Teacher Tune-up

Quick Content Refresher for Busy Professionals

What types of waves are there, and what do they have in common?

Waves transfer energy from one place to another without transferring matter, and they can be classified into two major categories: mechanical and electromagnetic. Mechanical waves require a material medium. Electromagnetic waves do not.

Waves can also be classified as either longitudinal or transverse. Mechanical waves can be either longitudinal or transverse, while electromagnetic waves are always transverse.

In longitudinal mechanical waves (like sound), particles in the medium move back and forth parallel to the direction of energy travel. (Think motion *along* the path of *long*itudinal waves.)

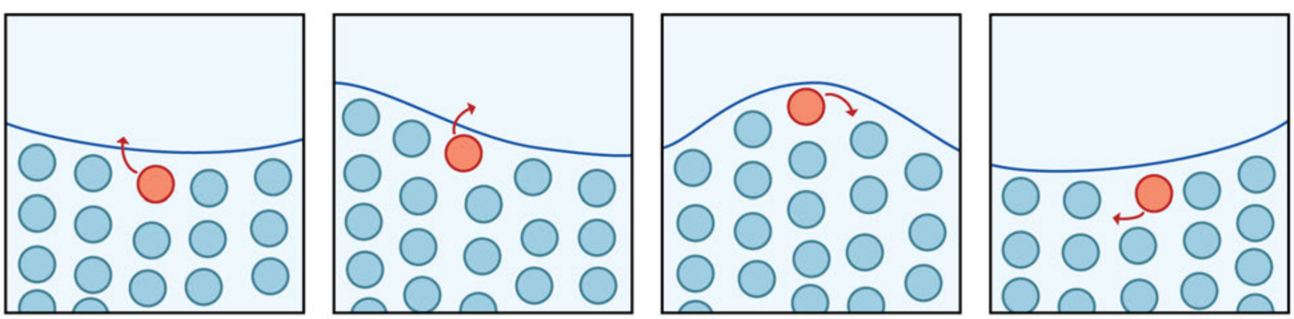
In transverse mechanical waves (like waves on the surface of water), particle in the medium move back and forth perpendicular to (transverse to) the direction of energy travel. While mechanical waves come in both longitudinal and transverse varieties, electromagnetic waves are always transverse. (See E4t3, “How can energy travel when matter doesn’t?” for more discussion of how electromagnetic waves travel without a material medium.)

What do waves have in common?

For all their variety, the phenomena we group under the heading of waves have some things in common, and the choice of the word “wave” as a collective name suggests that water waves may be a good prototypical illustration of their commonalities. (This illustration requires some qualification when extended to compression waves and waves that can travel through a vacuum, of course.)

So, consider the ripples that spread outward from a pebble that falls into a pond. The falling pebble creates a disturbance and then disappears below, adding no more energy to the system. We are interested in the response to the disturbance: waves.

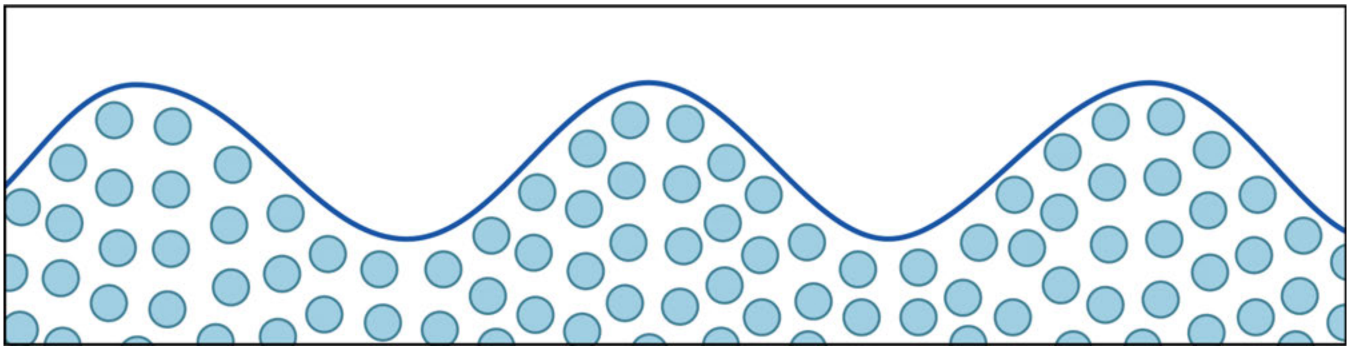
The main thing to notice is that the energy of the disturbance travels a long way even though the water does not. The water through which the waves travel moves a little, but basically stays in the same location. This transfer of energy without transfer of matter is an essential characteristic of waves.



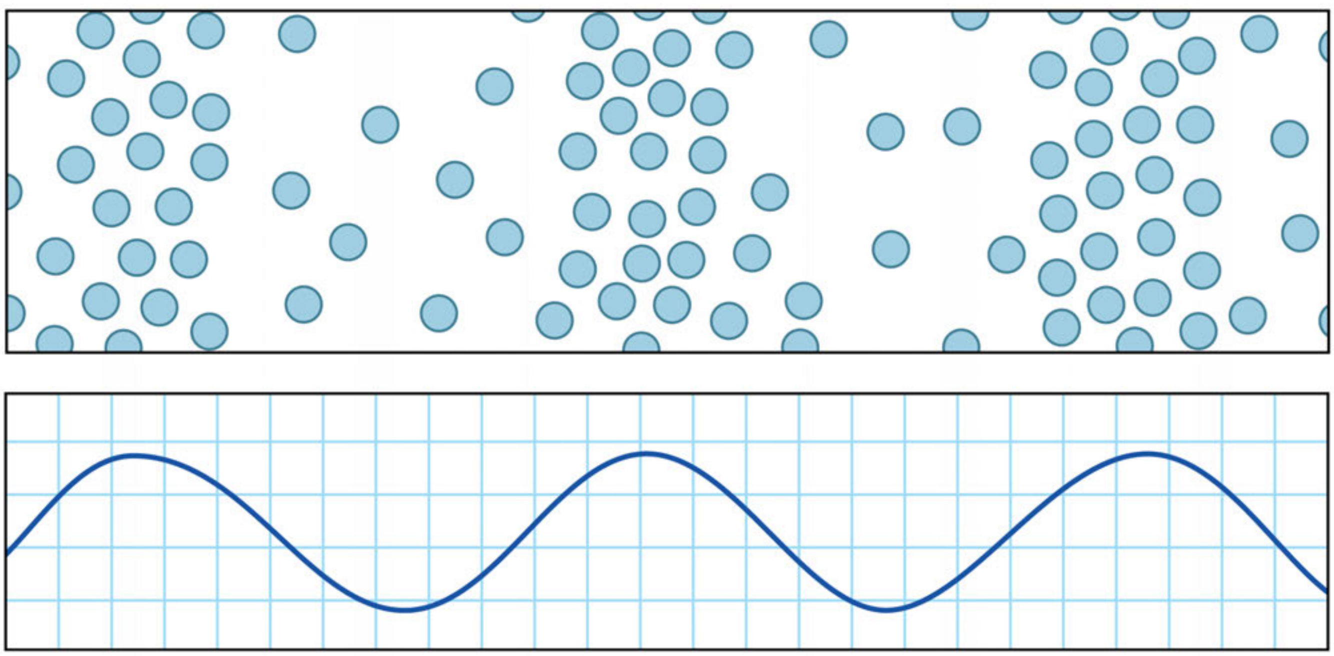
Water molecules near the surface tumble more or less in place as waves pass.

Waves have alternating peaks (crests) and valleys (troughs). Even compression waves, like sound, can be described in terms of crests and troughs, although in such a case these terms describe a graph of compression rather than the more literal peaks and valleys of waves in water.

Transverse waves:



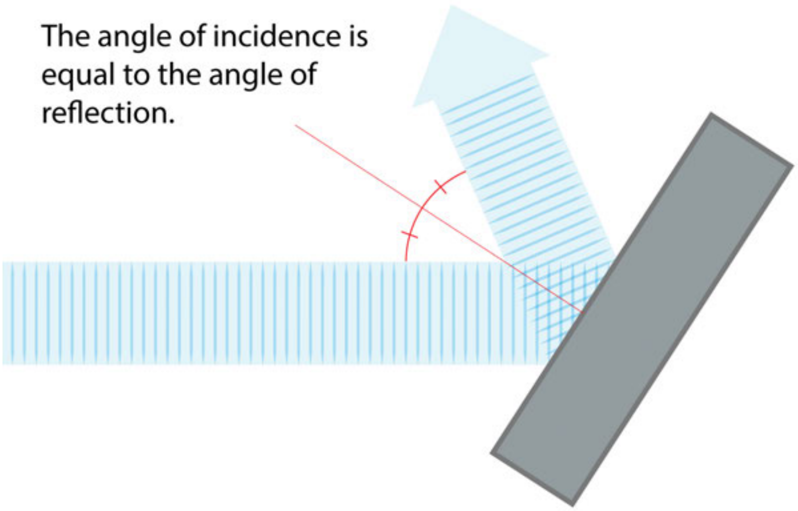
Longitudinal waves and corresponding wave graph:



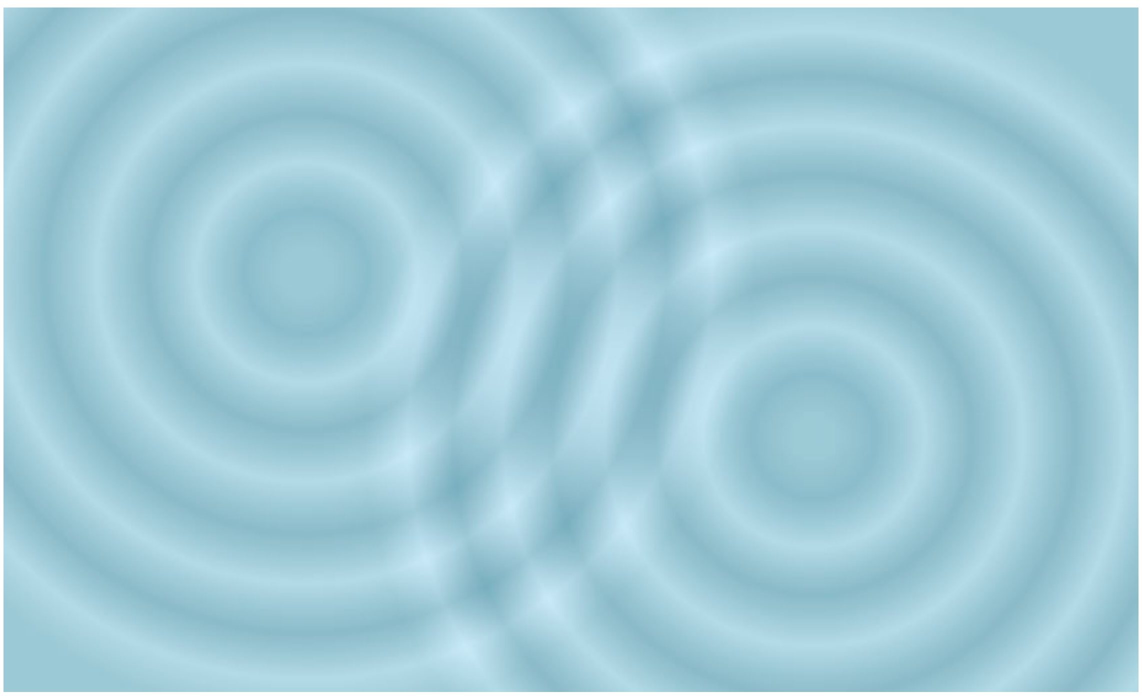
A *restoring force* (a force that tends to return a physical system to equilibrium, in this case gravity) brings peaks back toward their original level, but the water overshoots because of its momentum, creating a new valley where the peak was, and vice versa.

The speed at which the ripples spread does not depend on the size of the splash that started them. Ripples from bigger pebbles have peaks that are farther apart, not faster-moving peaks. Instead, the speed depends on the medium (water, in the case of our ripples).

When a set of ripples encounters a barrier, they are *reflected*. The angle of reflection is equal to the angle of incidence.



If there are other ripples (from another stone, or from reflections), the two sets of ripples combine in *interference patterns* as they pass through each other. Where peaks combine with peaks, or troughs with troughs, there is *constructive* interference (enhancing the highs and lows of the peaks and troughs, respectively). Where peaks combine with troughs, there is *destructive* interference, bringing the surface of the water nearer to its resting level.



The wave propagates from the origin only as long as energy is put into the system. Waves are a response to disturbance, and new waves will cease to form when a disturbance ceases.

How do waves differ?

As stated earlier, waves can be either mechanical or electromagnetic. Below are some ways the two major categories of waves differ.

	Mechanical Waves	**Electromagnetic Waves**
Need a medium?	Yes	No
Speed	Depends on the properties of the medium (such as density and compressibility)	Constant (c = the speed of light) in a vacuum, but can be slowed down by traveling through different media
Transverse?	Sometimes (for example, waves on the surface of water)	Always: EM waves are a type of transverse vibration of space itself
Longitudinal?	Sometimes (for example, sound waves)	No

<table>
<tr>
<td colspan="2">Mechanical waves

An event causes a displacement in some kind of medium (which can be any state of matter: solid, liquid, or gas). The displacement sends a disturbance quite far through the medium, even though each part of the medium makes only small motions (back and forth, or up and down, or both). The speed of such a wave depends on the properties of the medium (such as density and compressibility) rather than on what kind of event created the wave.</td>
<td rowspan="2">Electromagnetic waves

Electromagnetic waves such as visible light are always transverse. They are not a vibration of matter, and can travel through a vacuum. In a sense, they are a vibration of space itself. In fact, light travels fastest through empty space—matter slows it down (or even absorbs or reflects it, depending on the EM wavelength and type of matter involved).
The wavelike nature of light is shown by its interference patterns, as well as by the way it reflects and how it bends when going through prisms and lenses. But in some situations, light also acts as if it is made of particles (called photons) that travel at the speed of the light wave but concentrate the wave energy in individual packets, with the amount of energy in each packet depending on the color of the light.</td>
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<td>Longitudinal mechanical waves

In the simplest mechanical-wave situation, a push on the medium creates a compression wave that moves in the same direction as the push. The material right next to the initial push moves slightly, leading it to push on the adjacent material. This effect causes a sequence of compressions that move farther and farther away from the initial push, even though each part of the medium only moves slightly, then decompresses and settles back at its original position (until and unless it gets another push). Sound is a compression wave of this kind.</td>
<td>Transverse mechanical waves

In some situations, mechanical waves travel perpendicular from the push that creates them. These transverse waves can occur along a surface where displaced liquid is restored to its average level by gravity (e.g., water-surface waves), or as shear waves within solid materials (e.g., S-type earthquake waves), or along something linear like a rope or cable. Transverse waves cannot travel through the interiors of gases or liquids, since the weak attraction between the molecules of those kinds of materials will not pull on each other hard enough to cause a transverse wave.</td>
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