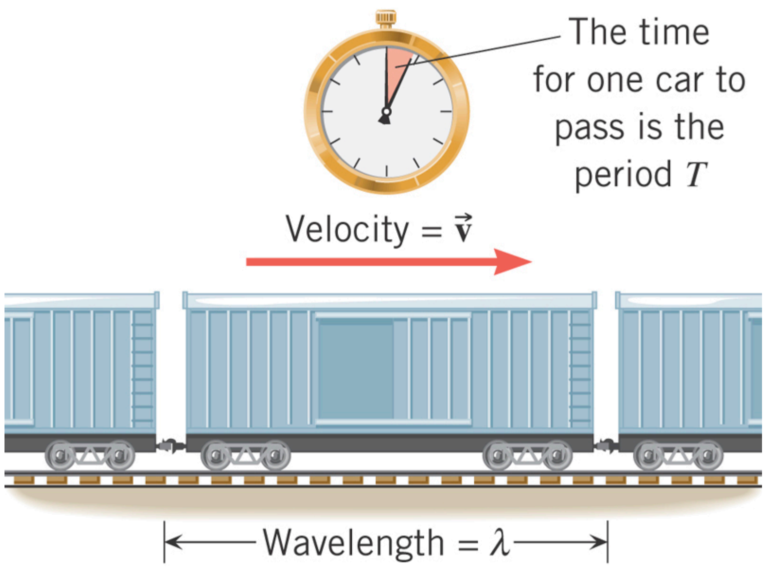
It is the source alone that determines the frequency of the wave.

The frequency and period of a wave are the same as those of the source, and they are not affected by changes in the speed of the wave.

Once the wave is produced, its frequency never changes, even if its speed and wavelength do. The behavior is characteristic of all waves.

Moving Train as Analogy for Traveling Wave.

A train moving at a constant speed is an analogy for a traveling wave.
The motion of a long train can be viewed as a periodic wave which repeats itself with the passing of each identical boxcars.
(wave = boxcar)
The train is a long line of identical boxcars. Each boxcar has a length (λ) and requires a time (T) to pass. v is the speed of a boxcar.



Wave Equation:

The wave equation is the relationship between the period (T) , the wavelength (λ), and the speed (v) of a wave. The propagation velocity or speed of a periodic wave is related to its frequency and wavelength.

Speed = distance / Time

Considering one wave:

$$v = \lambda / T$$

We know that:

$$f = 1 / T$$

So:

$$v = f\lambda$$

Wave Equation

Speed = Frequency x Wavelength

$$v = f\lambda$$

The unit of speed is m/s.

The wave equation applies to all waves, visible and invisible.

The speed of the a wave depends on the properties of the medium in which the wave travels. A change in the medium results in changes both in the speed of the wave and in its wavelength.

The speed of a wave is unaffected by changes in the frequency or amplitude of the vibrating source. If the frequency of a wave increases, the wavelength decreases provided that the medium does not change.

Practice Problems:

1. The wavelength of a water wave in a pond is 0.080 m. If the frequency of the wave is 2.5 Hz, what is its speed?

$$v = f\lambda$$

= (2.5 Hz)(0.080 m) = 0.20 m/s

2. The wavelength in a water wave is 4.0 m, and the crest travels 9.0 m in 4.5 s. What is the frequency of the wave?

$$v = f\lambda$$

$$f = v / \lambda$$

= 2.0 / 4.0 = 0.50 Hz.

3. The period of a sound wave from a piano is 1.18×10^{-3} s. If the speed of the wave in air is 3.4×10^{2} m/s, what is its wavelength?

$$v = \lambda / T$$

$$\lambda = v\,T$$

$$= (3.4 \times 10^{2})(1.18 \times 10^{-3}) = 0.40 \text{ m.}$$

References:

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Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current. www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

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