



When one thinks of “waves” the most common visual which probably comes to mind is waves moving across a body of water like a lake or an ocean. A water wave is most definitely an example of a wave, however, there are many more. Sound waves are how you are currently hearing me, visible light is an electromagnetic wave and is how you see me, radio waves are also an electromagnetic wave and are likely how your electronic device is receiving this video, seismic waves are waves of energy which travel through the Earth’s crust, and waves on a string are electrical potential energy stored in the string being transferred from one location to another.

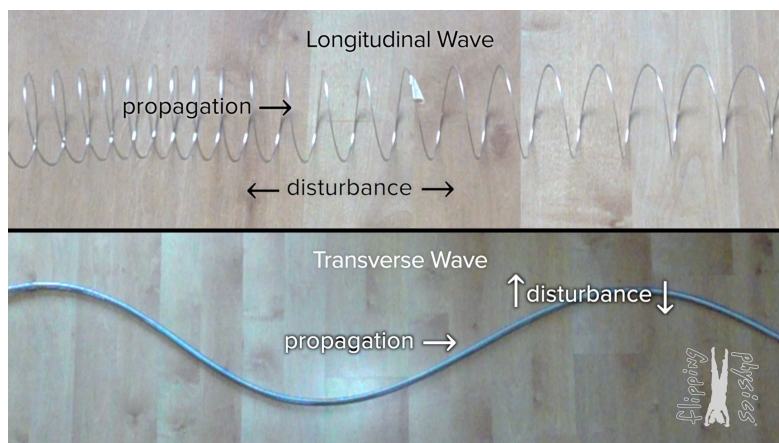
Please note that electromagnetic waves are not mechanical waves and do not require a medium to travel through. Visible light and radio waves are components of the electromagnetic wave spectrum. We will discuss these concepts in detail in later lessons. This lesson is about mechanical waves.

A mechanical wave is a disturbance of a medium which travels through the medium transferring energy from one place to another. Please realize waves transfer energy from one location to another, they do not move matter from one location to another. Wave motion is the motion of the disturbance of the medium, not the motion of the medium itself.

We will use waves on a spring to show the properties of mechanical waves. We will start with a single wave pulse traveling through the spring. The piece of tape which is on the spring is a part of the medium because it is attached to the spring. As the wave pulse travels along the spring, the tape moves up and then down, however, the overall displacement of the piece of tape is zero, because the medium does not change locations. The energy is contained in the disturbance of the medium travels along the spring. In other words, the wave is a pulse of energy traveling through the medium. The larger the amplitude of the wave, the more energy contained in the wave. Amplitude being the maximum displacement of the wave from equilibrium position. Equilibrium position being the position of the medium before and after the wave passes by that point.

A wave pulse is a single disturbance of a medium, whereas a periodic wave is a connected series of wave pulses. A periodic wave is also sometimes called a continuous wave.

Waves can be classified as either transverse or longitudinal. A transverse wave is where the direction of wave propagation is perpendicular to the direction of the disturbance of the medium. Transverse means “in a position or direction that is at an angle of 90° to something else”¹. A longitudinal wave is where the direction of wave propagation is parallel to the direction of the disturbance of the medium. Longitudinal means “lengthwise”² or “in the direction of the longest side”³ which means parallel. (Note: The only difference between the definitions of transverse and longitudinal wave is transverse uses “perpendicular” and longitudinal uses “parallel.”)



¹ <https://dictionary.cambridge.org/us/dictionary/english/transverse>
² <https://dictionary.cambridge.org/us/dictionary/english/longitudinal>
³ <https://dictionary.cambridge.org/us/dictionary/english/lengthwise>

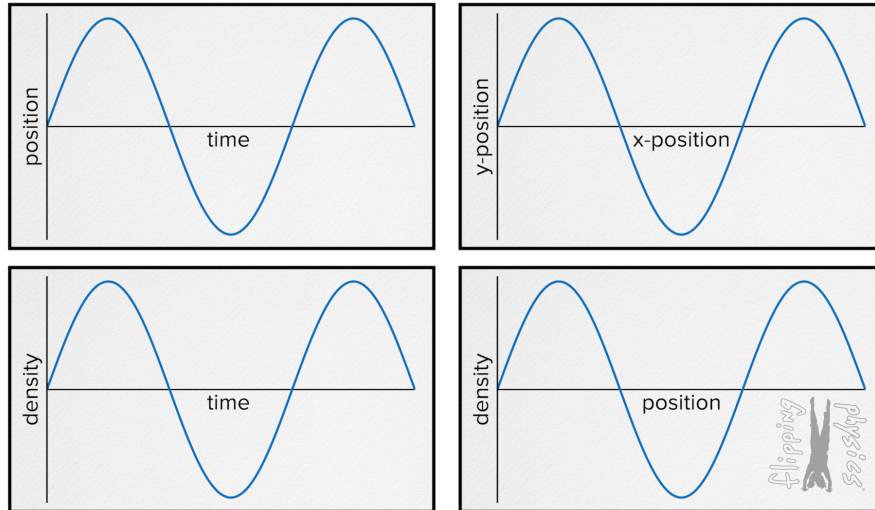


Flipping Physics Lecture Notes:

Wave Graphs - Longitudinal and Transverse - Wavelength and Period

<https://www.flippingphysics.com/wave-graphs.html>

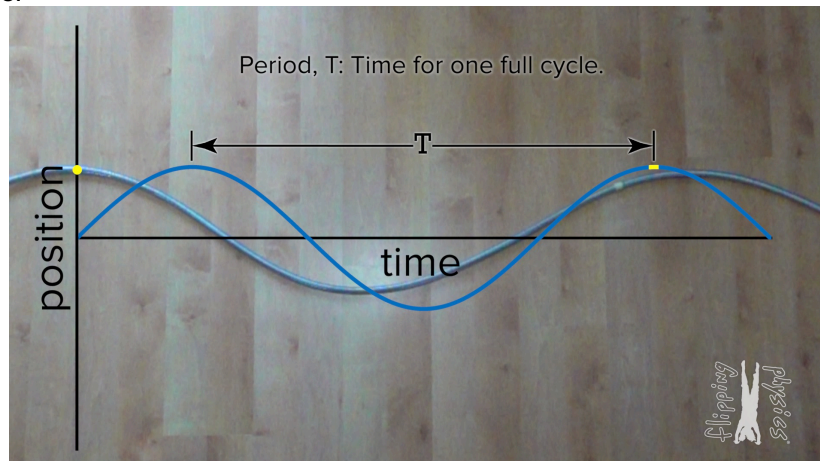
These are four graphs of mechanical waves which, at first, might look identical, however, it is very important that you understand the differences.



The key difference here is what is on the y and x axes. On the y-axis we have either position or density. On the x-axis we have either time or position. Let's start with understanding the position as a function of time graph. If we have a mass-spring system moving in simple harmonic motion, this could describe the position of a mass-spring system as a function of time. This could also describe the movement of a mechanical wave as a function of time. More specifically, this describes a transverse wave. A transverse wave is where the direction of wave propagation is perpendicular to the direction of the disturbance of the medium. This graph represents the position of a specific point on the transverse wave as a function of time.

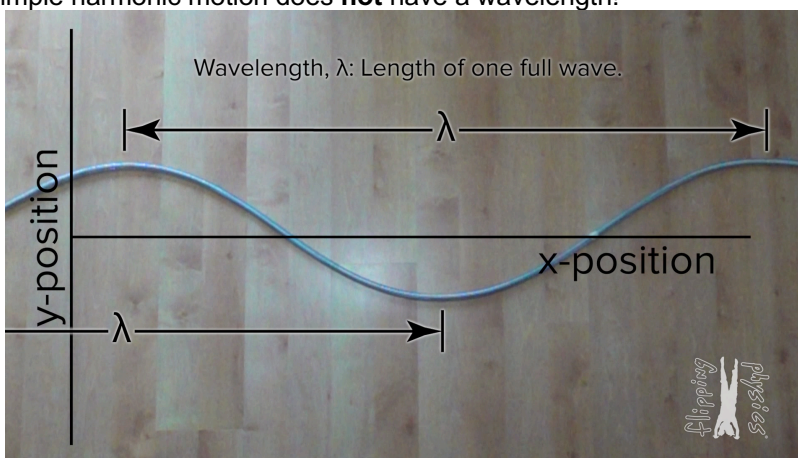
Let's change the x-axis now to position in the x-direction. Notice this graph can no longer describe the motion of a mass-spring system moving in simple harmonic motion, because a mass-spring system only moves in one dimension. However, this graph can describe the motion of a mechanical wave. This graph simply describes the location of all of the particles of a mechanical wave at one specific moment in time.

Now what about the measurement which extends between successive crests or successive troughs? Going back to the graph of position as a function of time, that measures the Period, T , or the time it takes for the system to oscillate through one full cycle. This is true for both simple harmonic motion and mechanical waves.



However, what is the measurement between successive crests for a graph of y-position as a function of x-position? This is called Wavelength:

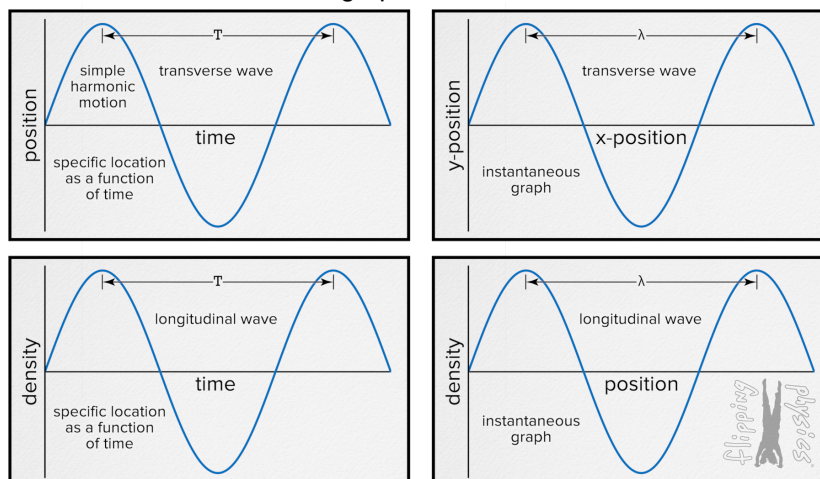
- Wavelength: The length of one complete wave cycle. Measured from crest to successive crest, trough to successive trough. In other words, measured from one point on the wave to the next corresponding point on the wave which is going in the same direction.
- Wavelength: The distance travelled by a wave during one period.
- The symbol for wavelength is λ , the lowercase Greek letter lambda.
- Notice because simple harmonic motion does not have a graph of y-position as a function of x-position, simple harmonic motion does **not** have a wavelength!



Let's now change the graph to density as a function of time. How is this different? This describes a mechanical wave and not simple harmonic motion, but how? This describes a longitudinal wave. A longitudinal wave is where the direction of wave propagation is parallel to the direction of the disturbance of the medium. In other words, a crest on the graph represents a location of higher density in a longitudinal wave; a location of compression. A trough on the graph represents a location of lower density in a longitudinal wave; a location of rarefaction. This represents the density of a specific location of the longitudinal wave as a function of time.

If we talk about the last graph which is density as a function of position, again this describes a mechanical, longitudinal wave, just the density of the whole wave at one specific point in time. The terms period and wavelength are still applicable for the longitudinal wave. Period for the density as a function of time graph. And wavelength for the density as a function of position graph.

Remember, the only one of these graphs which describes an object moving in simple harmonic motion is the first one, the position as a function of time graph.





Flipping Physics Lecture Notes:

Wave Speed Equation Derivation and Demonstration

<https://www.flippingphysics.com/wave-speed.html>

$$v = \frac{\Delta x}{\Delta t}$$

The equation for the magnitude of velocity is:

If the magnitude of the displacement of the wave equals the wavelength of the wave, λ , then the time for

$$v = \frac{\Delta x}{\Delta t} = \frac{\lambda}{T}$$

that to occur is the period, T :

$$f = \frac{1}{T}$$

We know frequency and period are inversely related:

$$v = \frac{\Delta x}{\Delta t} = \frac{\lambda}{T} = f\lambda \Rightarrow \boxed{v = f\lambda}$$

Therefore, the equation for the magnitude of the velocity of a wave is:

The amplitude, frequency, and wavelength of the wave do not affect the speed of the wave. The only thing that affects the speed of the wave in the medium is the properties of the medium itself.

An important point to notice is that this equation describes the speed of the wave pulse, not the speed of the particles of the medium. Also, we use the symbol “ v ” for the speed of the wave here. Frequency and wavelength are both scalars, so “ v ” here cannot be velocity because velocity is a vector, however, we use the velocity equation to derive the speed of the wave, so the symbol “ v ” is typically what is used.

Looking at the demonstration of 1 wave passing through the screen we can take the following measurements:

The length of one wave measured on the screen: $\lambda = 1.58\text{m}$

The time it takes 1 full wave to pass by a point is 0.29 seconds: $T = 0.29\text{sec}$

Therefore: $f = \frac{1}{T} = \frac{1}{0.29} = 3.448276 \text{ Hz}$ and $v = f\lambda = (3.448276)(1.58) = 5.448276 \approx 5.4 \frac{\text{m}}{\text{s}}$

The time it takes one wave to go across the entire screen is 0.35 sec: $\Delta t = 0.35\text{sec}$

The width of the screen is 1.92 m: $\Delta x = 1.92\text{m}$

Therefore: $v = \frac{\Delta x}{\Delta t} = \frac{1.92}{0.35} = 5.485714 \approx 5.5 \frac{\text{m}}{\text{s}}$

The percentage difference between those two measurements is:

$$\%_{\text{difference}} = \frac{5.485714 - 5.448276}{\frac{(5.485714 + 5.448276)}{2}} \times 100 = 0.681150 \approx 0.68\%$$