PHet Simulations

Waves Intro

Section 9.1 - Wave Interference

Learning Goal: By the end of today, I will be more familiar with the interaction of two independent waves.

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.

Waves are the result of particle vibrations, and that the particles in a medium are connected by forces that behave like small springs.

Wave motion is efficient: in most media, little energy is lost as waves move. When waves come together, this efficiency continues.

The basic motion of a vibrating particle in a travelling wave is modelled with an oval (in the form of an arrow). An ideal wave would have particles moving only up and down. If you have ever floated in deep water on a lake you would feel not only an up and down sensation, but a back and forth sensation as well.

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.

(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

Constructive Interference

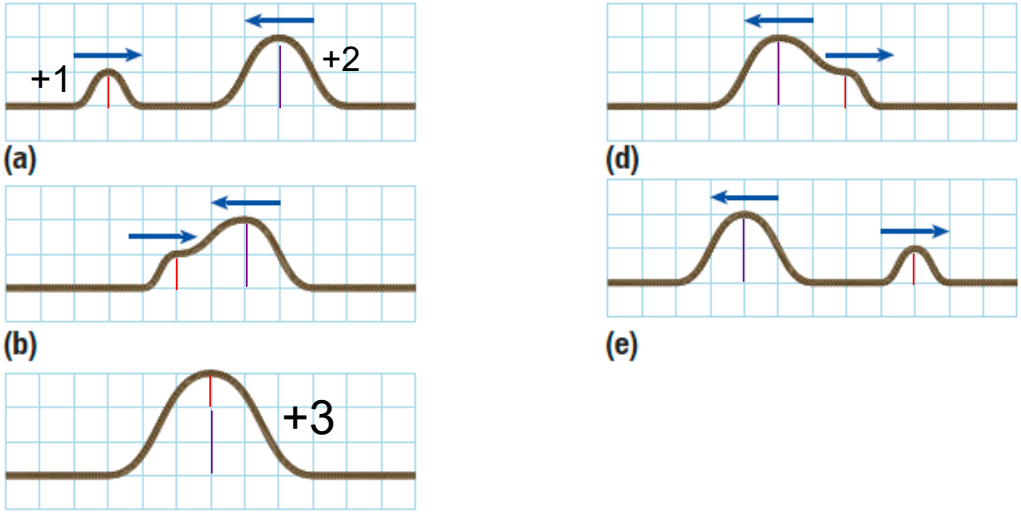

Figure 3 Constructive interference. Two wave pulses approach each other on a rope. Notice how the amplitudes of the two waves add together. Notice, also, how the waves are unchanged after they pass through each other. The amplitude during interference in (c) is the sum of the amplitudes of the two waves.

Destructive Interference

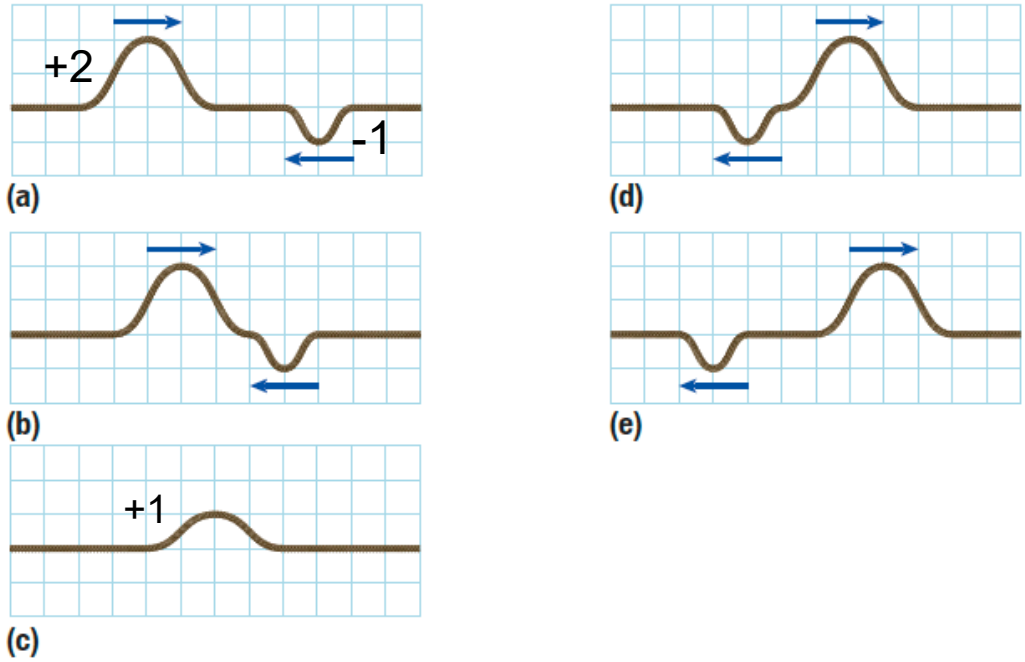

Figure 4 Destructive interference. When two wave pulses that are out of phase come together, the resulting amplitude is reduced.

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.

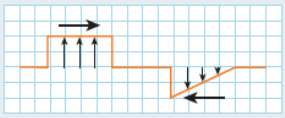

Figure 6

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.

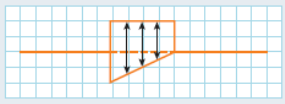

Figure 7

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**).

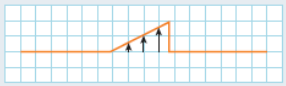

Figure 8

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

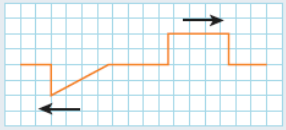

Figure 9

Practice

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

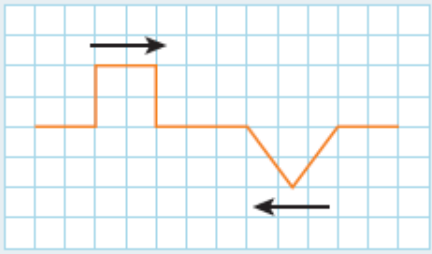

Figure 10

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

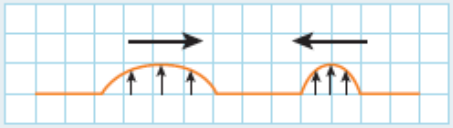

Figure 11

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.

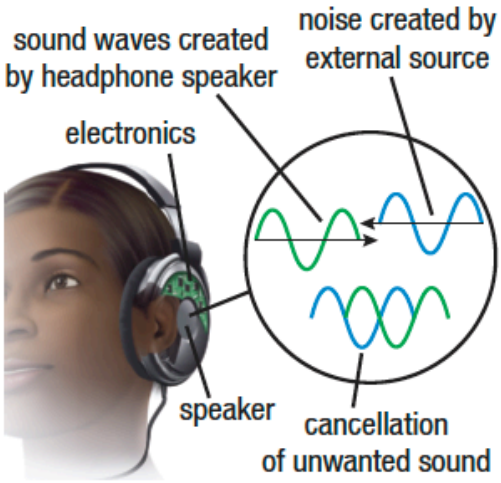

Figure 5 A detector inside the headset determines what noise there is, and a speaker in the headphone emits the out-of-phase wave.

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.

PHet Simulation

Wave Interference

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

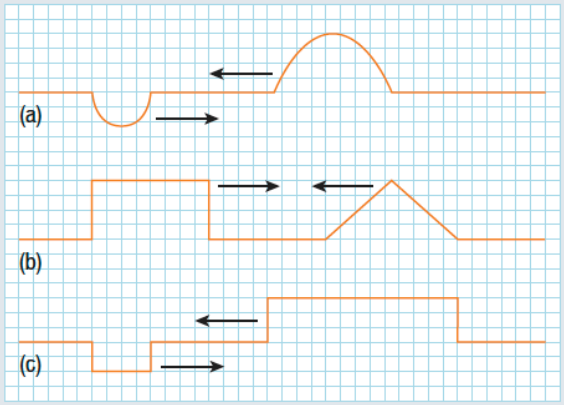

Figure 12

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

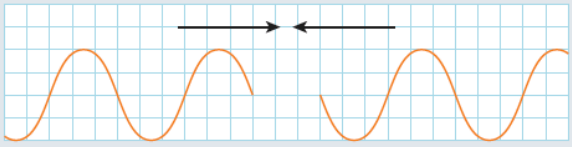

Figure 13

(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.

Section 9.1 #1-3