Wave Behaviors

Reflect

Even though we may not always notice them, waves are an essential part of our everyday lives. From the gentle ripples on a pond to the invisible signals that carry our favorite radio stations, waves are all around us. In this passage, we will look into the world of waves, specifically focusing on mechanical waves and electromagnetic waves. We will examine their behavior when it comes to refraction, reflection, transmission, absorption, and diffraction as well as how they behave in different media or a vacuum.

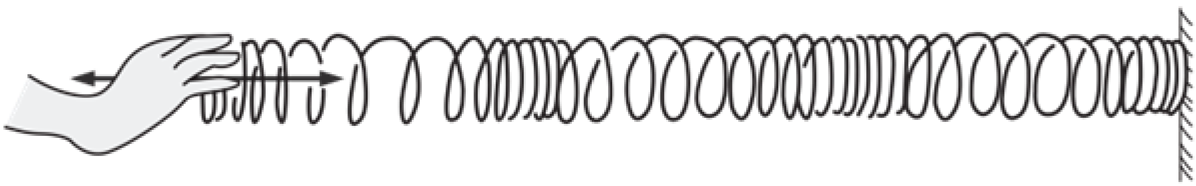
Look Out!

Mechanical Waves: Waves That Need a Medium

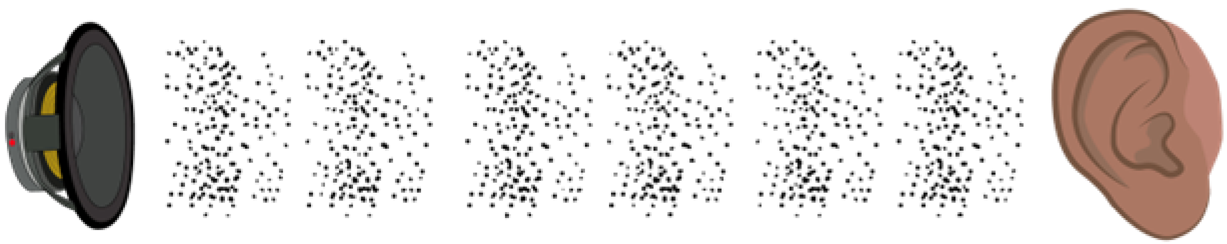
Mechanical waves are waves that require a material **medium**, such as air, water, or a solid, to travel through. These waves involve the physical displacement of particles within the medium to transfer energy. There are three types of mechanical waves: longitudinal waves, transverse waves, and surface waves. Common examples of mechanical waves are sound waves, seismic waves, and water waves. Air molecules vibrate in a sound wave, material in the ground moves in seismic waves, and water molecules vibrate in a water wave.

Wave Behaviors

Sound energy moves in longitudinal waves. The energy in longitudinal waves vibrates particles in a back-and-forth motion in the same direction as the wave itself. It looks like a spring toy being pushed and pulled back and forth.



While you can't see the sound waves traveling to your ear, you can sometimes see a music speaker moving back and forth as the sound waves are being pushed forward.



Longitudinal waves transfer energy through solids, liquids, and gases. They are mechanical waves and need a medium to move through. For example, sound requires a medium such as air for its energy to be transferred. If a medium is not present, such as in a **vacuum** or space, then the sound energy will not be transferred.

Longitudinal waves are characterized by compressions and rarefactions. Compression is the result of compressing particles into a smaller space, increasing their density. Compression is the denser, tightly compressed region of a longitudinal wave. Rarefaction is where particles move and expand into a larger space, decreasing their density. Rarefaction is the less dense, more spread-out region of longitudinal waves.

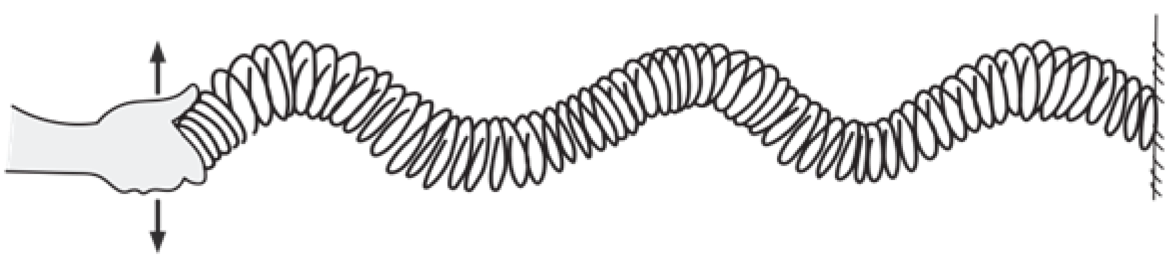
Another way to visualize energy from sound is to put some rice on a speaker. It will bounce to the music because of compressions and rarefactions. Some of the waves formed during earthquakes stretch and push Earth's crust together. These longitudinal waves are responsible for the loud sounds one might hear during the beginning of an earthquake.

Energy in surface-water waves and another kind of seismic wave in earthquakes moves in transverse waves. The energy in transverse waves vibrates particles in an up-and-down motion, causing a disturbance that moves through the medium. The wave itself moves horizontally. The motion of the particles is perpendicular to the wave.

During an earthquake, some of the energy that travels through Earth moves rock up and down, or perpendicular to the direction the wave is moving.

From the side, it looks like a wavy line with peaks and valleys. The peaks and valleys, or the highs and lows, are crests and troughs.

You can see the up-and-down motion of a spring toy when you shake it. The spring toy is moving up and down, but the direction of the wave is forward.

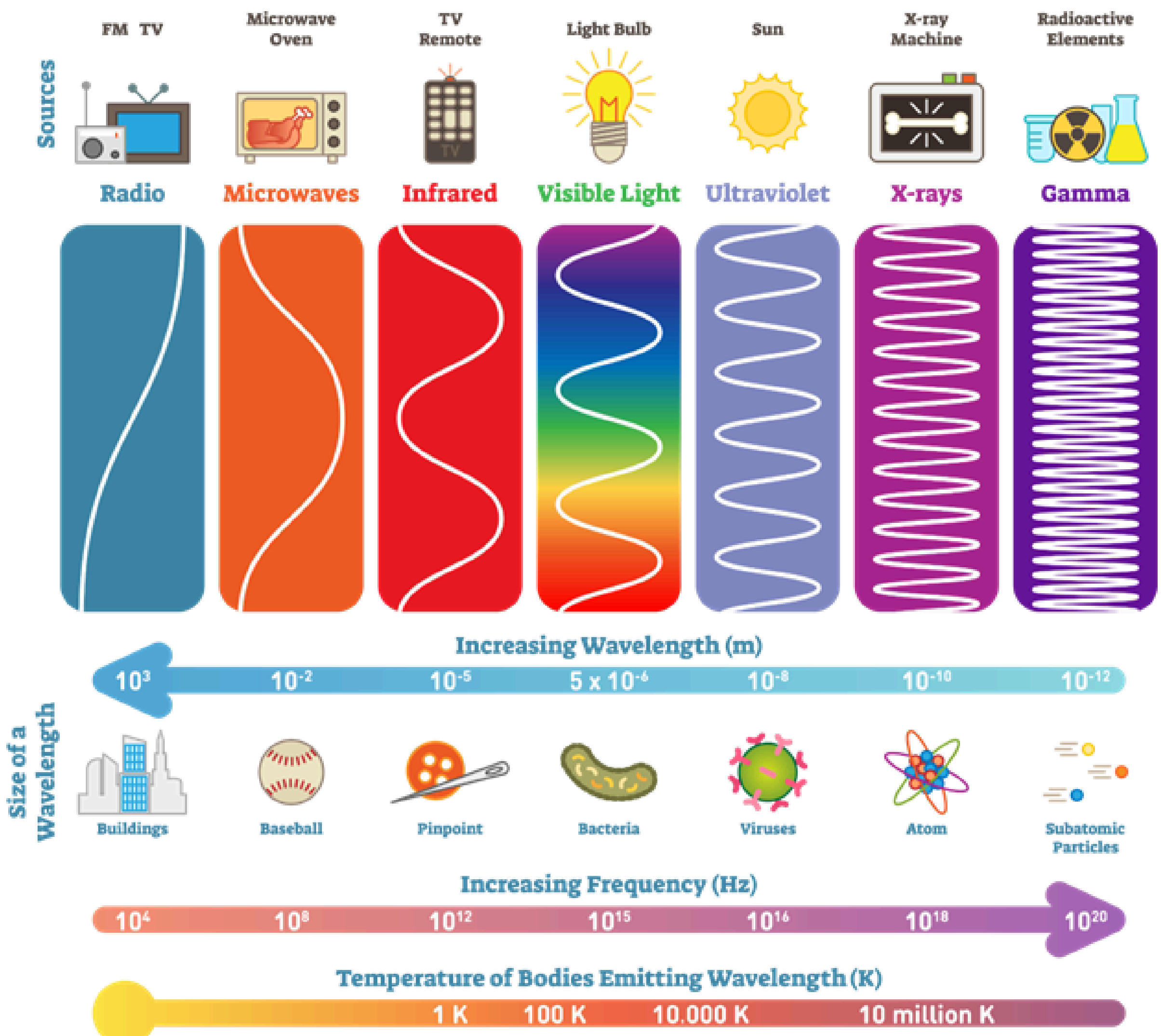


Similarly, you can see the vibrations on a guitar string as you pluck it. The vibrations are left to right, but the movement of the energy is forward.

Electromagnetic Waves: Waves That Don't Need a Medium

Electromagnetic waves are transverse waves, but they are not the same as mechanical waves because they do not require matter. They can travel through mediums such as air, water, and solid material, but they can also travel through space, which has no matter in it.

When we talk about light or electromagnetic energy, we are using two names for the same idea. **Electromagnetic waves** are oscillations of electromagnetic fields that carry energy through a medium or a vacuum. The **electromagnetic spectrum** is an arrangement of electromagnetic waves according to frequency and wavelength, beginning with radio waves and progressing to gamma radiation.



Frequency is used to describe electromagnetic waves, which is useful because of the vastly different properties of different kinds of waves. Radio and microwaves with longer wavelengths are described in hertz, with their massive wavelengths that vary in length between the size of buildings and that of a baseball. Infrared and visible light are described in meters, with their wavelengths somewhere between the length of a pinpoint and a microscopic protozoan. High-energy, short-wavelength waves like radiation and gamma rays are described in terms of the energy they have. These high-energy waves have a wavelength only about the size of atoms or atomic nuclei—incredibly small compared to radio waves!

Wave Behaviors

Visible light is a small part of the complete electromagnetic spectrum, with wavelengths ranging from 380 to 740 nm. Humans perceive differences in wavelength as different colors. In addition, the amplitude of light in the visible area of the spectrum can be perceived by human eyes. Higher-amplitude waves come from brighter, more intense light.

Reflect

Waves carry energy, not mass. There are two forms of waves: transverse and longitudinal. Transverse waves include earthquakes, surface-water waves, and electromagnetic energy (light energy). The energy in transverse waves vibrates particles up and down while the waves move horizontally. These waves do not need a medium for energy to be transferred. Sound waves are longitudinal waves and need a medium (such as air molecules) for energy to be transferred. The energy in longitudinal waves vibrates particles in a back-and-forth motion in the same direction as the waves themselves.

What Do You Think?

Suppose you were looking at the reflected image of a mountain on the surface of a lake. Can you trace the path of the light that makes it possible for you to see the reflected image? How are we able to see the image of the mountain in the water?

Look Out!

Behaviors of Waves

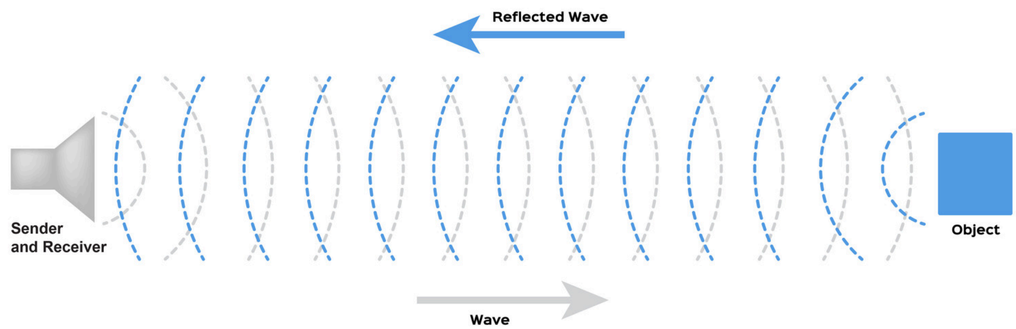
Before we compare the differences in the behavior of mechanical and electromagnetic waves, let's look at some basic ideas about waves. Waves are **transmitted** when a wave moves through a medium, passing something from one place to another. Waves travel in straight lines from the source of the disturbance and can change their path in different ways. **Refraction** occurs when waves bend and change direction and speed as they pass from one type of object to another. **Reflection** happens when waves bounce off the surface of an object. **Absorption** is the transfer of energy into a medium. **Diffraction** is when a wave encounters an object in its path and bends around it.

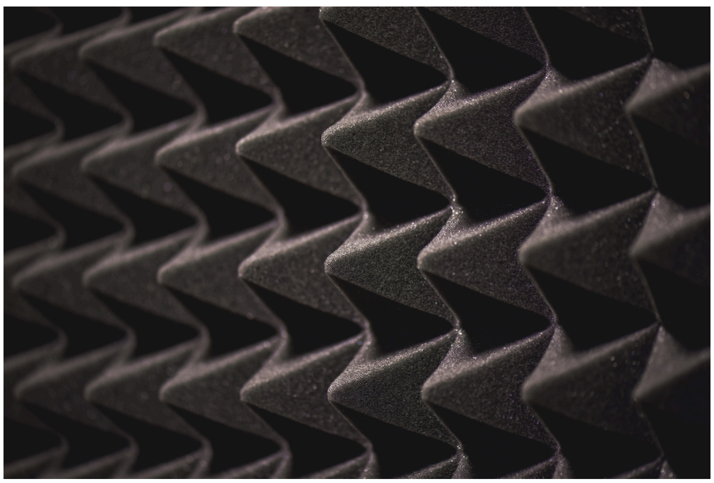
Transmission: Mechanical waves can pass through certain materials. When sound travels through your ear, it is an example of wave transmission. However, not all materials are transparent to mechanical waves. Electromagnetic waves can transmit through various materials. For example, glass is transparent to visible light, allowing us to see through windows.

Refraction: Mechanical waves, like sound waves, can refract or change their direction when they pass from one medium to another with different properties. For instance, sound waves travel faster through water than through the air, so when they move from air to water, they change direction. Electromagnetic waves, such as light, can also refract when they transition from one medium to another, like when passing from air into water. This bending of light is responsible for optical phenomena like the apparent bending of an object in a glass of water.

Reflection: Mechanical waves can also reflect when they encounter a boundary between two different materials. Think about the way sound bounces off the walls of a room, creating echoes. This is an example of wave reflection. Electromagnetic waves, such as light or radio waves, can reflect off surfaces. Mirrors reflect light, and radio waves bounce off buildings and hills, allowing us to receive signals.

Wave Behaviors





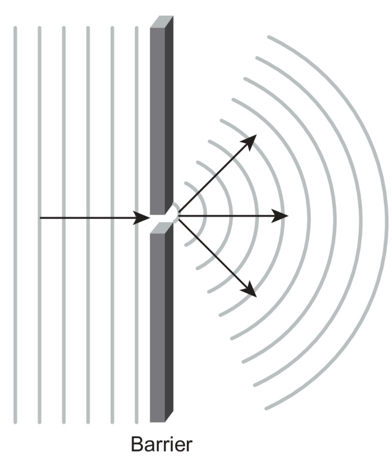
Absorption: Some materials absorb mechanical waves, converting their energy into other forms. For example, when sound waves enter a soft, porous material like foam walls or a sponge, they get absorbed and lose their energy.

Some materials absorb electromagnetic waves, converting their energy into heat or other forms. For instance, microwave ovens use electromagnetic waves to heat and cook food by absorbing the waves' energy.

Shiny surfaces such as mirrors reflect almost all light, while black surfaces absorb almost all light. Absorption occurs when all or some of the light energy from light waves is transferred from one medium to another. Colored surfaces absorb all wavelengths except for the color reflected (the color we see). That is, certain pigments reflect or transmit the wavelengths they cannot absorb, making them appear in the corresponding color. Visible light is made up of all the colors of the rainbow; this range of colors is called the visible light spectrum.

Diffraction: Have you ever watched water waves pass through a narrow slit in a barrier? When the waves pass through, they spread out radially. This is known as diffraction. For example, when a light bulb is turned on in a dark room, light waves spread out radially from the light bulb.

However, once the waves have traveled a certain distance, they can be thought of as plane waves that move in parallel "sheets," like in the image on the right. When a plane wave passes through a narrow slit or a barrier, the wave will act as though it is originating from a point source again. Thus, the wave spreads out, or diffracts.



This can also happen when a wave approaches a solid barrier. In these cases, when the wave passes along any edge of the barrier, it will spread out radially around the barrier. In this way, waves will appear to “bend” around barriers. This is the reason you can hear sounds that are emitted from behind a wall or large building.

Reflect

Comparing and Contrasting: Mechanical vs. Electromagnetic Waves

In summary, both mechanical and electromagnetic waves exhibit behaviors like refraction, reflection, transmission, absorption, and diffraction. However, mechanical waves require a material medium to propagate, while electromagnetic waves can travel through various materials and even through a vacuum.

Understanding these differences is crucial in fields like physics, engineering, and telecommunications, where wave behavior plays a significant role in technological advancements and everyday applications. Waves, in their diverse forms, are a fascinating part of our natural world, and we continue to unlock their mysteries as we explore the universe.

Try Now

1. Which wave example does not need a medium for energy to be transferred?
   A. Ocean wave
   B. Light
   C. Sound
   D. Earthquake

2. Describe how sound waves travel, and be sure to include the medium used.

3. The path of a wave can be bent through–
   A. refraction.
   B. absorption.
   C. reflection.
   D. all of the above.

4. Explain how a rainbow is produced.

5. What are electromagnetic waves, and how can they be seen?

6. Why do you see something as white, black, or another specific color?

Connecting With Your Child

Building a Periscope

A periscope is a tool in which several mirrors at opposite ends of a long tube allow people to see around objects. Designing and building a periscope is an excellent way for your child to learn about the fundamental laws of reflection. Remember that light travels in straight lines, and the angle of incidence (where it hits) equals the angle of reflection (how it bounces off). In other words, the angle at which a light ray approaches a mirror is the same as the angle at which the light ray bounces off the mirror. Plans and instructional videos for building a periscope can easily be found on the internet.

For most designs, you will need these items:

- 1 Long, square box, or enough cardboard to make such a box
- 2 Small pocket mirrors
- 1 Protractor
- 1 Sharp knife
- 1 Roll of duct tape

As you and your child position the mirrors at either end of the box, explain the significance of the angles at which the mirrors are set. (The first mirror must reflect light entering the periscope toward the mirror at the other end of the periscope. This mirror must then reflect light toward the eyepiece of the periscope.) You may also watch videos of how a periscope is used onboard a submarine. Encourage your child to find other uses for the periscope. For example, a periscope can allow someone to look around a corner or above a couch.