9.1 Interference of Waves

On the surface of a lake on a windy day, you will see many complicated wave motions (**Figure 1**). You will not see a simple wave moving in a particular direction. The water surface appears this way because of the action of many thousands of waves from various directions and with various amplitudes and wavelengths. When waves meet, a new wave is generated in a process called **interference**. In this section, you will learn what happens when two waves meet and interfere with each other.

Figure 1 The surface waves on this lake are the result of the interference of thousands of waves of different wavelengths and amplitudes. Most of these waves are caused by the wind, but they are also caused by passing boats and ships.

interference the process of generating a new wave when two or more waves meet

Wave Interference at the Particle Level

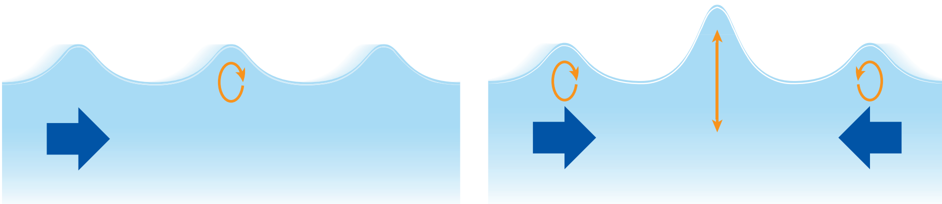
You learned in Chapter 8 that waves are the result of particle vibrations, and that the particles in a medium are connected by forces that behave like small springs. Wave interference is influenced by the behaviour of the particles.

Wave motion is efficient: in most media, little energy is lost as waves move. When waves come together, this efficiency continues. When one wave passes in the vicinity of a particle, the particle moves up and down in an oval path, which allows the wave to move in a specific direction, as shown in **Figure 2(a)**. When a second wave is also present, the vibration of the particle is modified. The oval motion of the particles stimulates the next particle in the direction of the wave's motion to begin vibrating. When two (or more) waves come together, as shown in **Figure 2(b)**, the particle moves up and down rather than in an oval path because the speeds of the combined waves cancel each other out. The motion of the particle allows the waves to pass through each other. The waves are not modified, so the amount of energy stays the same. Thus, when two or more waves interact, the particle vibration is such that the direction and energy of each wave are preserved. After the waves have passed through each other, none of their characteristics—wavelength, frequency, and amplitude—change.

WEB LINK

To see a simulation of simple interference,

GO TO NELSON SCIENCE



(a) (b)

Figure 2 (a) The basic motion of a vibrating particle in a travelling wave. (b) When two waves meet, the particle motion is more up and down. The wave characteristics are unchanged after the waves pass through each other.

Constructive and Destructive Interference

principle of superposition at any point the amplitude of two interfering waves is the sum of the amplitudes of the individual waves

constructive interference the process of forming a wave with a larger amplitude when two or more waves combine

destructive interference the process of forming a wave with a smaller amplitude when two or more waves combine

When two waves meet, the forces on their particles are added together. If the two waves are in phase (the phase shift between them is zero), then the resulting amplitude is the sum of the two original amplitudes. This is called the **principle of superposition**: the resulting amplitude of two interfering waves is the sum of the individual amplitudes. **Constructive interference** occurs when two or more waves combine to form a wave with an amplitude greater than the amplitudes of the individual waves (**Figure 3**). **Destructive interference** occurs when two or more waves that are out of phase combine to form a wave with an amplitude less than at least one of the initial waves (**Figure 4**).

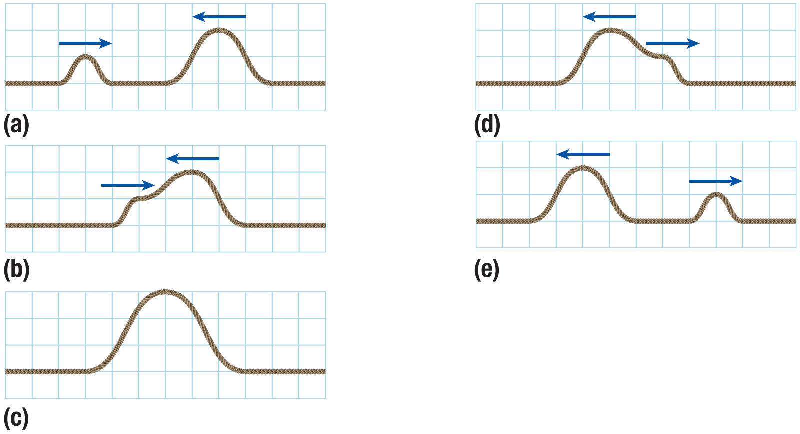


Figure 3 Constructive interference. Two wave pulses approach each other on a rope. Notice how the amplitudes of the two waves add together. Notice, also, how the waves are unchanged after they pass through each other. The amplitude during interference in (c) is the sum of the amplitudes of the two waves.

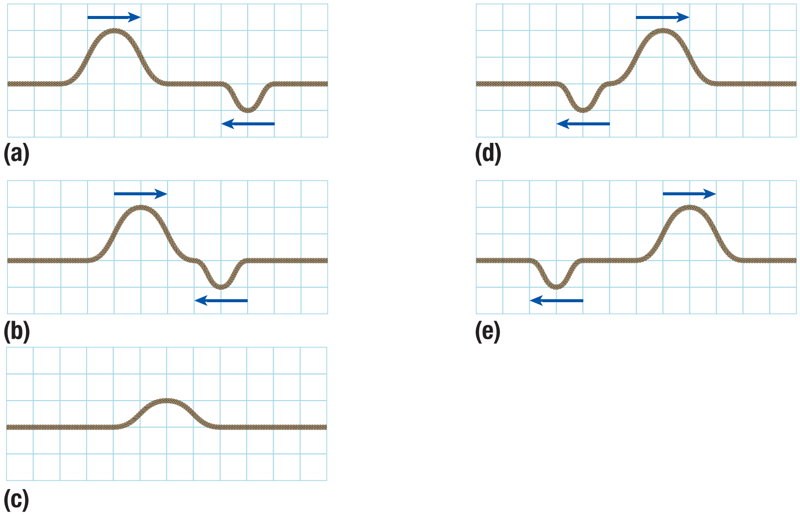


Figure 4 Destructive interference. When two wave pulses that are out of phase come together, the resulting amplitude is reduced.

Mini **Investigation**

Demonstrating Interference with Springs

Skills: Performing, Observing, Analyzing

SKILLS HANDBOOK A2.1

You can use a Slinky to demonstrate both constructive and destructive interference. In this investigation, you will observe the amplitude of waves caused by constructive and destructive interference.

Equipment and Materials: Slinky or long spring; masking tape

1. Form a small tab from the masking tape, and attach it to the middle of the Slinky.
2. With a student at each end, stretch the Slinky to an appropriate length (for example, 2.0 m).

Hold the Slinky firmly and do not overstretch it. Observe from the side, in case of an accidental release.

3. With one end held firm, send a positive pulse (a pulse where the tab moves in the positive direction) down the Slinky, noting the displacement of the tab.
4. Send a simultaneous positive pulse from each end of the Slinky, each with the same amplitude. Note the displacement of the tab.
5. Repeat Step 4, except send a positive pulse from one end of the Slinky and a negative pulse from the other.

A. Describe the amplitude the tab reached when a single pulse was sent down the Slinky. K/U

B. Describe the amplitude the tab reached when two positive pulses were sent down the Slinky from opposite ends. K/U

C. Describe the amplitude the tab reached when a positive pulse and a negative pulse were sent down the Slinky. K/U

CAREER LINK

Product design engineers, such as designers of audio equipment, must understand properties of sound, including interference. To learn more about becoming a product design engineer,

GO TO NELSON SCIENCE

Technology Using Interference of Waves

Noise-cancelling headphones, shown in **Figure 5**, use the concept of destructive interference. The electronics inside the headphones generate a wave that is out of phase with sound waves in the exterior environment. This out-of-phase wave is played inside the headset. Using destructive interference, the outside noise is cancelled. Such devices allow users to listen to music at lower volume levels, reducing potential damage to their hearing.

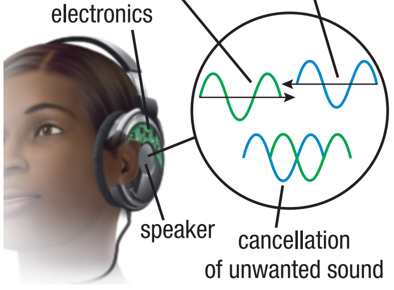


Figure 5 A detector inside the headset determines what noise there is, and a speaker in the headphone emits the out-of-phase wave.

Tutorial 1 Applying the Principle of Superposition

To determine the resulting pattern when two waves interfere with each other, apply the principle of superposition.

Sample Problem 1

The two waveforms shown in **Figure 6** are about to interfere with each other. Draw the resultant waveform.

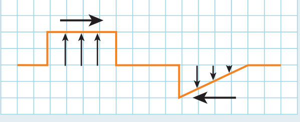


Figure 6

Step 1. On graph paper, draw the two waveforms, exactly as shown in Figure 6, but with one over the other. To draw the resultant waveform, use the point at which the midpoint of the waveform on the left coincides with the midpoint of the waveform on the right (**Figure 7**). Include the arrows showing the amplitudes above and below the equilibrium position.

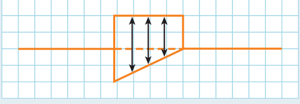


Figure 7

Step 2. For each segment of the graph paper, add the amplitudes of the top and the bottom waveforms. Use negative numbers for the bottom waveform. Draw the resultant waveform (**Figure 8**).

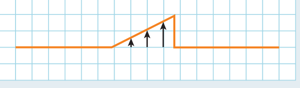


Figure 8

Step 3. Draw the waveforms moving away from each other, with the same characteristics they started with (**Figure 9**).

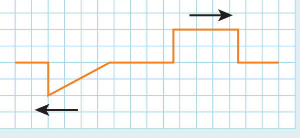


Figure 9

Practice

1. The two waveforms in **Figure 10** are about to interfere with each other. Draw the resultant waveform. K/U T/I

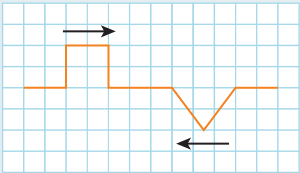


Figure 10

2. The two waveforms in **Figure 11** are about to interfere with each other. Draw the resultant waveform. K/U T/I

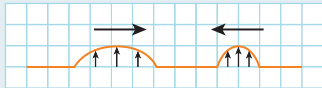


Figure 11

9.1 Summary

- The process of generating a new wave when two or more waves meet is called interference.
- Vibrating particles in a medium react to the sum of all forces on them. Their motion is caused by the sum total of forces on them.
- The principle of superposition states that, when two waves meet, the resulting amplitude is the sum of the individual amplitudes.
- Constructive interference occurs when two waves combine and the amplitude of the resulting wave is greater than the amplitudes of all the individual waves.
- Destructive interference occurs when two waves combine and the amplitude of the resulting wave is less than at least one of the original amplitudes.
- Humans can design technologies to take advantage of wave properties. An example of such a technology is noise-cancelling headphones.

UNIT TASK **BOOKMARK**

You can apply what you learned about interference to the device you construct for the Unit Task described on page 486.

9.1 Questions

1. Describe how waves combine. K/U
   (a) What happens when waves that are in phase combine?
   (b) What happens when waves that are out of phase combine?
2. Use the principle of superposition to determine the resulting waveform when the waves in **Figure 12** interfere with each other. T/I C

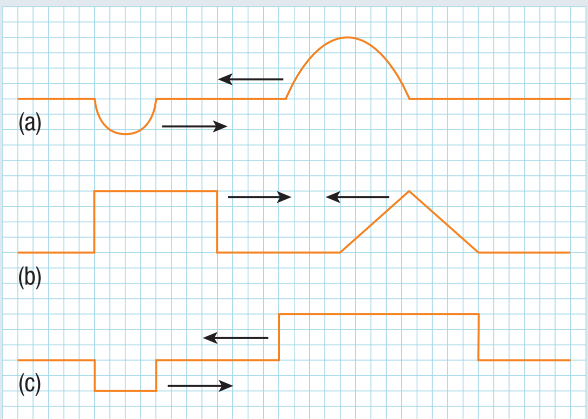


Figure 12

3. Study **Figure 13**. K/U T/I C

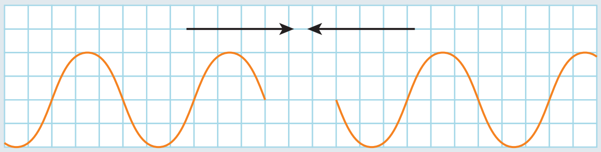


Figure 13

   (a) How would the pattern of the two waves coming together appear? Hint: Refer to Figure 5.
   (b) Make a sketch of what you would expect to see. Explain your thinking.
   (c) Assume that the continuous waves are out of phase by half a wavelength and are interfering. Make a sketch of what you would expect to see. Explain your thinking.