



WHAT MAKES THESE RIPPLES MOVE THROUGH THE WATER?

WAVES MADE IT HAPPEN

By Tricia J. Hoover

Imagine throwing a pebble into a pond. Circles begin to ripple out on the surface of the water from the spot where the pebble hits. The pebble sinks to the bottom of the water. It can't be making the water move. So what is causing the ripples?

It may seem like the rippling surface of the water is some sort of magic, but what we are seeing is the power of waves. Waves are all around us: in water, underground, and in the air. Though we can't see all types of waves, the waves are constantly moving. These waves don't move matter along them, but they do cause the water or the earth, and even the invisible particles in air, to shift back and forth as the wave passes through. Let's take a deeper look to see why.

What You Need to Know About This Performance Expectation

In this performance expectation, we want to develop a model of waves that will describe patterns in terms of the wavelength and amplitude of the waves. We also want to show that waves can cause objects to move. When students were younger, they were introduced to the idea of this as we showed how sound is caused by and can cause vibrations. Here we are digging in deeper, looking at the different kinds of waves and how their patterns (wavelength and amplitude) are defined. Now let's get on with the details of the performance expectation.

Waves Cause Objects to Move

Waves are a fun concept to introduce to students because they've almost certainly seen examples of waves before in the real world. You can start by telling students what a wave is. A simple definition of a **wave** is a regular pattern of motion. A more complex definition of a wave is the transportation of energy from one location to another without the transportation of matter. You can also mention that all waves are started by some sort of disturbance.



Waves move through the rope.

Once you've introduced the idea of waves, it's time to show that waves can cause matter to shift back and forth. Why not create some waves that you can observe as a class? Find a rope and tie one end of it to a tree. Hold the other end. Now move the rope up and down. What happens? Waves move through the rope. The rope moves up and down as the waves move through it. The wave is causing the rope to move.

This can also be done using a long spring or a Slinky. The nice thing about a Slinky is that you can create two types of waves. If you stretch the Slinky out on the floor or across the top of a table, you can create a wave by moving one end of the Slinky left to right or up and down. Students can watch the Slinky move like a wiggly worm. If instead you pinch some of the coils of the Slinky together and then let go, you create a different type of wave. Students can see this compressed area move down the Slinky while behind it is an area where the coils are spread apart. This is a great way to show that not all waves look the same.

Some other fun ways to create your own waves are:

- Ripples in water: Throw a pebble into a pond, and watch the ripples move outward along the surface of the water.
- Guitar strings: Pluck the strings of a guitar, and watch the guitar string vibrate up and down.



We can feel sound from a marching band.

Sound travels as waves, and it can also cause objects to vibrate back and forth. Vibrations create sound, and sound creates vibrations.

Most students have been making music since they started school, if not before, so music provides an excellent opportunity to introduce vibrations that create sound.

As students have used drums, bells, stringed instruments, and even their own voices, they have been feeling the vibrations on the instruments as they hear the sounds. They may have never given this much thought, but this performance expectation is the perfect opportunity for them to discover how the two are related.

Sound can cause materials to vibrate. Students may have felt this before if they've ever attended a live music concert or been near a marching band. They would have felt vibrations in their chest, like a rumbling that kept time with the music. Loud thunderstorms might be another time students have felt these vibrations.



Crystals will bounce around as the plastic wrap vibrates.

There's a fun experiment you can do as a class to observe sound making materials vibrate. Cover the top of a mixing bowl with plastic wrap, and secure it with the rubber band. Then place salt or sugar crystals on top of the plastic wrap. Now encourage your students to make some loud sounds. They may be surprised to see the crystals bounce and move around on the plastic wrap. The plastic wrap is vibrating and causing the crystals to move, and the vibration is caused by sound.

One final thing you may want to mention to students is how we are able to hear. When sound waves reach our ears, it causes our eardrums to vibrate, and this is how we are able to hear. Wearing earplugs can help us protect our hearing from loud sounds because it will block some of those sound waves from reaching our eardrums.

Different Kinds of Waves

Waves are a repeating pattern of motion that transfers energy from place to place without transferring matter. Let's look at all the different types of waves that exist. There are two big categories:

- Mechanical waves
- Electromagnetic waves

Both sound and light are waves. Sound is a mechanical wave, and light is an electromagnetic wave.

Mechanical Waves

A **mechanical wave** is a wave that oscillates and must travel through a medium. **Oscillation** is movement back and forth in a regular, repetitive manner. The **medium** is a material or substance, such as water, the earth, or the air. The energy of the waves is transferred through the medium.

Though waves don't exactly move objects as they travel, the medium that the waves are traveling through shifts back and forth, making it seem as though the waves are moving objects. This makes sense if you think about our rope photo on page two. You can see the waves moving the rope up and down, but the rope doesn't move from point A to point B. It is still held in the same spot at both ends. The rope just shifts up and down as the energy from the wave passes through the rope.

Mechanical waves themselves can travel long distances, but the displacement of the medium they are traveling through is limited. It can only move so far from its resting position. There are different kinds of mechanical waves that move in different ways. We'll look at some examples of these below.

Mechanical waves can be categorized into two groups: transverse waves and longitudinal waves. Sound is a longitudinal wave. Some things to note about transverse vs. longitudinal waves:

- Mechanical waves traveling through a solid can be either transverse waves or longitudinal waves.
- Mechanical waves traveling through a liquid or a gas are always longitudinal waves.



MISCONCEPTION MYTH-BUSTER

Can waves carry matter?

Many kids and adults think waves carry material from one place to another.

This is not true!

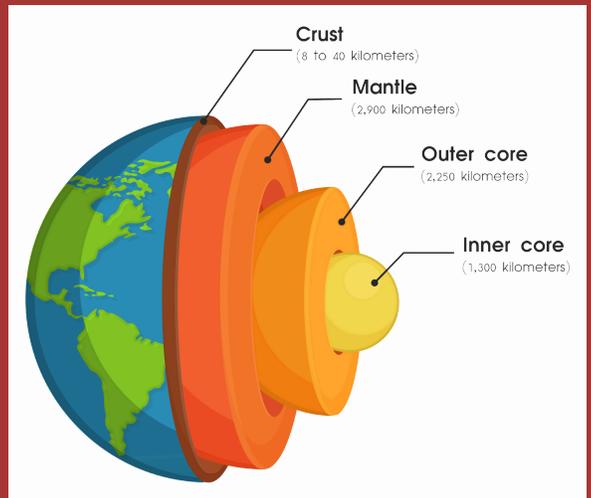
Waves don't move matter from point A to point B. They only move ENERGY!

A Fun Fact



Structure of the Earth

How do we know the outer core of the earth is a liquid? Scientists have studied waves created by earthquakes. Earthquakes can cause both transverse and longitudinal waves.

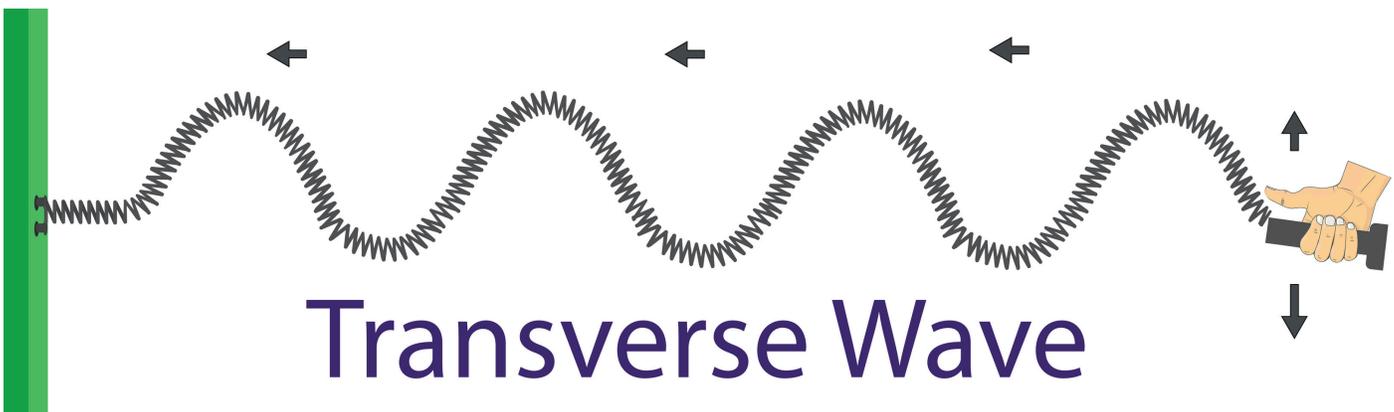


Scientists noticed that only the longitudinal waves passed through the outer core of the earth. If the outer core was solid, both types of waves would have passed through. Since only the longitudinal ones did, the outer core of the earth is believed to be a liquid—most likely molten iron.

Transverse Waves

A **transverse wave** is a wave that moves matter perpendicular (or at a right angle) to the direction the wave is moving. So in a wave pool, the energy from the wave is moving toward the shore while the people and the water (the matter) are moving up and down.

A transverse wave can visually be thought of as an oscillating or rising and falling, line.



Transverse Wave

Transverse waves cause particles of the medium to move perpendicular to the direction the wave is moving.

Some examples of transverse waves are:

- Water waves created when someone jumps in a pool
- The “WAVE” in a sports stadium generated by fans
- The visible vibration of a guitar string when plucked
- Stretching a Slinky between two students and having one of them move their end back and forth, left to right, or up and down
- A jump rope stretched between two people and one person shakes their end up and down
- Seismic S-waves

FUN FACT!

Have you ever wondered how that crowd wave got started? It seems like it's been around forever, but the crowd wave at a sporting event is thought to have started in the United States in the late 1970s and early 1980s. Crazy George Henderson is a professional cheerleader who is credited with starting the wave at National Hockey League games.

Here's a fun video [of the wave moving around a college football game.](#)



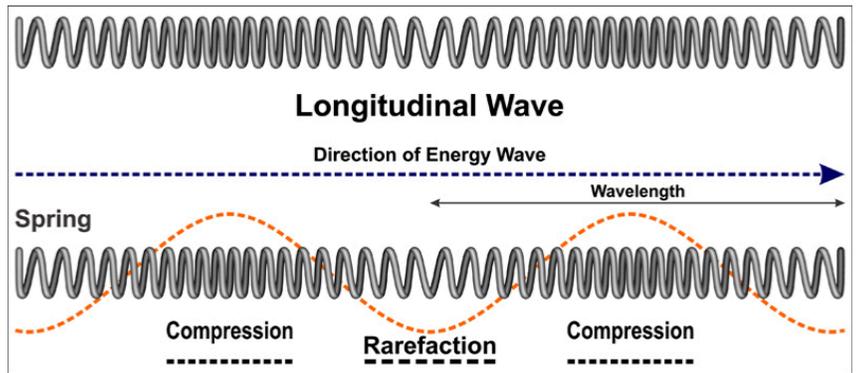
Longitudinal Waves

A **longitudinal wave**, sometimes called a compressional wave, is a wave that moves matter parallel (or along the same line) to the direction the wave is moving. Imagine the matter as a long line of individual particles. Each particle pushes on the particle next to it. This pushes the new particle forward and restores the original particle to its original position. This continues down the line in the same direction the energy of the wave is moving, each particle pushing on the one next to it. The result of this is that for some areas of the medium, the particles are very close together. For other areas, the particles are farther apart. These regions of some particles closer together and some farther apart are how we identify longitudinal waves.

Think back to our Slinky example. When you pinch (compress) some of the coils of a Slinky together and then let go, you create a longitudinal wave. The compressed area moves forward along the Slinky. This is the same direction the energy is moving. The coils of the Slinky vibrate in the same direction the energy is moving. The particles of the medium are moved parallel to the wave, shifting forward and backward as the wave moves through the Slinky.

Some examples of longitudinal waves are:

- Sound waves
- Seismic P-waves
- Ultrasound waves
- Sonar

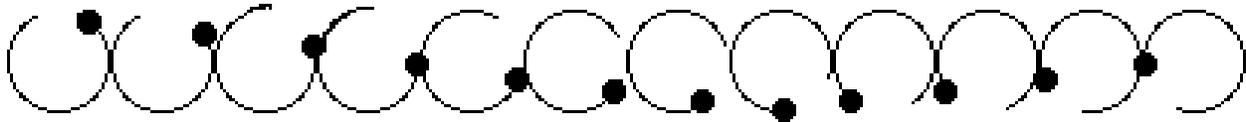


Surface Waves

You have probably seen waves moving along the surface of the ocean or water. These are **surface** waves. A surface wave is not a transverse nor a longitudinal wave because the particles of the medium do not travel in a parallel or perpendicular direction. The particles of the medium in surface waves travel in a circular motion. As you get farther from the surface, the particles of the medium tend to not move as much.

Longitudinal waves cause particles of the medium to move forward and backward parallel to the direction the wave is moving.

Surface Wave



Surface waves move the particles of the medium in a complete circle.

Mechanical circular waves are an example of surface waves. They are sometimes mistaken as transverse waves because they look like transverse waves. An example of mechanical circular waves is waves on the surface of water. Mechanical circular waves in water are different than transverse waves in water. Transverse waves in water are created by a disturbance that is perpendicular



Wind blowing over the surface of water causes mechanical circular waves.

to the water, such as someone jumping in a pool or a boat motor that creates a wake. In contrast, mechanical circular waves are generated by wind blowing over the surface of water. The wind is blowing parallel to, or in the same direction as, the water.

Electromagnetic Waves

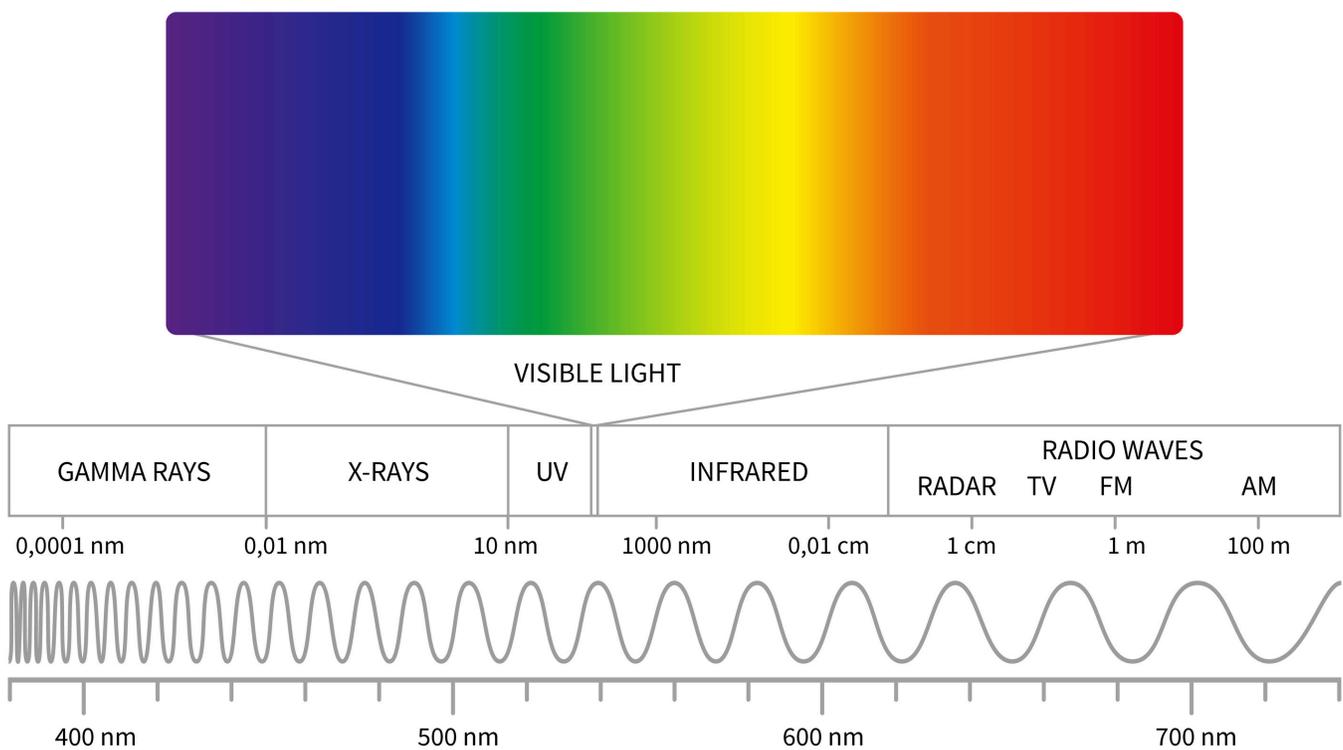
Though not part of the performance expectation, for teachers to have a better understanding, this is a brief mention of the electromagnetic spectrum. Visible light is part of the electromagnetic spectrum, which is the range of all types of electromagnetic radiation.

Electromagnetic waves, unlike mechanical waves, do not need a medium to travel through. They can travel through a vacuum like space. Because they don't need a medium to travel through, when they do get transmitted to a material, they will either go through it, reflect off the surface of it, or be absorbed or blocked by it.

Think about putting sunscreen on when you go out in the sun. We do this so the ultraviolet radiation will either be reflected by the sunscreen or absorbed by it. We don't want the ultraviolet light (UV) to enter our bodies.

Radiation, which is energy that travels and spreads out as it goes, is a word that immediately puts worry in the minds of many, but this radiation exists all around us. Lights in your house put off electromagnetic radiation as does your car radio. Other types of electromagnetic radiation you may have heard of are microwaves, infrared and ultraviolet lights, X-rays, and gamma rays.

VISIBLE SPECTRUM



The electromagnetic spectrum from highest energy/shortest wavelength to lowest energy/longest wavelength.

Scientists and engineers have designed many systems using electromagnetic waves for transferring information across long distances, communication, storing information, and more. This transfer of information will be covered in future performance expectations.

Measuring Waves:

A key part of this performance expectation is describing patterns of waves. There are three physical characteristics that define every wave: **frequency**, **wavelength**, and **amplitude**.

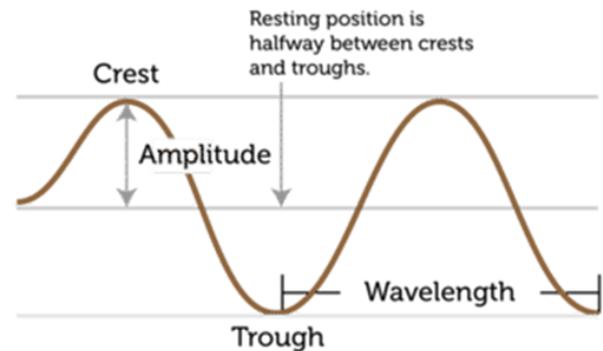
For transverse waves, the wavelength is the horizontal distance between two adjacent crests (or two troughs) of the wave. The **crest** is the highest point the wave reaches. The **trough** is the lowest point. For longitudinal waves, there are no crests or troughs, so the wavelength is measured as the distance between two corresponding points on adjacent waves. The usual unit for measuring wavelength is meters (m), though other units of distance can be used. The wavelength is not something that we can change directly. That said, by changing the frequency of the disturbance that causes the wave, you also change the wavelength. If the frequency increases, the wavelength decreases.

Frequency

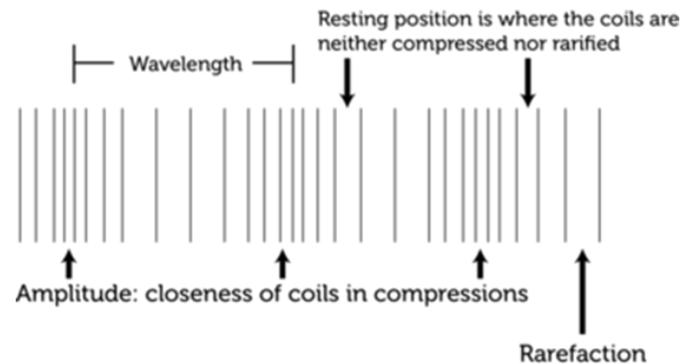
The frequency of a wave is a measure of how many waves pass a certain point in a given amount of time. If you are watching something in the water bob up and down as the water waves pass beneath it, the frequency is the rate at which the object bobs up and down. The frequency is measured in a unit called a hertz, named after Heinrich Hertz, a scientist who proved the existence of electromagnetic waves. Hertz is a measurement of how many wave cycles there are in a second. For the unit, 1 hertz = 1 wave/sec. You can think of it as the number of waves there are per second.

We also sometimes talk about the 'period' of a wave. The period is the time it takes from one wave to the next, or the time it takes the wave to travel a distance equal to its wavelength. The unit for the period is seconds, though it is equivalent to seconds/wave. It is related to the frequency: they are inverses of one another. For example, if it takes 2 seconds between the crest of one transverse wave to the next wave, the period is 2 seconds per wave, and the frequency (Hertz) is the inverse or $\frac{1}{2}$ which is 0.5 Hz.

Transverse Wave



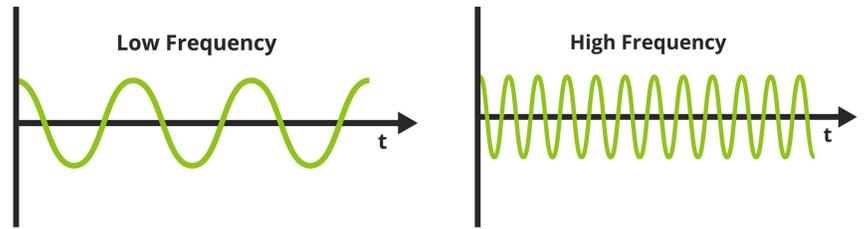
Longitudinal Wave



Waves can be measured.

The shorter the wavelength, the shorter the period and the higher the frequency. The longer the wavelength, the longer the period, and the lower the frequency. Wavelength and frequency are inversely related to each other. If you double the frequency, the wavelength is cut in half. If you triple the frequency, the wavelength is cut into a third.

Frequency



In the same medium, lower frequency waves have a longer period (more time between crests). Higher frequency waves have a short period (less time between crests).

Amplitude

For a transverse wave, the **amplitude** of a wave is the height of the wave from the midline, or resting position, to the crest or trough. Many students incorrectly think that the amplitude of a wave is the distance from the crest to the trough. But it is always measured from the resting position. The higher the crest and the lower the trough, the more energy the wave has.

For longitudinal waves, there are areas of compression where the particles of the medium are close together, and there are areas of rarefaction where the particles of the medium are far apart. The amplitude of the wave is found by measuring how far the molecules of the medium are at maximum compression or maximum rarefaction from their normal resting position.

The amount of energy a wave has determines the amplitude. For sound, louder sounds have a higher amplitude, and softer sounds have a lower amplitude.

Speed

How fast waves move, or their **speed**, depends on what medium they are moving through. Though many people think they are the same, the speed and frequency of a wave are two different measurements. Speed, wavelength, and frequency are all related. The formula showing this is:

As we noted above, frequency is measured in hertz (1/sec). Wavelength is measured in meters (m). Speed is measured in meters per second (m/sec).

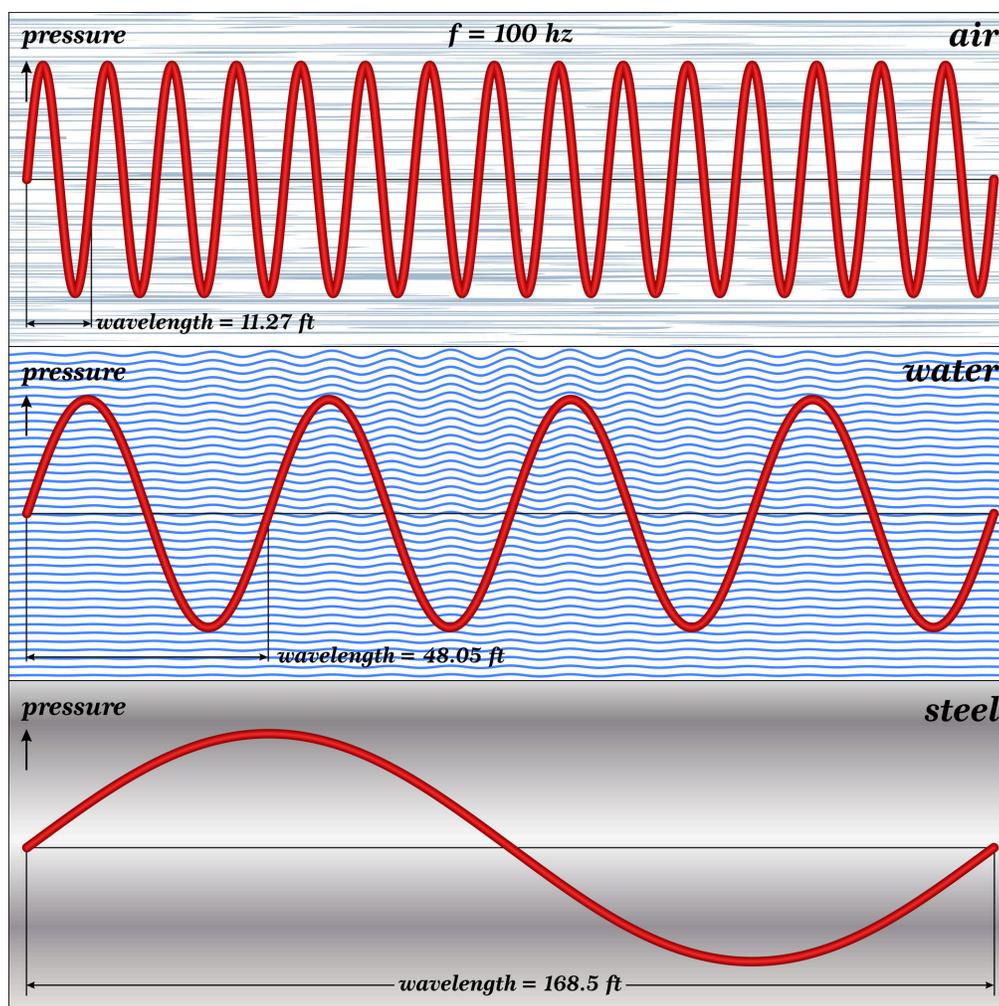
$$\text{speed} = \text{frequency} \times \text{wavelength}$$

As we noted above, frequency is measured in hertz (1/sec). Wavelength is measured in meters (m). Speed is measured in meters per second (m/sec).

From this equation, we can see that:

- If frequency remains constant, then speed is directly related to wavelength (as speed increases, wavelength increases). Remember that frequency is caused by the source of the disturbance. If the source of the disturbance vibrates faster, the frequency will increase.
- If speed remains constant, then frequency is inversely related to wavelength (as frequency increases, wavelength decreases). Remember that speed depends on the medium a wave is traveling through. So if the medium is not changed, the speed will remain constant.

In the below image, we see that for a constant frequency of 100 hertz, the medium is what affects the speed of the wave. As the speed increases, the wave will spread out. In this image, the wave is moving fastest in steel and slowest in water.



For a constant frequency, the medium a wave is traveling through will affect its speed which can affect its wavelength.

Did You Know?

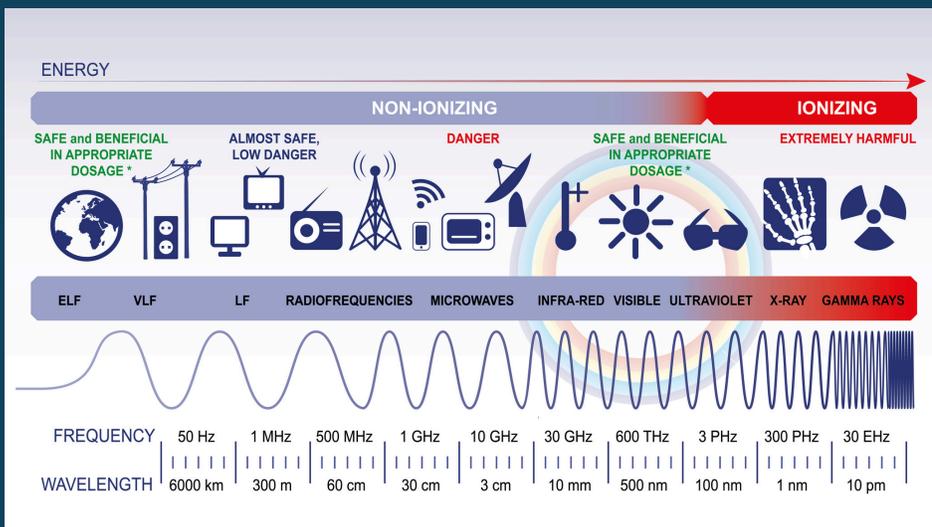


For sound waves, which are longitudinal waves, all frequencies of sound, which are the different notes that you hear when you listen to music, travel at the same speed. Higher frequency

notes do not travel faster than low pitch or low frequency notes. The sound made by different instruments at the same time will reach you at the same instant. It will take longer for the sound to travel to someone who is much further away.



When you listen to a symphony, the sound from each of the instruments travels at the same speed.



All types of electromagnetic radiation travel at the same speed.

Just like sound waves, for electromagnetic waves, all frequencies travel at the same speed. The higher frequency types of radiation, for example, gamma rays, which are also more damaging and dangerous to humans, do not travel faster than lower frequencies types of radiation, like radio waves. So visible light travels at the same speed as X-rays which travels at the same speed as infrared rays which travels at the same speed as ultraviolet light.

Some Final Thoughts

There is a lot to learn about all the various types of waves and where they can be observed. Knowing this very straightforward truth about waves is key: Waves move energy but they also can cause objects to move. Matter does not move along the path of the wave, but matter can be shifted as the wave passes through a medium.

Waves are all around us, in the air, in the water, and in the land. This is such a cool concept for students to understand. When they are introduced to this idea, it may cause them to wonder what other mysteries of science are out there waiting for them.

Glossary

wave – a regular pattern of motion; the transportation of energy from one location to another without the transportation of matter

mechanical wave – a wave that oscillates and must travel through a medium

oscillation – movement back and forth in a regular, repetitive manner

medium – a material or substance, such as water, the earth, or the air

transverse wave – a wave that moves matter perpendicular (or at a right angle) to the direction the wave is moving

longitudinal wave – a wave that moves matter parallel (or along the same line) to the direction the wave is moving

surface wave – a wave that moves matter in a circular motion to the direction the wave is moving

mechanical circular waves – an example of surface waves

electromagnetic wave – a wave that does not need to travel through a medium

crest – for waves, the highest point of a wave

trough – for waves, the lowest point of a wave

wavelength – for waves, the distance from one crest to the next

amplitude – for waves, the height from the midline of the wave to the crest

frequency – for waves, this can be thought of as its rate, or how many wave cycles there are in a certain period of time

speed – for waves, this is how fast waves move