

Types of Mechanical Waves

Mechanical waves can be classified according to the direction of the particle motion compared to the direction of the wave motion. There are two basic types of mechanical waves: transverse waves and longitudinal waves.

Transverse Waves

A **transverse wave** describes a wave in which the particles vibrate perpendicular to the direction of the flow of energy. For example, when you strum the string of a guitar, you cause the string to vibrate (**Figure 1**). The stimulus (origin of vibration) provided by your finger strumming the guitar is near one end of the guitar string. The vibration moves along the string and reflects off the far end, returns, and reflects again, and so on. However, the guitar string does not move in the direction of the energy flow. Instead, the string vibrates perpendicular to the direction of the flow of energy.

Water waves are a familiar example of transverse waves. A boat bobbing on waves moves up and down. This direction is perpendicular to the direction of the flow of energy of the water waves.

transverse wave a wave in which particles vibrate perpendicular to the direction of the flow of energy



Figure 1 In this image of a single vibrating guitar string, the particles in the string are moving up and down, and the energy is flowing back and forth along the string.

Longitudinal Waves

A **longitudinal wave** describes a wave in which the particles vibrate in the same direction as the energy flow. If you performed the activity at the beginning of this chapter, you created longitudinal wave motion in a Slinky by sending pulses along the length of the Slinky. A pulse is a single wave or single disturbance. **Figure 2** illustrates a longitudinal wave.

longitudinal wave a wave in which particles vibrate parallel to the direction of the flow of energy

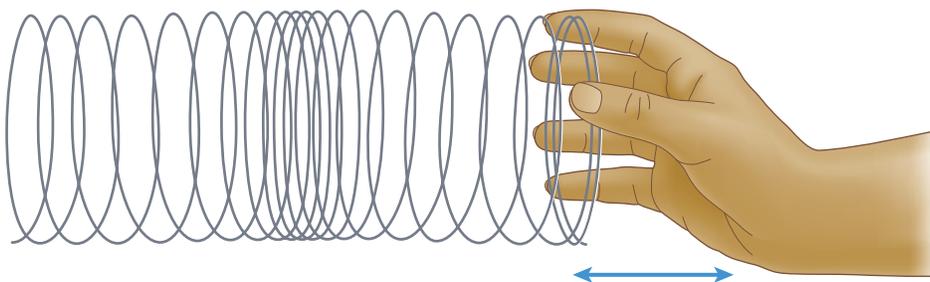


Figure 2 Longitudinal wave motion in a Slinky

Another way to demonstrate a longitudinal wave is to connect a number of masses together with springs, as shown in **Figure 3**. If you pull mass A to the left and then release it, the spring action will pull mass A toward mass B. The energy is transferred from mass A to mass B, then from mass B to mass C, and so on. The particles transferring the energy—the springs or the masses—all move parallel to the direction of the flow of energy.

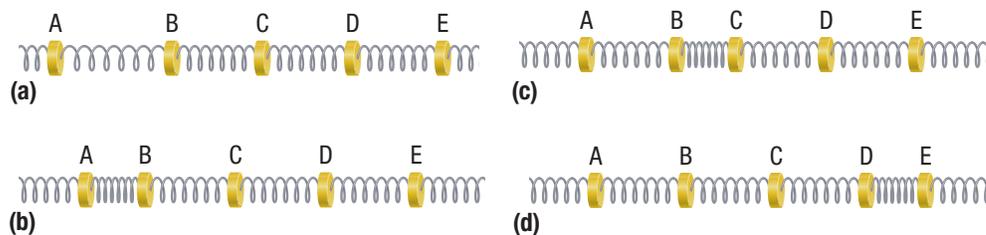


Figure 3 (a) Mass A is pulled to the left and released. (b) Masses A and B move closer together, moving the energy from the stimulus along the springs and masses. (c) The vibration moves along causing masses B and C to be closer. (d) The wave has now made it to mass E. In the entire transfer, the particles have all moved parallel to the direction of the flow of energy.

compression the region in a longitudinal wave in which the medium's particles are closer together

rarefaction the region in a longitudinal wave in which the medium's particles are farther apart

LEARNING TIP

Rarefaction

The term “rarefaction” may be new to you, but you may have heard the term “rarefied” used to describe the air at high altitudes, where a passenger jet flies, for instance. At an altitude of 9000 m, the air is much less dense than at sea level, so we say this less dense air is rarefied. “Rarefied” comes from the word “rare,” which has two older meanings: “loose” and “thin.”

sound a form of energy produced by rapidly vibrating objects detectable by sensory organs such as the ear

Compressions and Rarefactions

Gas molecules have much greater freedom of movement, and they are in constant motion due to their temperature. A longitudinal vibration in a gas results in regions where the particles are closer together, called **compressions**, and regions where they are farther apart, called **rarefactions** (Figure 2).

The terms “compression” and “rarefaction” correspond to the local pressure differences as the wave’s energy passes through the medium. When the particles are closer together, or compressed, the pressure is increased above ambient pressure. The term “ambient pressure” describes the average pressure of the gas; that is, the pressure it would have if the wave were not present. The regions where particles are farther apart, or rarefied, have a pressure that is lower than ambient pressure. This concept is illustrated in **Figure 4**.

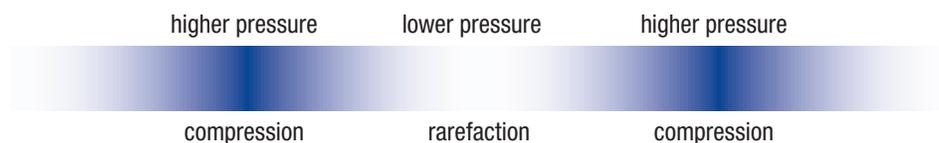


Figure 4 Rarefaction and compression regions in a longitudinal wave correspond to regions of pressure differences.

Sound

A vibrating object can produce longitudinal waves in a part of the medium that surrounds it. If these waves have properties that make them detectable to the human ear, they are called **sound**. The energy transferred through successive compressions and rarefactions of a sound wave causes vibrations in our ears that the brain interprets as sound. (Human hearing is discussed further in Chapter 10.) Sound is also transmitted through liquids and solids. Our ears are less suited to detecting sound waves in liquids and solids, however. In fluids, sound is transmitted as a longitudinal wave. In solids, sound can be transmitted as either a transverse wave or a longitudinal wave.

Complex Wave Motion

Transverse and longitudinal waves are basic types of waves. However, in many cases, these types of waves combine to form a more complex wave. For example, water waves on the surface of a lake are largely produced by wind. The wind will impart some longitudinal motion to the water molecules, resulting in a motion of the water molecules that is oval in shape. The shape of the oval is controlled by how much the molecules move in each

direction. For example, if the perpendicular motion is much greater than the motion parallel to the surface, then the oval is longer (**Figure 5(a)**).

Another example of a complex wave occurs when you strike a solid surface with a solid object. For example, suppose you strike a piece of wood with a hammer. Some molecules are driven forward, initiating a longitudinal wave. The intermolecular forces that connect to the rest of the surface also create a transverse wave that radiates out along the surface (**Figure 5(b)**). 

WEB LINK

To see animations of transverse, longitudinal, and complex waves,



GO TO NELSON SCIENCE

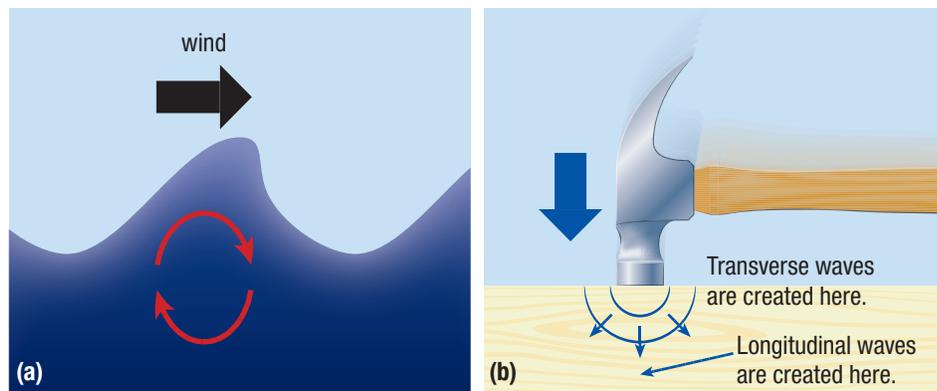


Figure 5 (a) The wind blowing over the surface of water causes the water molecules to move in the shape of an oval. The shape of the oval becomes thinner and more vertical with reduced wind speed. (b) When a wood surface is struck by a hammer, the impact creates a longitudinal wave below the surface, and a transverse wave along the surface.

Mini Investigation

Simulating Transverse and Longitudinal Wave Motion

Skills: Performing, Observing, Analyzing, Evaluating, Communicating

SKILLS
HANDBOOK  A2.1

In this activity, you will investigate longitudinal and transverse wave motion by simulating particle motion. Your teacher will have the class move out into the hall, outside, or to some other suitably large room. Perform movements only when instructed by your teacher.

Part A: Transverse Wave Motion

- Form a line in which all students are standing side by side, facing in the same direction. Leave approximately 1 m between yourself and the student on either side. You and your classmates represent the particles in a medium, and the space between students represents the chemical bonds. The student at one end is student 1, the student next to student 1 is student 2, and so on.
- (a) Student 1 moves forward three steps, student 2 moves forward two steps, and student 3 moves forward one step.
(b) Student 1 moves three steps back and returns to the starting point, student 2 moves ahead one step and then back two, and student 3 moves ahead two steps and back one step. Student 4 moves ahead three steps, student 5 moves ahead two steps, and student 6 moves ahead one step.
- Examine the shape of the wave.
- Repeat Step 2 with the next six students. Continue until the wave has made its way to the end. Repeat as instructed by your teacher.
- Observe how the wave travels down the line of students.

Part B: Longitudinal Wave Motion

- Form a line in which all students are standing one behind the other. Leave about 3 m between each

student. The distance between students should be about 3 m.

- The students near one end of the line will move forward three steps. The motion is to go forward three steps and then back three steps.
 - The student at the back of the line is student 1, the student ahead of student 1 is student 2, and so on. Student 1 takes three steps forward. Student 2 takes two steps forward, and student 3 takes one step forward.
 - Student 1 takes three steps back and remains stationary from now on. Student 2 takes one step forward and two steps back. Student 3 takes two steps forward and then one step back. Student 4 takes three steps forward. Student 5 takes two steps forward, and student 6 takes one step forward.
 - Inspect the progress of the wave.
 - Repeat Step 7 with the next six students. Repeat as instructed by your teacher.
- In the transverse wave demonstration, what did you notice about the distances between you and your neighbours? 
 - Did you feel it was possible to move farther than 3 m from the line, or was this difficult to accomplish? In a true medium, what would control this aspect of the wave's motion? 
 - In the longitudinal wave demonstration, was it difficult to maintain the motion? Why or why not? 
 - Were the simulations in this activity fair? What compromises were made? 

How could you apply information about sound and sound waves to the Unit Task on page 486?

- In transverse waves, the particles of the medium move perpendicular to the direction of the flow of energy.
- In longitudinal waves, the particles of the medium move parallel to the direction of the flow of energy.
- In a fluid, longitudinal waves transfer energy through regions of higher and lower pressure. These regions are called compressions and rarefactions, respectively.
- Sound, an important example of a longitudinal wave, is a form of energy produced by rapidly vibrating objects.
- Many wave motions in nature are a combination of longitudinal and transverse motion.

8.2 Questions

1. In your own words, describe the characteristics of the two basic types of mechanical waves. Make a labelled diagram of each. **K/U C**
2. Provide two examples of transverse waves that you have encountered in everyday life. Explain why each example is considered a transverse wave. **K/U C A**
3. Provide two examples of longitudinal waves that you have encountered in everyday life. Explain why each example is considered a longitudinal wave. **K/U C A**
4. In sports stadiums an activity called the “wave” is sometimes performed by the crowd. Is this a true mechanical wave? If not, what compromises are being made with respect to the definitions given in this section? **K/U**
5. Define sound, and explain how a medium can transfer sound waves efficiently. **K/U C**
6. Is sound a mechanical wave? Explain your answer. **K/U T/I**
7. Aside from communicating by speech, list three benefits of being able to detect sound. **A**
8. Provide two examples of a complex wave motion. Describe the wave motions, and explain how you know that transverse and longitudinal waves are present. **K/U C A**
9. **Figure 6** is an image of an electric ringer inside a bell jar. A vacuum pump can be connected to the jar. You turn the ringer on, and slowly start removing the air from the bell jar. Then you slowly allow the air back in. **K/U T/I**
 - (a) Predict how the sound from the ringer will change as you remove the air and then as you allow the air back in.
 - (b) Explain why the sound will change.



Figure 6 The connection to evacuate the air is hidden from view.