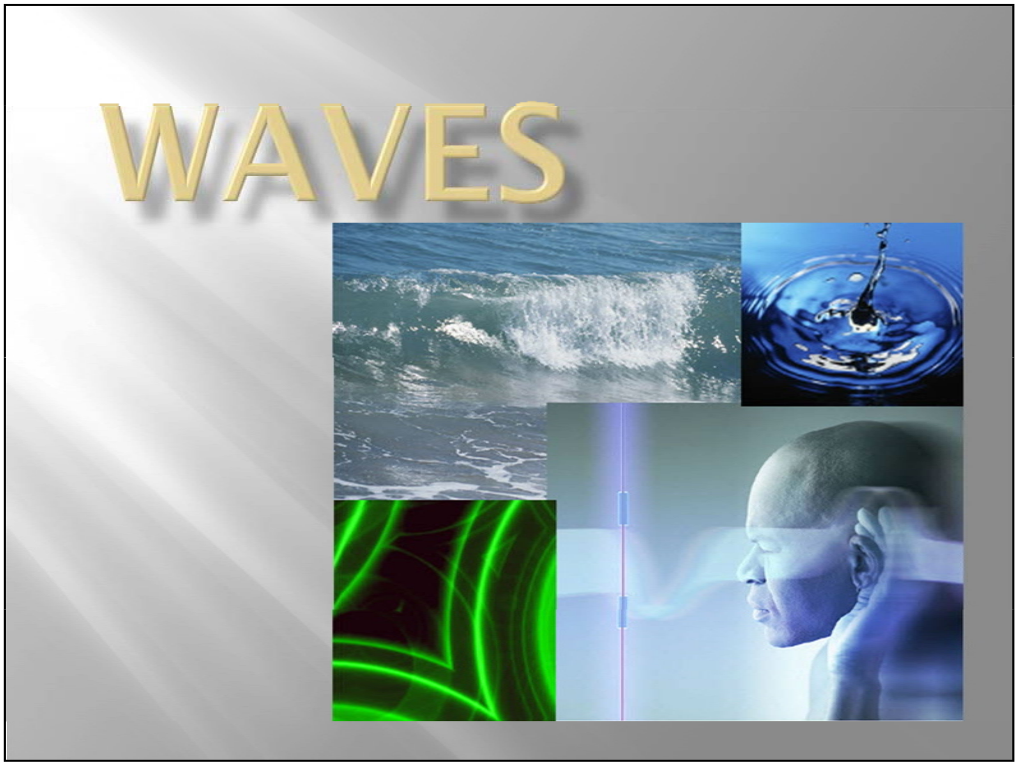
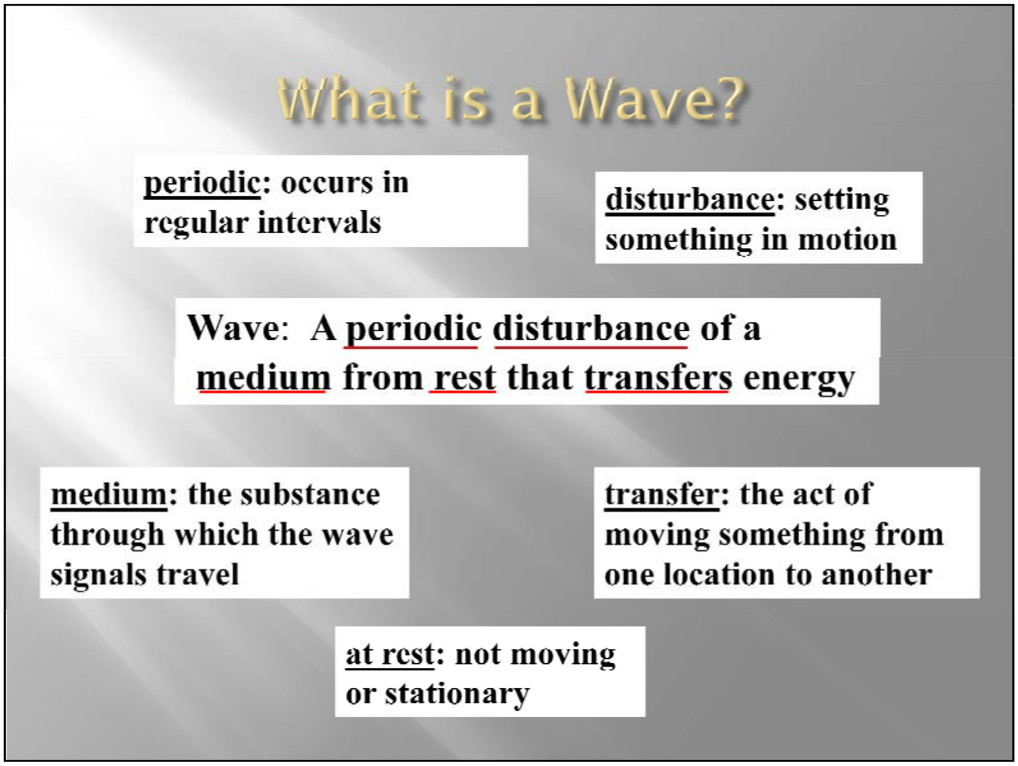
Module 6: Waves
Topic 1 Content: Waves Presentation Notes



Waves



Our study of waves begins with a definition. We will say that a wave is a periodic disturbance of a medium from rest that transfers energy. In order to make sense of this definition, let's look at each key word and define it.

Something that is periodic is something that occurs in regular intervals. To disturb is to set something in motion. A medium is the substance through which the wave signals travel. At rest means not moving or stationary. To transfer is the act of moving something from one location to another.

So you can see that a wave is something that regularly sets a substance in motion from it's previously stationary position and moves energy from one place to another. Our definition will apply to most types of waves, with a few exceptions.

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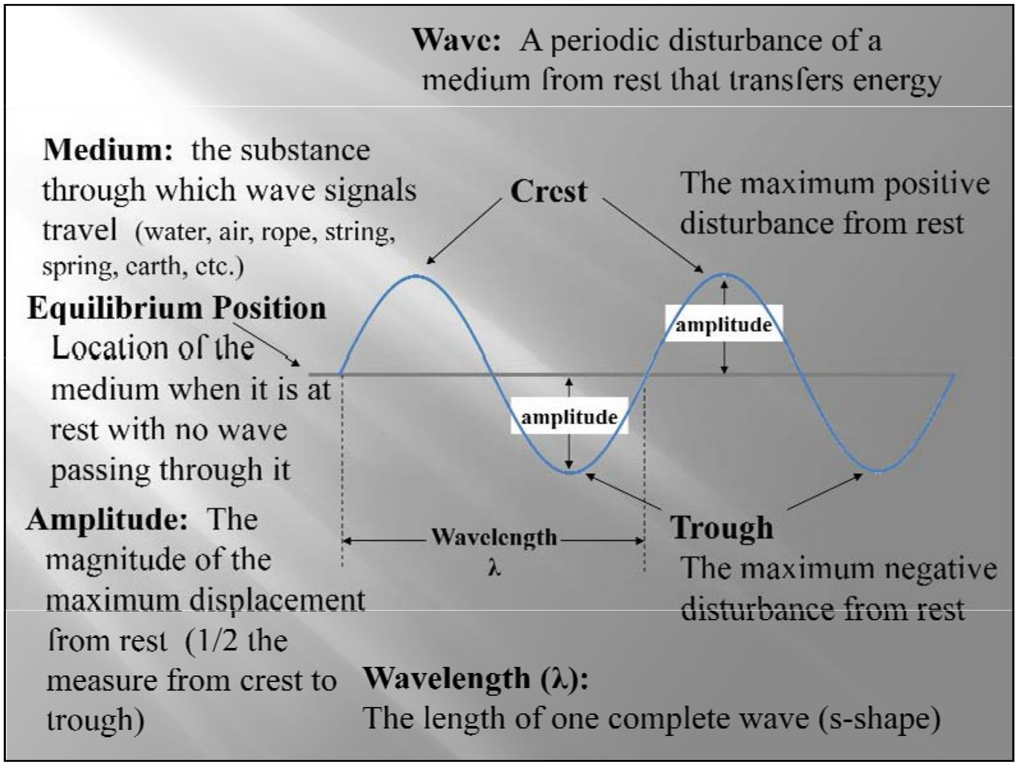


It is also important to become familiar with the terms we will be using to describe waves.

We start with the medium, which is the substance through which the waves or signals will travel. This can be water, air, rope, string, springs, the earth or just about any other substance. Waves can travel through different media and the same medium can carry different types of waves.

The medium begins at rest, in its equilibrium position. It is important to note where the equilibrium position of the medium is for later measurements.

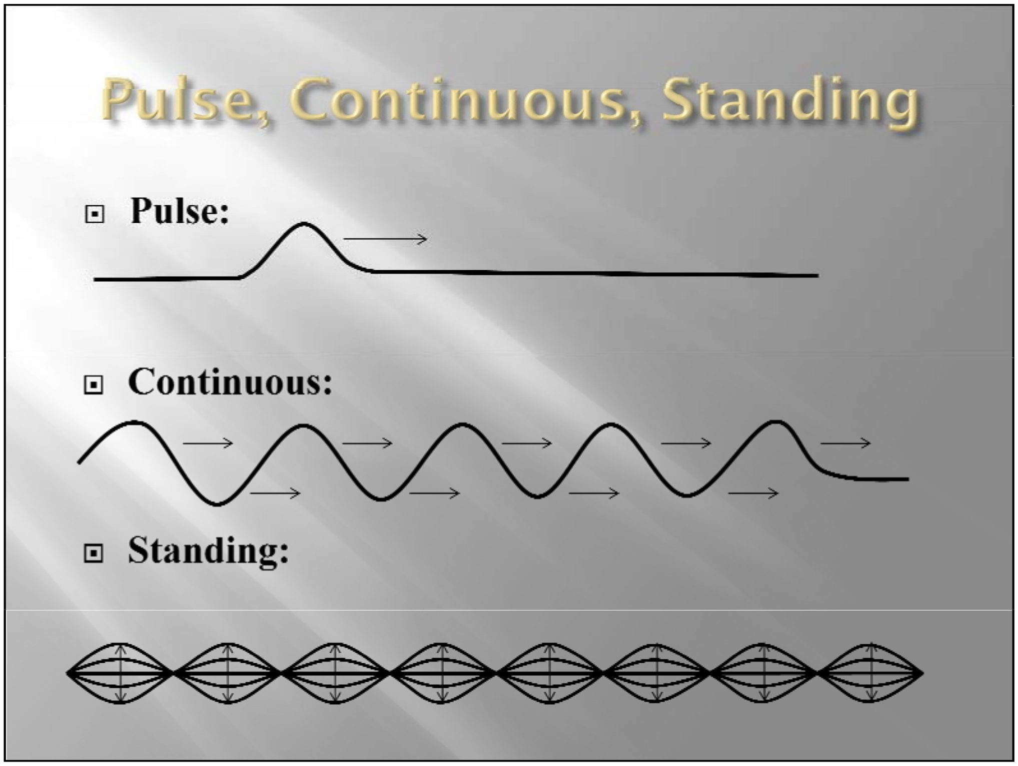
Now, we disturb the medium to produce a wave.

The high points of the wave, where the medium is disturbed a maximum positive distance are called crests, and the low points of a wave, where the medium is disturbed a maximum negative distance are called troughs.

The amplitude of a wave is the maximum amount the medium is displaced from rest. It is measured from the equilibrium position to the crest or trough. Some students will make the mistake of measuring the entire height of the wave from the bottom of the trough to the top of the crest, but this would be twice the amplitude.

The wavelength is the length of one complete wave. It must include one crest and one trough. It can also be determined by measuring the horizontal distance from crest to crest or trough to trough. The symbol used for wavelength is a lower case Greek letter lambda. If you look closely, you can almost see a wave shape in the lambda symbol.

Become familiar with these terms, as they will be used throughout this module.

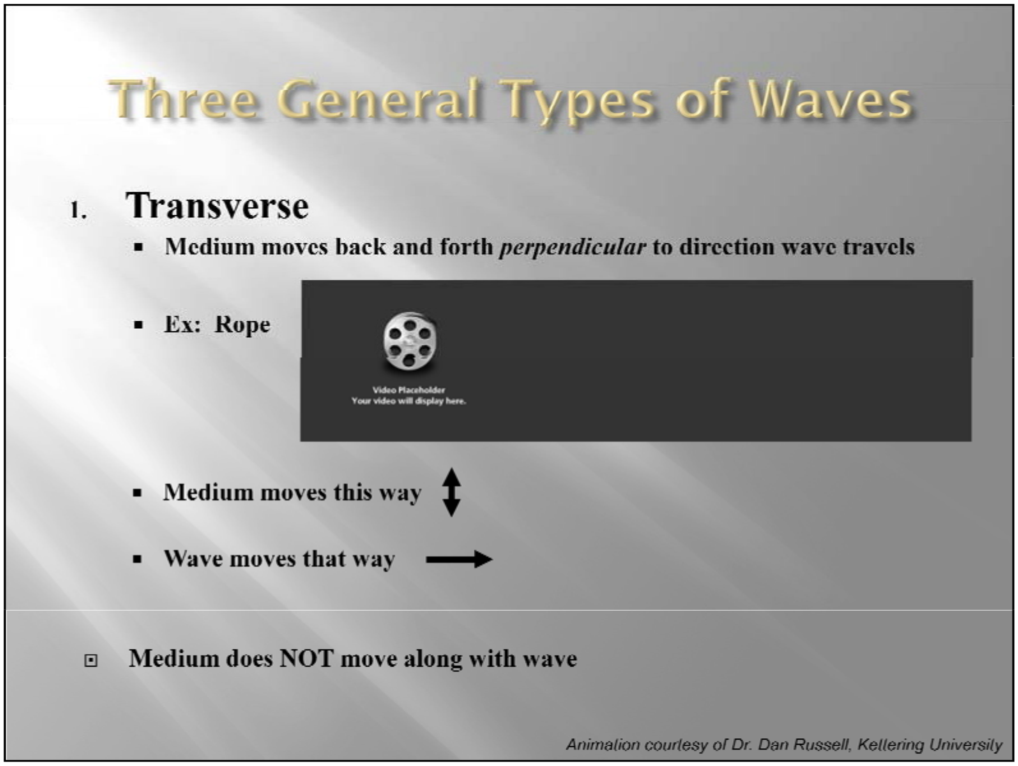


Waves can take the form of pulses, continuous waves or standing waves.

A pulse is a simple waveform, that looks like half a wavelength, that results from a single disturbance of the medium.

A continuous wave is how we would characterize most of the waves we will analyze. It is the periodic disturbance of the medium that sends energy in the direction the wave travels.

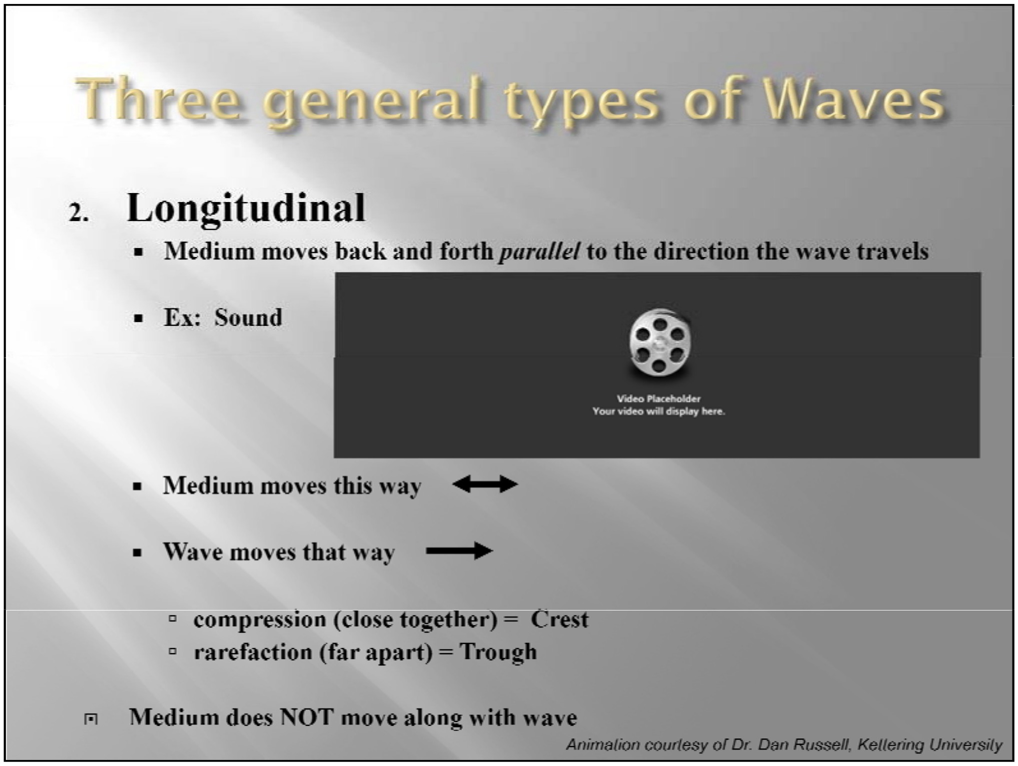
We also will encounter standing waves which have fixed positions along the medium that appear to be not moving. We will discuss the formation of standing waves in a later lesson.



There are also three general types of waves.

The first type of wave is a transverse wave. In a transverse wave, the medium vibrates in a direction that is perpendicular to the direction that the wave travels. An example would be the motion of a wave on a rope. If you jiggle the rope up and down, you send a wave travelling down the length of the rope. If you watch the animation carefully and focus on a single dot, you will notice that the dot moves up and down, while the wave shows an overall left to right motion.

Notice that the medium simply oscillates up and down in place, the medium has no net displacement and does not move along with the wave.



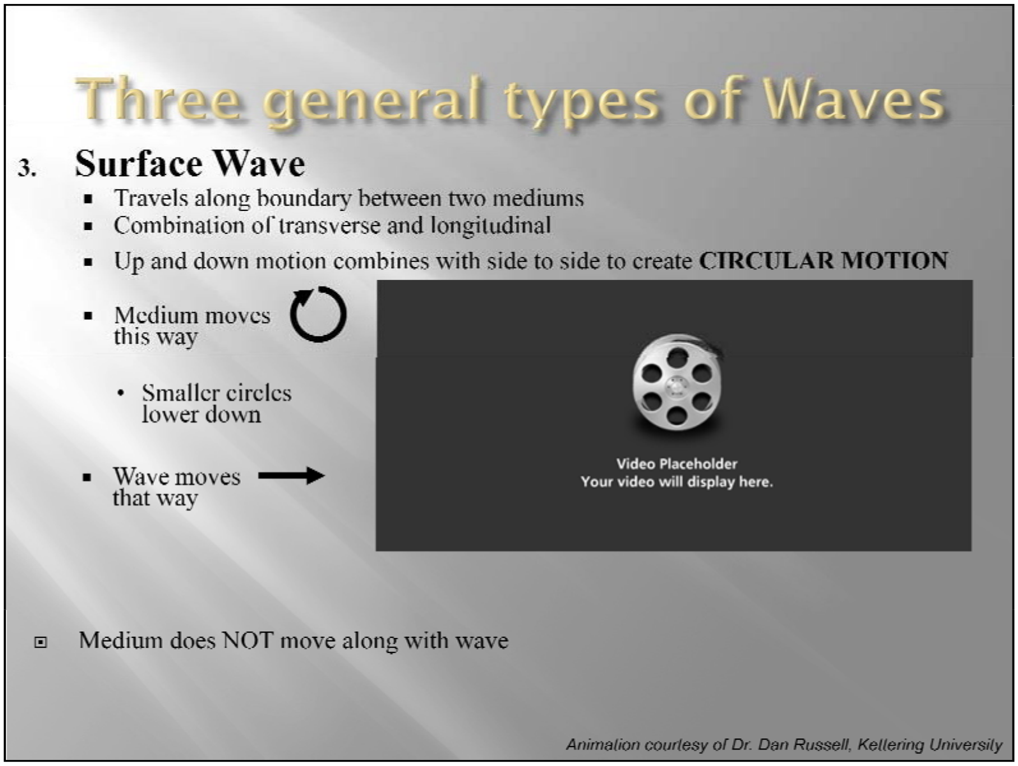
The second type of wave is a longitudinal wave. In longitudinal waves, the medium vibrates parallel to the direction that the wave travels.

Sound is a longitudinal wave of air pressure. The molecules of air vibrate back and forth, creating regions of high and low pressure.

If you focus on a single dot, you will see that it wiggles back and forth while the wave travels left to right.

The places where the particles of the medium are close together are called compressions. These regions of high pressure correspond to the crests of a transverse wave. The places where the particles of the medium are farther apart are called rarefactions. These regions of low pressure correspond to the troughs of a transverse wave.

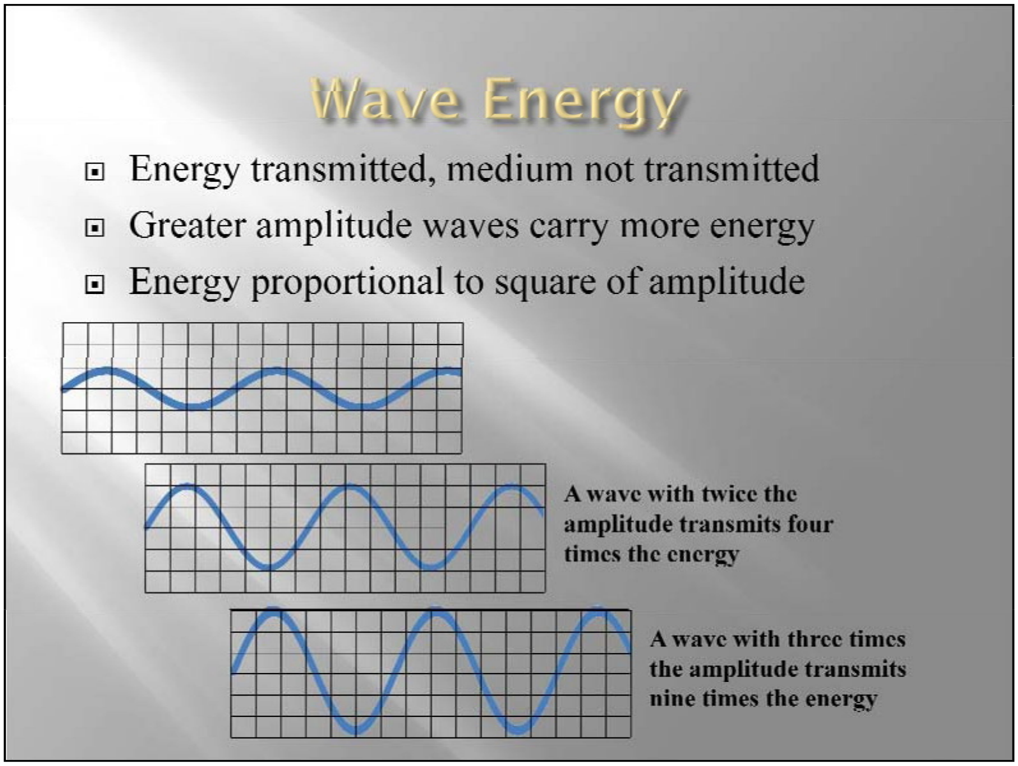
Again, you'll notice that the medium does not move along with the wave, but it simply oscillates back and forth in place.



The third type of wave is one that you find on the boundary between two different media. This is called a surface wave. The waves you see on a lake or out in the ocean are surface waves.

These waves exhibit characteristics of both transverse and longitudinal waves. A combination of up and down and side to side motion results in the particles of the medium each tracing a circular path as the energy of the wave passes through.

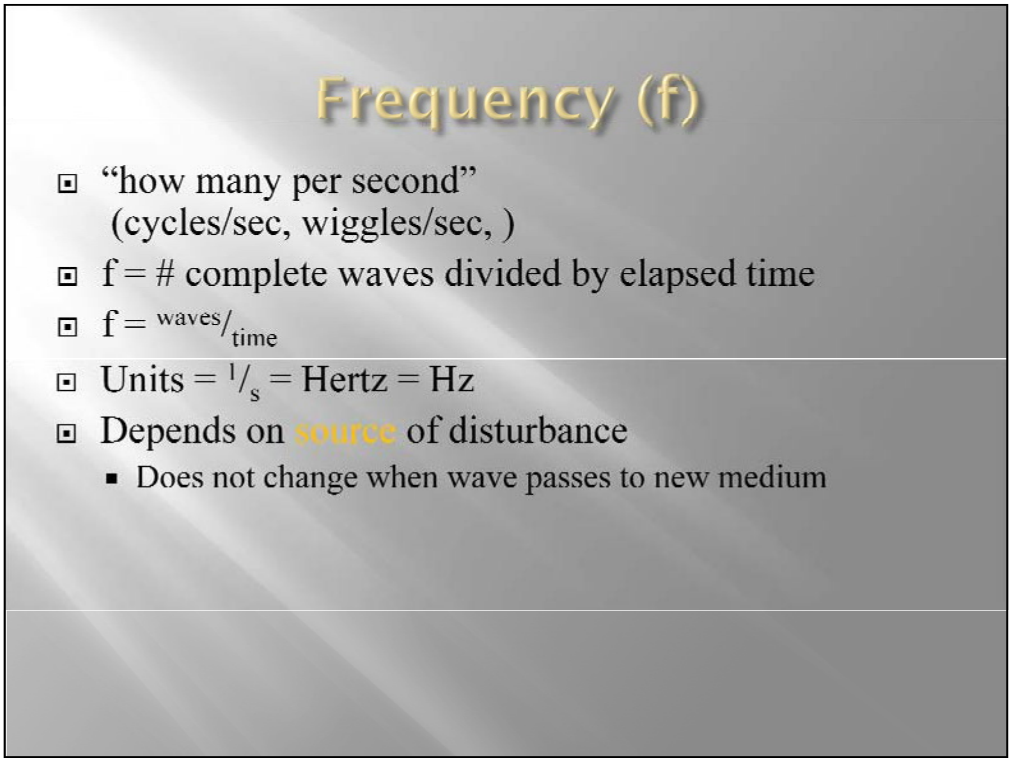
Again, note that the medium does not move along with the wave.



In all cases, the medium does not experience any net displacement as it vibrates. The disturbance passes through the wave carrying energy.

The amount of energy transmitted by a wave is related to the amplitude of the wave. Waves with larger amplitudes transmit more energy.

The amount of energy transmitted is proportional to the square of the amplitude, so a wave with twice the amplitude transmits four times the energy. A wave with three times the amplitude transmits nine times the energy.



All types of waves can be characterized by their frequency and wavelength.

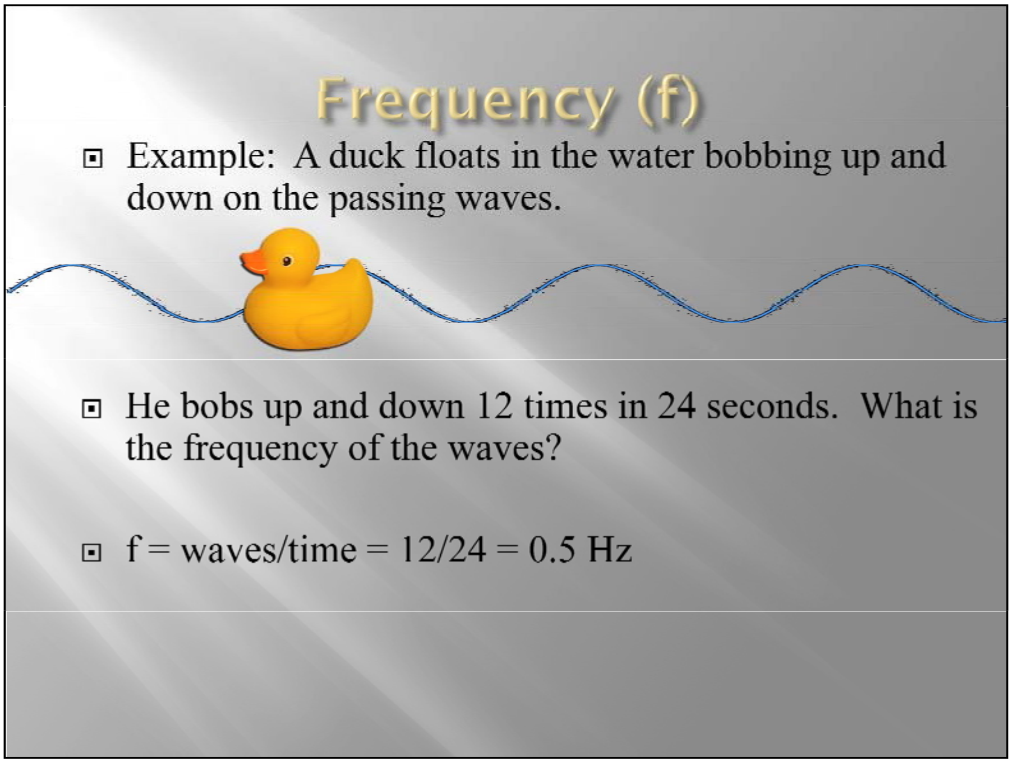
For waves, frequency refers to how many waves pass a particular point each second. We calculate frequency by dividing the number of waves by the elapsed time.

The symbol commonly used for frequency is a lower case f.

The standard units for frequency are Hertz, where 1 Hertz is one per second. Hertz is abbreviated H Z.

The frequency of a wave is the same as the frequency of vibration of the source of the disturbance creating the w Frequency does not depend on the medium.

When waves pass from one medium to another, the frequency does not change.



As an example, a duck floats in the water, bobbing up and down on the passing waves. He bobs up and down twelve times in twenty four seconds.

What is the frequency of the waves?

Frequency is number of waves divided by elapsed time.

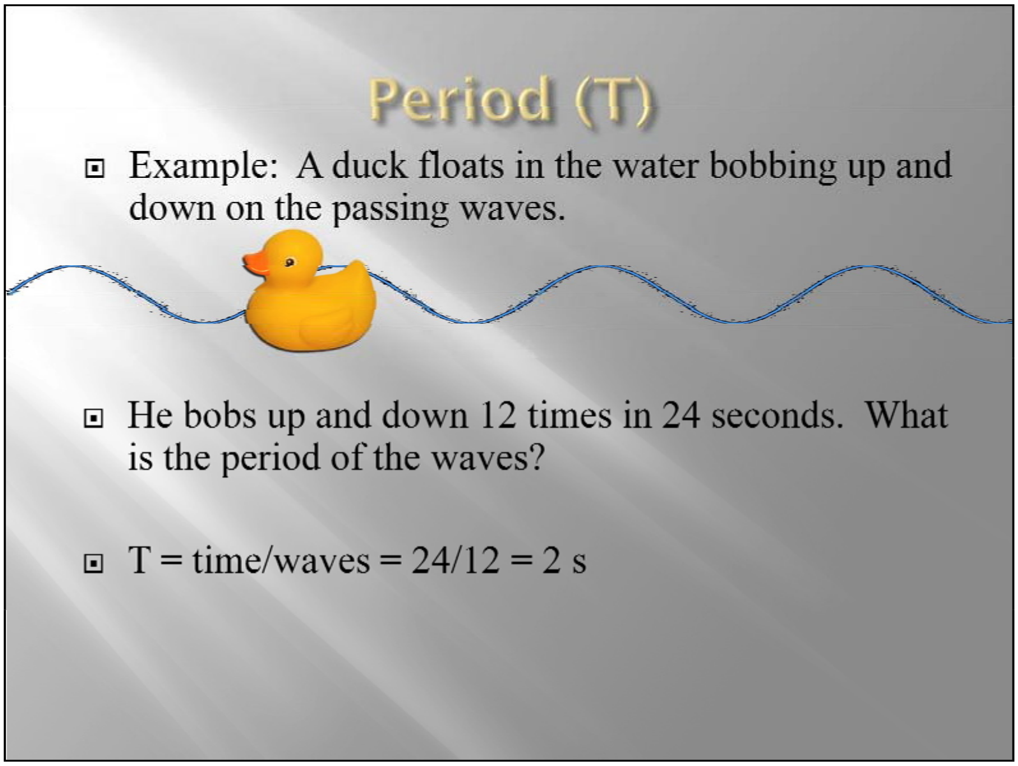
The duck saw twelve complete waves in twenty four seconds, so the frequency is twelve divided by twenty four, Half a wave passes every second.

Period (T)

- Seconds per wave
- $T = {}^{1}/_{f} = {}^{time}/_{\#waves}$
- Units = seconds (s)

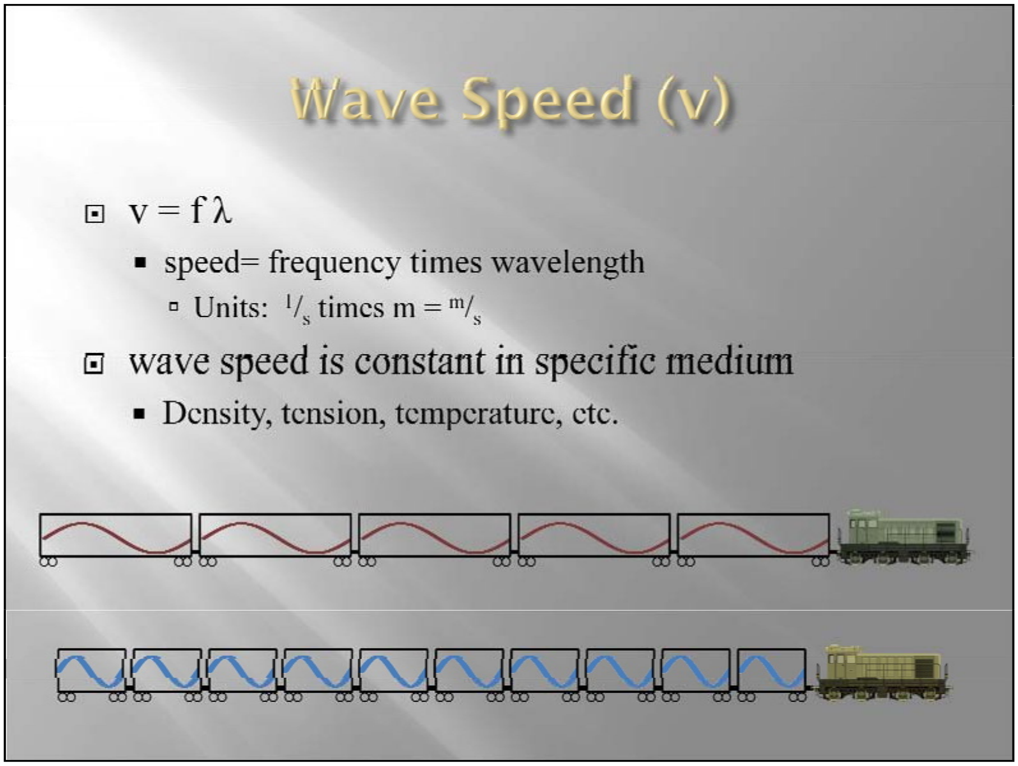
The period of a wave is the amount of time it takes for a point in the medium to complete one vibration. This is equivalent to the amount of time it takes for a complete wave to pass that point.

We calculate period by dividing the elapsed time by the number of waves. Notice that this is the reciprocal of how we calculate frequency, so we could also calculate period as one over the frequency. The symbol we use for period is a capital T. The units for period are seconds.



As an example, a duck floats in the water bobbing up and down on the passing waves. He bobs up and down twelve times in twenty four seconds. What is the period of the waves?

Period is elapsed time divided by the number of waves. In this case, period equals twenty four seconds divided by twelve waves for a period of two seconds. It takes two seconds for a single wave to pass.



The speed of a wave is found by multiplying its frequency by its wavelength, or v equals f lambda. The units are Hertz times meters or one over seconds times meters, which gives meters per second.

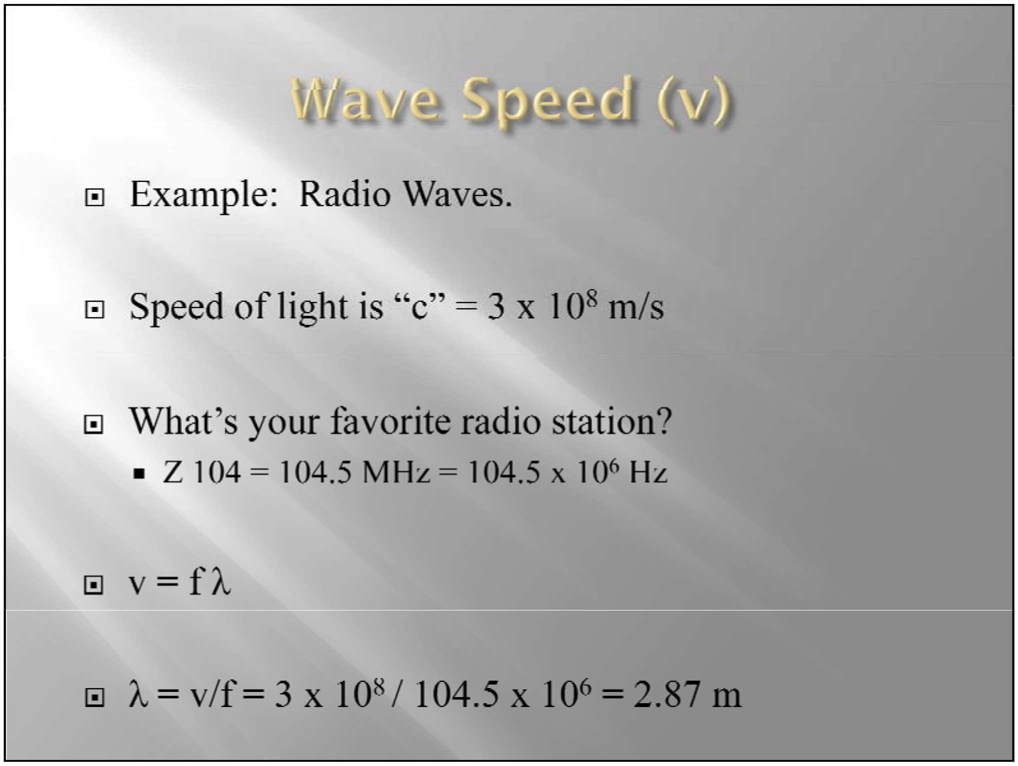
The speed of a wave depends on the medium it is in. Generally, a particular wave will have a constant speed within a specific medium, but the speed can depend on the properties of the medium, including density, tension, temperatures, etc.

Since the speed of a wave depends on the medium, changes in frequency do not affect the speed of a wave. From the equation, we can see that if wave speed is constant, and frequency is increased, the wavelength must decrease.

Frequency and wavelength are inversely related for waves in a given medium.

One way to think of speed, frequency and wavelength is to imagine sitting at a railroad crossing while a train passes by. If you knew the length of each car, and you counted how many passed by each second, you could multiply these two figures together to determine the speed of the train.

If a different train passed by at the same speed, but had shorter cars, then more of them would pass by each second.



Let’s look at an example using the wave speed equation. Radio waves travel at the speed of light, which is three times ten to the eighth meters per second. Let’s calculate the wave length of your favorite radio station.

Let’s say you listen to Z 104 out of Virginia Beach. This station broadcasts set frequency of one o four point five mega Hertz, or one hundred four point five times ten to the sixth Hertz. We know the frequency and the speed.

To calculate the wavelength, we divide the speed by the frequency. We get a wavelength of two point eight seven meters. One hundred four point five of these two-point-eight-seven-meter-long waves pass by each second!

Summary

- A wave is a periodic disturbance of a medium from rest that transfers energy without transferring matter.
- Wave vocabulary includes: medium, crest, trough, amplitude, wavelength, frequency and period.
- Three types of waves include transverse, longitudinal and surface waves.
- The frequency of a wave tells you how many waves pass a given point every second.
- The frequency of a wave is determined by the frequency of the vibration that created the wave.
- The period of a wave tells you how long it takes one wave to pass a given point.
- The speed of a wave is calculated by multiplying the frequency and the wavelength.
- The speed of a wave is determined by the medium the wave travels in.

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