

# WAVES

## (SCIENCE KEY CONCEPTS SERIES)

**FOR USE IN:** Physics

**LEVEL:** Grades 9-12

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### EDUCATIONAL OBJECTIVES

To help the student understand these key concepts about waves:

- The nature of waves, transverse and longitudinal waves.
- Reflection.
- Refraction.

### BEFORE SHOWING THE VIDEO

Some questions which may be used to stimulate discussion:

1. Have you ever noticed an object floating in water? Why does the object remain nearly in the same place as the wave passes? *(The water molecules oscillate vertically in place, while the wave's energy passes along at right angles to the water movement – a transverse wave.)*
2. What is the speed at which waves of light travel? *(Light waves are the visible part of the electromagnetic wave spectrum, which travels through a vacuum at  $3 \times 10^8$  meters/second. Light waves from the sun reach the Earth in just 8 minutes.)*
3. How is sound like light, and how is it different? *(Both are waves, but sound is carried by the compressions and rarefactions of molecules in the propagating medium, whether air, water, earth, etc., oscillating within a narrow space, and passing the energy of the wave along. Light is a periodic disturbance of an electromagnetic field, which can travel through a vacuum. Sound travels much more slowly than light because of the inertia and varying properties of whatever medium through which the sound is traveling.)*

### BACKGROUND INFORMATION

Waves are disturbances that carry energy. We can see waves along the surface of water as the water moves up and down and the energy moves down wind. We can hear sound waves within the frequencies audible to our ears, which are vibrations of the transmitting medium. We can see light waves only in the narrow range of the visible electromagnetic spectrum that the cones and rods on the retina of our eyes are sensitive to.

Waves took on new meaning in the early part of the 20th century when experiments showed that our traditional view of energy as waves and matter as particles became less distinct. The quantum theory evolved as we began to realize that both energy and matter have properties of both waves and particles.

### CONTENT OF THE VIDEO

The video contains the following key concepts. To play only concepts 2 or 3, simply fast forward to its title.

#### RUNNING TIME MIN:SEC

1. Characteristics, Transverse, and Longitudinal	3:46
2. Reflection	5:06

### 3. Refraction

4:37

The concepts are illustrated with imaginative experiments and models which are too dangerous, costly, or complicated to be done in the classroom. Computer animation and positioned captions clarify what is happening.

#### Characteristics, Transverse, and Longitudinal

Waves have energy, whether sea waves, laser light waves, sound waves, waves in the Earth's crust - earthquakes, or the natural frequency of waves in a bridge. Waves in a ripple tank illustrate transverse waves in a water medium, in which the oscillating motion of the medium (water) is at right angles to the direction of the energy. Wavelength and frequency are explained. A coiled spring illustrates longitudinal waves in which the oscillating medium (the spring) is in the same direction as the movement of energy. In both transverse and longitudinal waves, the medium oscillates in place, but the energy is passed along.

#### 1. Reflection

A pool ball bouncing off a cushion clarifies the angle of incidence and of reflection. In a ripple tank, the water waves reflecting off an inserted plate can be seen by the shadows cast on the tank bottom. A magician uses the reflection of light to create a virtual image, which appears real to the audience. Ships use sound reflected off the ocean floor to measure the ocean depth. Bats use reflected ultra-sound to locate prey. Space satellites reflect radio and microwaves back to Earth. The focal point of a concave satellite dish is that point to which all received waves are reflected and focused and is also where a match will ignite when a heat source is placed in front of the dish.

#### 2. Refraction

Light travels in straight lines. But when it both enters and leaves another medium, such as a glass block, it bends in different directions. The shift in direction is called refraction. When water waves in ripple tank pass over a shallower part, the wave speed slows and the wave frequency increases. When the wave strikes the shallower part at an angle, the waves change both speed and direction. Similarly with light striking a glass block at an angle, it changes both speed and direction. Light passing from air to water changes direction, which makes objects in water seem bent. Light and laser beams can be both refracted and reflected as they travel through streams of water, or a rotating glass block. Total internal reflection of light inside an optic fiber makes today's global communications possible.

#### AFTER SHOWING THE VIDEO

Some suggestions for stimulating discussion are:

1. As a physicist thinks of them, what are waves? (*Waves are disturbances of matter or fields that carry energy.*)
2. How does matter differ from energy? Recent studies have shown that the difference between matter and energy becomes unclear when we look at them in great detail. (*Although we usually think of matter as made up of atoms and molecules, and energy as waves; at the subatomic scale, matter and energy become indistinguishable.*)
3. Organize and conduct demonstrations that show how sound and light waves are refracted and reflected. (*Demonstrate that a reflected sound - an echo - can be heard around a corner.*)
4. *The refraction of a beam of light can be shown with light from a flashlight, as it passes from water to air.*

#### EXPLORING AND INVESTIGATING

One experiment shown in the video can be replicated in the classroom, of course, without the explanatory graphics. Obtain a long, coiled Slinky, and tie a ribbon to one coil. Stretch it out between two people so that the tension stretches the spring. If a person at one end quickly vibrates the Slinky to the side and back, you can observe the sideways wave travel to the far end of the slinky. This is a transverse wave. Repeat the procedure above, but this time quickly vibrate the spring toward the person at the far end and then back. The impulse that moves along the spring this time is a longitudinal wave. Note that the ribbon in both cases oscillates in place, but the wave energy is passed along.

Make a ripple tank with a shallow, transparent pan of water on a light source, such as the platen of an overhead projector. (Do NOT allow water to spill into the projector. Electricity and water can be a fatal combination!) Quickly touch the surface of the water with a small object like the end of a pencil. Notice how the waves travel outward and how they are reflected by the sides of the container. Place objects like wooden blocks in the pan and observe how the waves change frequency and direction when they encounter the obstacles. A barrier with two narrow openings can be especially interesting.

Ask students to devise and conduct their own experiments to measure the speed of sound and the speed of light. (The latter is difficult due to the extreme speed of light.)

#### INTERNET WEB SITES FOR FURTHER INFORMATION ON:

The Birth of a Wave

<http://tqd.advanced.org/2804/wave.html>

Seismic (earthquake) Waves

<http://www.geo.mtu.edu/UPSeis/waves.html>

Ocean Waves and Power Generation

<http://members.aol.com/cloverted/wave.html>

The Electromagnetic Spectrum

<http://library.advanced.org/11119/physics.html>

Waves and Quantum Mechanics

<http://members.aol.com/cloverted/wave.html>

San Diego Gas & Electric Energy Arcade

[http://www.sdge.com/sdge.cgi?template=Arcade/er\\_fl.html&frame1=er\\_cl.html&frame2=er\\_h0.html&frame3=er\\_0.html&change=yes](http://www.sdge.com/sdge.cgi?template=Arcade/er_fl.html&frame1=er_cl.html&frame2=er_h0.html&frame3=er_0.html&change=yes)

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