Making Connections

4. Actual water waves do not behave exactly like the ideal transverse waves described in this section. For example, ocean waves increase in amplitude and decrease in wavelength as they approach a beach, but when they near the shore, they "break." Research this issue and, on one page, describe with a diagram how the water particles in a water wave actually move and why this affects their behaviour when waves crash on the beach. Follow the links for Nelson Physics 11, 6.5.

GO TO www.science.nelson.com

6.6 Interference of Waves

Up to this point, we have been dealing with one wave at a time. What happens when two waves meet? Do they bounce off each other? Do they cancel each other out? When pulses travel in opposite directions in a rope or spiral spring, the pulses interfere with each other for an instant and then continue travelling unaffected. This behaviour is common to all types of waves.

Types of Interference

Wave interference occurs when two waves act simultaneously on the same particles of a medium. There are two types of interference: constructive and destructive. For transverse pulses, **destructive interference** occurs when a crest meets a trough. If the crest and trough have equal amplitude and shape, their amplitudes cancel each other for an instant. Then the crest and trough continue in their original directions, as shown in **Figure 1**. For longitudinal pulses, destructive interference occurs when a compression meets a rarefaction.

Constructive interference occurs when pulses build each other up, resulting in a larger amplitude (**Figure 2**). This occurs for transverse pulses when a crest

wave interference: occurs when two or more waves act simultaneously on the same particles of a medium

destructive interference: occurs when waves diminish one another and the amplitude of the medium is less than it would have been for either of the interfering waves acting alone

constructive interference: occurs when waves build each other up, resulting in the medium having a larger amplitude

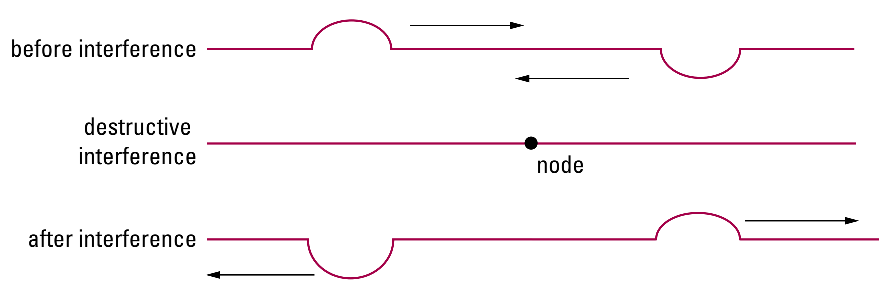

Figure 1
Destructive interference of pulses

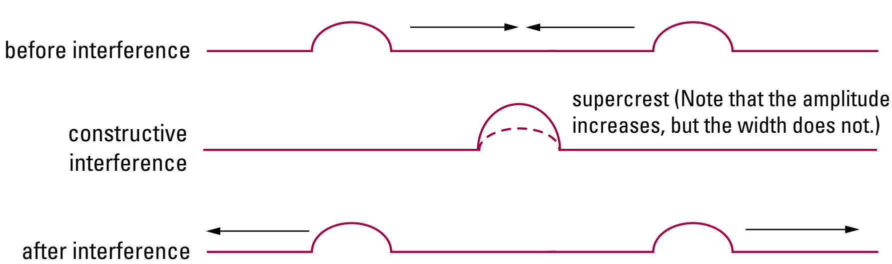

Figure 2
Constructive interference of pulses

supercrest: occurs when a crest meets a crest

supertrough: occurs when a trough meets a trough

principle of superposition: At any point the resulting amplitude of two interfering waves is the algebraic sum of the displacements of the individual waves.

meets a crest, causing a **supercrest**, or a trough meets a trough, causing a **supertrough**. Constructive interference also occurs for longitudinal pulses.

In **Figure 1**, the interference in each case is shown at the instant that the pulses overlap or become superimposed on one another. If we call the amplitudes on one side of the rest axis positive and the amplitudes on the opposite side negative, then the superimposed amplitude is the addition of the individual amplitudes. For example, amplitudes of +1.0 cm and –1.0 cm are added to produce a zero amplitude. The concept of amplitude addition is summarized in the **principle of superposition**, which states that at any point the resulting amplitude of two interfering waves is the algebraic sum of the displacements of the individual waves.

This principle is especially useful for finding the resulting pattern when pulses that are unequal in size or shape interfere with one another. To learn how to apply the principle of superposition in one dimension, refer to **Figure 3**. In **Figure 3(a)** two straight-line pulses are added; in **Figure 3(b)** two curved-line pulses are added.

The principle of superposition may be used to find the resultant displacement of any medium when two or more waves of different wavelengths interfere. In every case, the resultant displacement is determined by an algebraic summing of all the individual wave displacements. These displacements may be added together electronically and the resultant displacement may be displayed on an oscilloscope (**Figure 4**). The resultant wave is the only one seen, not the individual interfering waves.

DID YOU KNOW ?

Principle of Superposition

The principle of superposition applies only to displacements that are reasonable in size because large waves that interfere may cause distortion of the medium through which they are travelling.

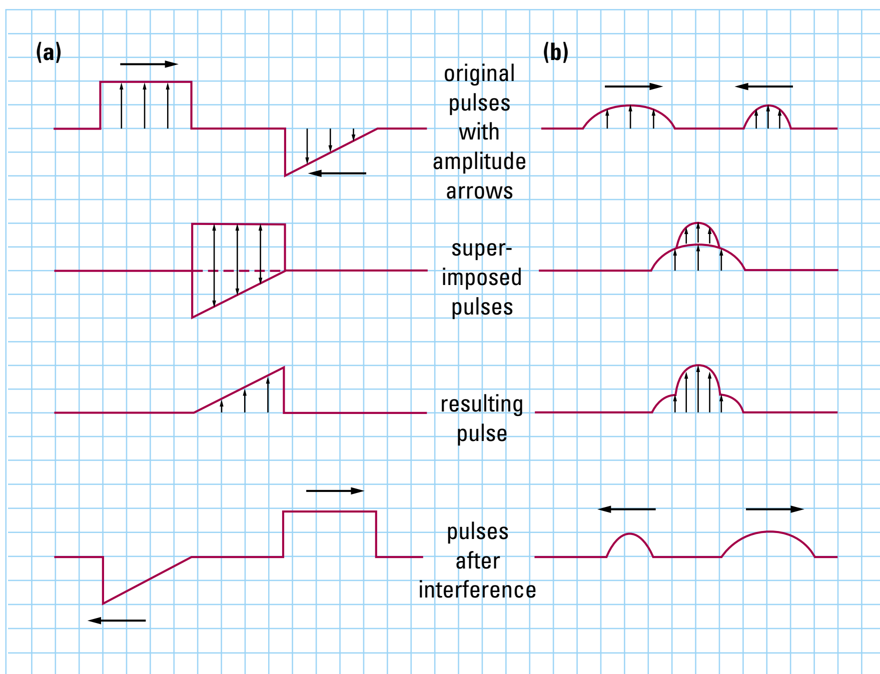

Figure 3
Applying the principle of superposition
(a) Straight-line pulses
(b) Curved-line pulses

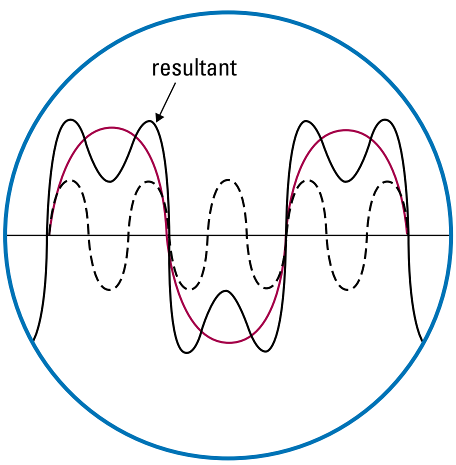

Figure 4
Resultant displacement as displayed on an oscilloscope. Note that only the solid black line would be observed.

Try This Activity

Demonstrating Interference with Springs

Both constructive and destructive interference can be demonstrated using the Slinky spring.

- Tape a small tab to a coil at the middle of the spring.
- With a student at each end, stretch the spring to an appropriate length (e.g., 2.0 m).
- With one end held firm, send a positive pulse down the spring, noting the displacement of the tab.
- Simultaneously, send a positive pulse from each end of the spring, each with the same amplitude. Note the displacement of the tab.
- Repeat the previous step, except send a positive pulse from one end of the spring and a negative pulse from the other.

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

Practice

Understanding Concepts

1. State whether the interference is constructive or destructive when
   (a) a large crest meets a small trough
   (b) a supertrough is formed
   (c) a small compression meets a large compression
2. Use the principle of superposition to determine the resulting pulse when the pulses shown in **Figure 5** are superimposed on each other. (The point of overlap should be at the horizontal midpoints of the pulses.)

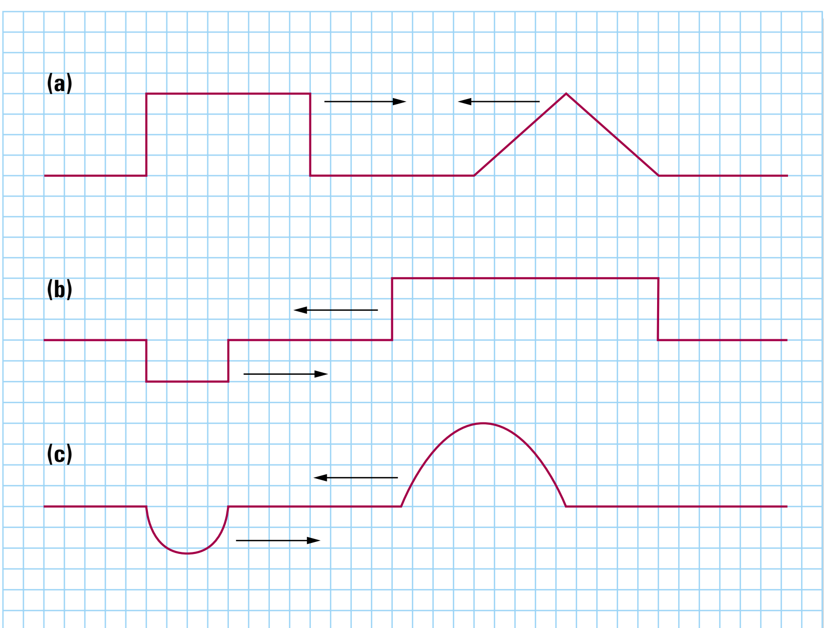

Figure 5

SUMMARY Interference of Waves

- Waves can pass through each other in a medium without affecting each other; only the medium particles are momentarily affected.
- The resultant displacement of a particle is the algebraic sum of the individual displacements contributed by each wave.
- If the resultant displacement is greater than that caused by either wave alone, constructive interference is occurring; if it is smaller, destructive interference is occurring.

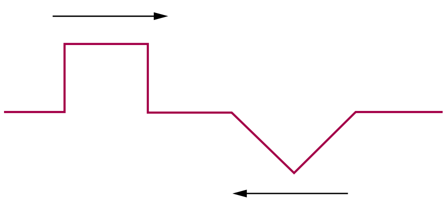

Figure 6
For question 1

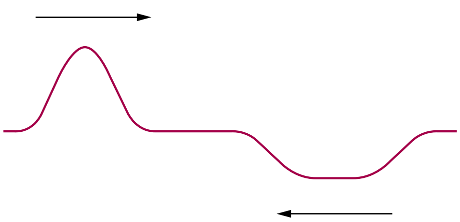

Figure 7
For question 2

Section 6.6 Questions

Understanding Concepts

1. **Figure 6** shows two pulses approaching one another. Sketch the appearance of the medium when the two pulses overlap, centres coinciding.
2. Two pulses move toward each other as shown in **Figure 7**. Sketch the resultant shape of the medium when the two pulses overlap, centres coinciding.
3. Trace the pulses illustrated in **Figure 8** into your notebook and determine the resultant displacement of the particles of the medium at each instant, using the principle of superposition.

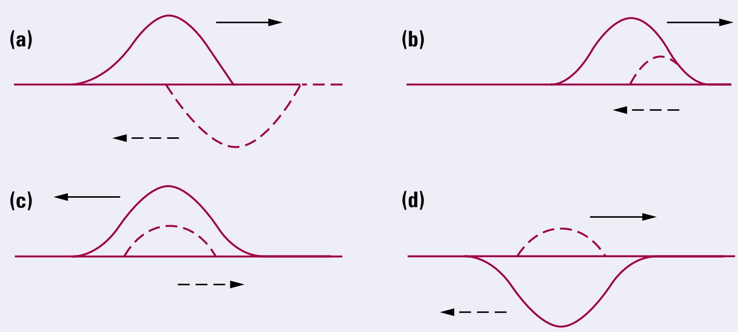

Figure 8

4. When waves crash into a seawall, the incoming waves interfere with the reflected waves, causing both constructive and destructive interference. How would you identify each type of interference?
5. What happens when two billiard balls, rolling toward one another, collide head on? How does this differ from two waves or pulses that collide head on?

Making Connections

6. (a) What is the difference between AM and FM radio signals?
   (b) Describe one advantage of FM broadcasting over AM broadcasting. Follow the links for Nelson Physics 11, 6.3.

GO TO www.science.nelson.com