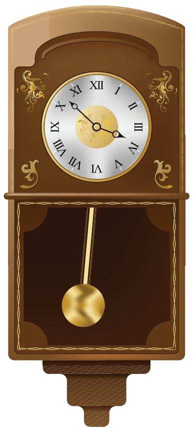
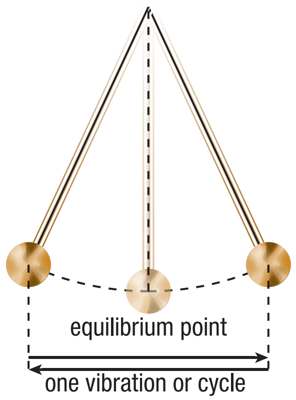
8.1 What Is a Vibration?

In your day-to-day experience you see many objects in back-and-forth motion. For example, the movements of windshield wipers and the pendulum in a clock are back-and-forth motions (**Figure 1(a)**). The wipers and pendulum repeatedly move back and forth along a fixed path, resulting in a cyclical motion. Many of these cyclical motions are more rapid and therefore difficult to see. For example, if you put your hand on the speaker of an operating stereo system, you will feel it shaking with the music. The walls of the speaker are moving back and forth, but they are moving too fast and too slightly to be seen under normal conditions. These objects move back and forth about a middle point, which is called an equilibrium point, or rest position. When the motion stops, the objects return to this point. For instance, if you stop the pendulum in Figure 1(a), it will hang straight down, at the equilibrium point. Notice how the equilibrium point is halfway between the maximum distance that the pendulum swings to the left and to the right. The cyclical motion about an equilibrium point is called a **vibration** (**Figure 1(b)**).



(a)



(b)

Figure 1 (a) A pendulum's swing has a predictable motion. This predictable motion is used to pace some clocks. (b) One vibration, or one cycle, of the pendulum is one complete vibration.

Vibrations and Mechanical Waves

A pendulum is an isolated object—consider instead particles that are part of a material, like a drumhead. If the particles in the drumhead are disturbed, such as when you beat the drum, the vibrations created by the disturbance are transferred throughout the material. This transfer of energy through a material by particle vibration is called a **mechanical wave**. The material through which a mechanical wave travels is called a **medium**. A medium can be a solid, a liquid, or a gas.

Particle Behaviour in Mechanical Waves

When vibrating, the medium tends to gain or lose very little energy. Thus, a vibration can continue for a long time in some media. A vibration is able to travel through a medium because each molecule in the medium is connected to neighbouring molecules by intermolecular forces. These forces allow the distances between atoms to increase slightly without losing energy. This molecular property of a medium allows a mechanical wave to be one of the most efficient forms of energy transmission in nature.

It is the net motion of the particles that causes a vibration. **Net motion** is the displacement of a particle over a certain time interval. The particle may follow a complex path, but the particle's net motion is how far it has moved (straight-line distance) from its starting point to its finishing point. After a wave has passed through a medium, the particles return to their original location. Ideally, there is no net motion of the particles when they have stopped vibrating, so their net displacement is zero. Therefore, no work is done on them by the wave—no energy is lost by the wave and it can continue indefinitely. **Figure 2** illustrates this point. The boat is going up and down when a wave passes, but the boat does not move with the wave energy.

vibration the cyclical motion of an object about an equilibrium point

mechanical wave the transfer of energy through a material due to vibration

medium the material that permits the transmission of energy through vibrations

net motion the displacement of a particle over a certain time interval; the difference between the particle's initial and final positions

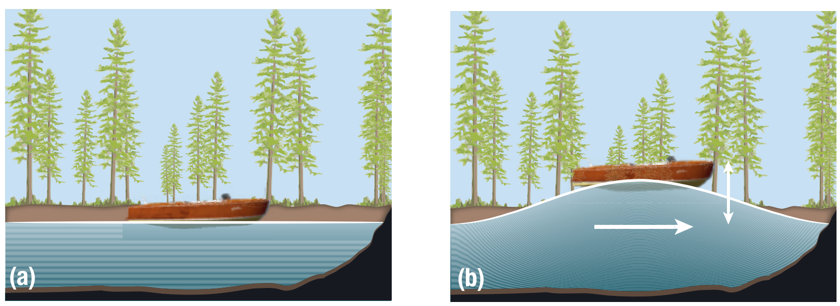


Figure 2 A boat on a lake does not move to shore due to wave action alone. After the wave passes, the boat returns to its position in (a).

Particle Behaviour in Different Media

Recall from previous science courses that molecules are always in motion because of thermal energy. However, thermal motion—motion resulting from thermal energy—is random and does not produce a transfer of energy in the form of a mechanical wave. Instead, the medium has to be disturbed by a vibration to set up a mechanical wave. **Figure 3** illustrates this concept using the example of the drumhead from page 378.

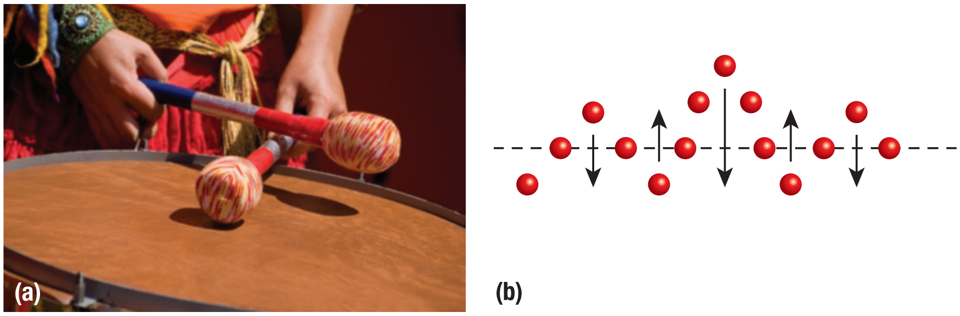


Figure 3 (a) After the musician strikes the drum, a mechanical wave transfers energy outward from the impact point. The wave travels through the medium; in this case, the skin of the drumhead. (b) The particles of the drumhead vibrate and transfer their motion to particles beside them. This allows the wave energy to move through the medium.

All vibrations need a medium to transfer waves. A medium's effectiveness at transmitting vibrations varies, depending on its molecular and mechanical structure, its density, and even its temperature. We now examine more closely how the behaviour of particles in different media allows energy to be transferred by vibrations.

Particle Behaviour in Solid Media

Suppose you sit at one end of a mattress, and at the other end you place some objects such as textbooks. If you bounce on one end of the mattress, the objects at the other end will move. This is because the material in the mattress is connected, so a disturbance at one end is transferred to the other end.

In a solid medium, the atoms are held securely in a crystal formation by strong intermolecular forces. Therefore, they can only vibrate slightly as the disturbance passes through the medium. If the medium returns to its original shape after the disturbance, the medium is said to be **elastic**. Most solid media have this property—even very rigid media, such as steel. In general, rigid materials transfer mechanical waves more efficiently than less rigid materials. Thus, mechanical waves in rigid materials last longer, go faster, and go farther than they do in less rigid media. During an earthquake, for example, vibrations through rigid media like rock can be transmitted thousands of kilometres from the source (**Figure 4**). You will learn more about earthquakes in Chapter 10.

Conversely, the less rigid a medium, the less efficient it is at transferring a vibration. A less rigid material, such as a pillow, disperses more energy through absorption, so a vibration weakens quickly. The speed and distance that a wave can travel are therefore reduced.

elastic the property of a medium that returns to its original shape after being disturbed

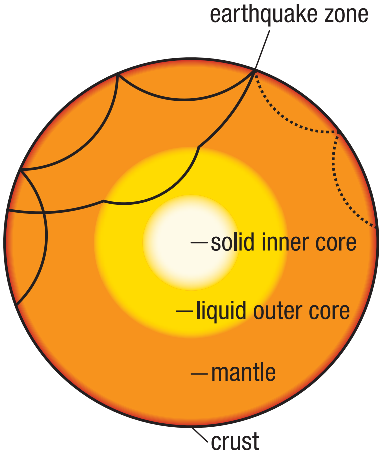


Figure 4 A cross-section of Earth during an earthquake shows how the waves pass through the planet.

Particle Behaviour in Fluid Media

Recall that liquids and gases are classified as fluids because they are materials that can flow. In liquids, the molecules are not in a crystal formation but are still very much in contact. So liquids are very effective transmitters of sound. For example, sound travels almost five times as fast and much farther in water than in air.

The individual molecules in a gas are much farther apart than they are in liquids and solids. Consequently, gas is the least dense state of matter. Gases rely on **translational molecular motion**, or straight-line motion, to transfer vibrations.

translational molecular motion the straight-line motion of a molecule; this motion is typical of gases because the particles in liquids and solids are not free to move in this manner

With their lower density, gases are less effective than solids and liquids at transmitting vibrations. How well a gas transmits a vibration also depends on the gas's temperature and density. **Figure 5** illustrates particle vibration in a solid, a liquid, and a gas.

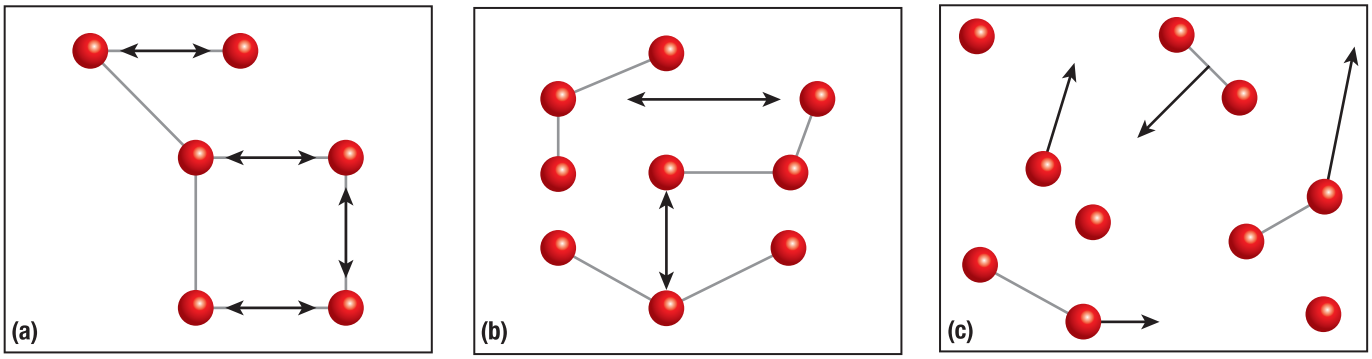


Figure 5 Microscopic particle vibration in (a) a solid, (b) a liquid, and (c) a gas. Solid and liquid media are generally more effective at transmitting vibrations than gases are.

8.1 Summary

- A vibration is the cyclical motion of an object about an equilibrium point.
- All vibrations need a medium to transfer waves.
- A mechanical wave is a transfer of energy through a medium by particle vibration. Particle vibration is caused by a disturbance to the medium.
- A medium is a material that permits the transmission of energy due to vibrations. A medium can be a solid, a liquid, or a gas.
- The particles of an elastic medium return to their original location after a wave passes through.
- The speed of a wave and the distance it can travel depend on the composition of the medium. A rigid medium allows a wave to travel longer and faster than a less rigid medium. A less rigid medium disperses more energy, thus reducing the speed and distance that a wave can travel.

UNIT TASK **BOOKMARK**

How could you apply information about vibrations to either the structure you research or the device you make in the Unit Task on page 486?

8.1 Questions

1. In your own words, explain the difference between a wave and a vibration. K/U
2. List five vibrating objects that you have observed or experienced in everyday life. K/U C A
   (a) Describe each vibrating object, and explain how you know it is a vibration.
   (b) How many of the vibrating objects that you listed can be considered to be transmitting a mechanical wave? List them, and explain your answer.
   (c) For each object from (b), identify the medium that transmits these waves.
3. What properties of a medium allow a wave to pass through most effectively? Provide an example in your answer. K/U C
4. Describe three ways in which we use a source of vibration to create waves that are useful to society. A
5. Describe two ways that you think mechanical waves produce effects that are harmful to society. Support your answer with an example not used in Question 2. A
6. In a graphic organizer, explain the relationship between the speed of a wave in different media and the particle nature of the media. K/U C