Transverse pulses 7

Introduction and key concepts

ESACF

This chapter forms the basis of the discussion into mechanical waves in the following chapters. We begin by discussing pulses. Pulses are disturbances in a medium. If you tap water in a bucket with your finger, notice that a ripple moves away from the point where you touched the water. The ripple is a pulse moving away from where you touched the water. See introductory video: (▶ Video: VPchw at www.everythingscience.co.za)

What is a medium?

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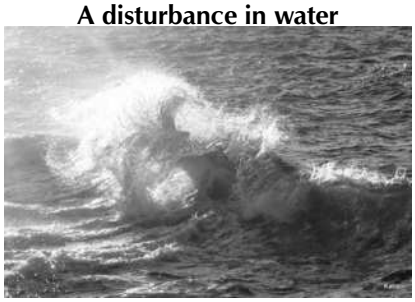
A medium is the substance or material through which a pulse moves. The medium carries the pulse from one place to another. The medium does not create the pulse and the medium is not the pulse. Therefore the medium does not travel with the pulse as the pulse moves through it.

In each medium, the particles that make up the medium are moved *temporarily* from their rest position. In order for a pulse to travel, the different parts of the medium must be able to interact with each other.

A disturbance in water



Picture by mikeyskatie on Flickr.com

> *DEFINITION: Medium*
>
> A medium is the substance or material in which a pulse will move.

Pulses: amplitude and length

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What is a pulse?

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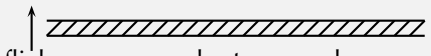
Investigation: Observation of pulses

Take a heavy rope. Have two people hold the rope stretched out horizontally. Flick the rope at one end only once.



flick rope upwards at one end, once only

What happens to the disturbance that you created in the rope? Does it stay at the place where it was created or does it move down the length of the rope?

In the activity, we created a *pulse*. A pulse is a *single* disturbance that moves through a medium. In a transverse pulse the displacement of the medium is perpendicular to the direction of motion of the pulse. Figure 7.2 shows an example of a transverse pulse. In the activity, the rope or spring was held horizontally and the pulse moved the rope up and down. This was an example of a transverse pulse.

DEFINITION: Pulse

A pulse is a single disturbance that moves through a medium.

DEFINITION: Transverse Pulse

A pulse where all of the particles disturbed by the pulse move perpendicular (at a right angle) to the direction in which the pulse is moving.

Pulse length and amplitude

The amplitude of a pulse is a measurement of how far the medium is displaced momentarily from a position of rest. The pulse length is a measurement of how long the pulse is. Both these quantities are shown in Figure 7.2.

DEFINITION: Amplitude

The amplitude of a pulse is the maximum disturbance or distance the medium is displaced from its rest (equilibrium) position.
Quantity: Amplitude (A) Unit name: metre Unit symbol: m

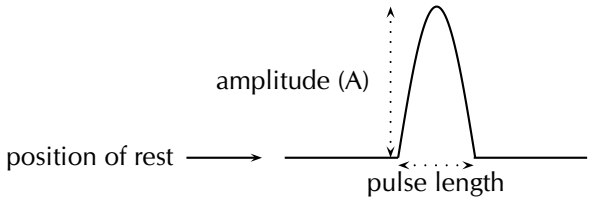
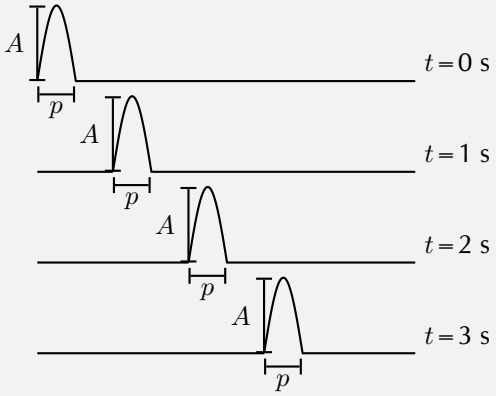


Figure 7.2: Example of a transverse pulse

The position of rest is the position the medium would be in if it were undisturbed. This is also called the equilibrium position. People will often use rest and equilibrium interchangeably.

Investigation: *Pulse length and amplitude*

The graphs below show the positions of a pulse at different times.



Use your ruler to measure the lengths of a and p. Fill your answers in the table.

Sign **Sign**	**Symbol** **Symbol**	**Meaning** **Meaning**
Time	A	p
$t = 0$ s		
$t = 1$ s		
$t = 2$ s		
$t = 3$ s		

What do you notice about the values of A and p?

In the activity, we found that the values for how high the pulse (A) is and how wide the pulse (p) is the same at different times. *Pulse length* and *amplitude* are two important quantities of a pulse.

Pulse speed

DEFINITION: Pulse speed

Pulse speed is the distance a pulse travels per unit time.
Quantity: Pulse speed (v) Unit name: metre per second Unit symbol: $\text{m} \cdot \text{s}^{-1}$

Speed is defined as the distance travelled per unit time (this will be covered in more detail in Motion in One Dimension). If the pulse travels a distance D in a time t, then the pulse speed v is:

$$v = \frac{D}{t}$$

Example 1: *Pulse speed*

QUESTION

A pulse covers a distance of 2 *m in* 4 *s on a heavy rope. Calculate the pulse speed.*

SOLUTION

Step 1 : ***Analyse the question***

We are given:

- the distance travelled by the pulse: $D = 2\,\text{m}$
- the time taken to travel $2\,\text{m}$: $t = 4\,\text{s}$

We are required to calculate the speed of the pulse.

Step 2 : ***Apply the relevant principles***

We can use:

$$v = \frac{D}{t}$$

to calculate the speed of the pulse.

Step 3 : ***Do the calculation***

$$\begin{aligned} v &= \frac{D}{t} \\ &= \frac{2\,\text{m}}{4\,\text{s}} \\ &= 0,5\,\text{m} \cdot \text{s}^{-1} \end{aligned}$$

Step 4 : ***Quote the final result***

The pulse speed is $0,5\,\text{m} \cdot \text{s}^{-1}$.

Tip

The pulse speed depends on the properties of the medium and not on the amplitude or pulse length of the pulse.

Exercise 7 - 1

1. A pulse covers a distance of 5 m in 15 s. Calculate the speed of the pulse.
2. A pulse has a speed of $5\,\text{cm} \cdot \text{s}^{-1}$. How far does it travel in $2,5$ s?
3. A pulse has a speed of $0,5\,\text{m} \cdot \text{s}^{-1}$. How long does it take to cover a distance of 25 cm?
4. How long will it take a pulse moving at $0,25\,\text{m} \cdot \text{s}^{-1}$ to travel a distance of 20 m?
5. The diagram shows two pulses in the same medium. Which has the higher speed? Explain your answer.

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(1.) 002q (2.) 002r (3.) 002s (4.) 002t (5.) 002u

Superposition of pulses

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See video: VPciu at www.everythingscience.co.za

Two or more pulses can pass through the same medium at that same time in the same place. When they do they interact with each other to form a different disturbance at that point. The resulting pulse is obtained by using the *principle of superposition*.

DEFINITION: Principle of superposition

The principle of superposition states that when two disturbance occupy the same space at the same time the resulting disturbance is the sum of two disturbances.

After pulses pass through each other, each pulse continues along its original direction of travel, and their original amplitudes remain unchanged.

Constructive interference takes place when two pulses meet each other to create a larger pulse. The amplitude of the resulting pulse is the sum of the amplitudes of the two initial pulses. This could be two crests meeting or two troughs meeting. This is shown in Figure 7.3.

DEFINITION: Constructive interference

Constructive interference is when two pulses meet, resulting in a bigger pulse.

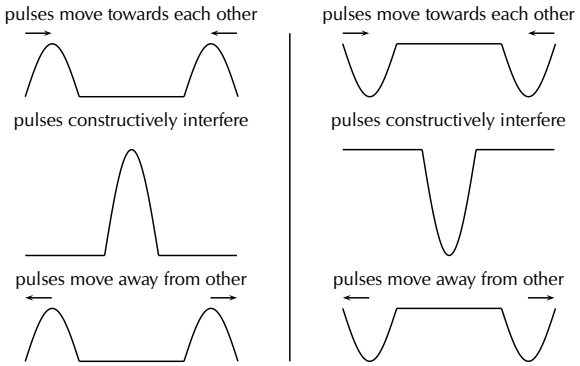


Figure 7.3: Superposition of two pulses: constructive interference.

Destructive interference takes place when two pulses meet and result in a smaller amplitude disturbance. The amplitude of the resulting pulse is the sum of the amplitudes of the two initial pulses, but the one amplitude will be a negative number. This is shown in Figure 7.4. In general, amplitudes of individual pulses are summed together to give the amplitude of the resultant pulse.

DEFINITION: Destructive interference

Destructive interference is when two pulses meet, resulting in a smaller pulse.

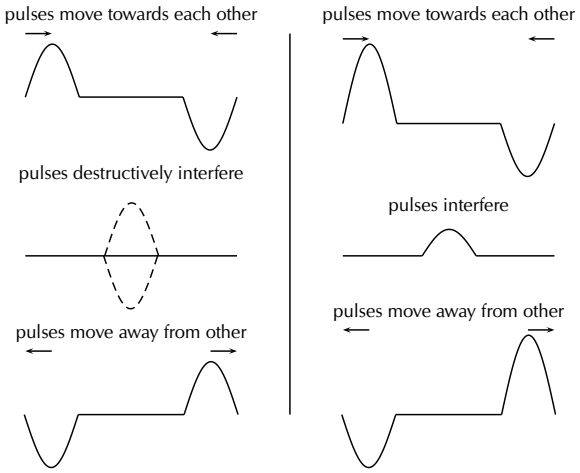
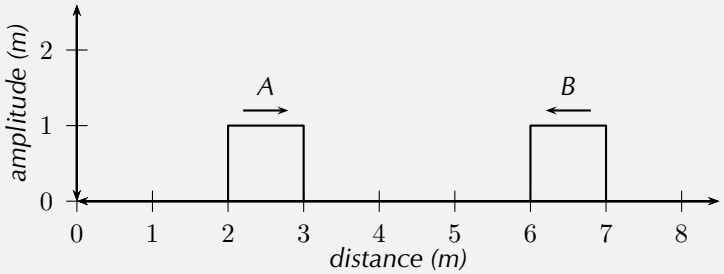


Figure 7.4: Superposition of two pulses. The left-hand series of images demonstrates destructive interference, since the pulses cancel each other. The right-hand series of images demonstrate a partial cancellation of two pulses, as their amplitudes are not the same in magnitude.

Example 2: *Superposition of pulses*

QUESTION

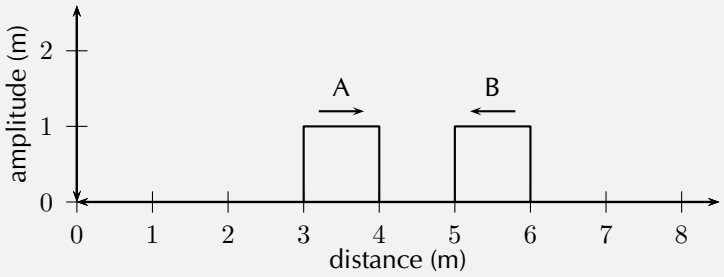
The two pulses shown below approach each other at 1 $m \cdot s^{-1}$. Draw what the waveform would look like after 1 s, 2 s and 5 s.



SOLUTION

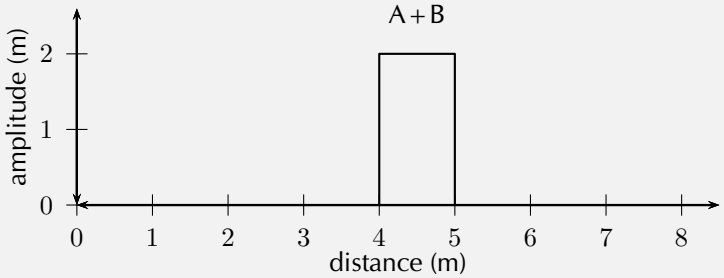
Step 1 : ***After 1 s***

After 1 s, pulse A has moved 1 m to the right and pulse B has moved 1 m to the left.



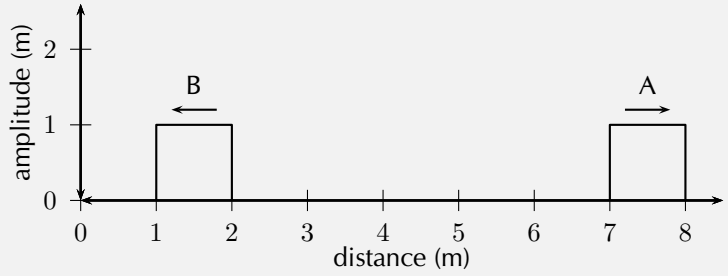
Step 2 : ***After 2 s***

After 1 s more, pulse A has moved 1 m to the right and pulse B has moved 1 m to the left.



Step 3 : ***After 5 s***

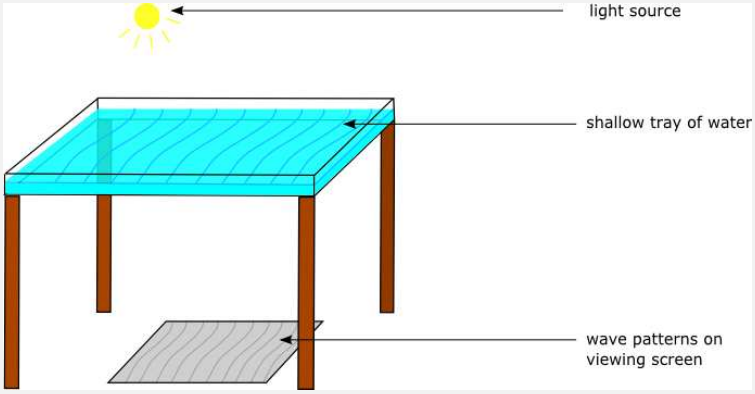
After 5 s more, pulse A has moved 5 m to the right and pulse B has moved 5 m to the left.



General experiment: *Constructive and destructive interference*

Aim: To demonstrate constructive and destructive interference

Apparatus: Ripple tank apparatus



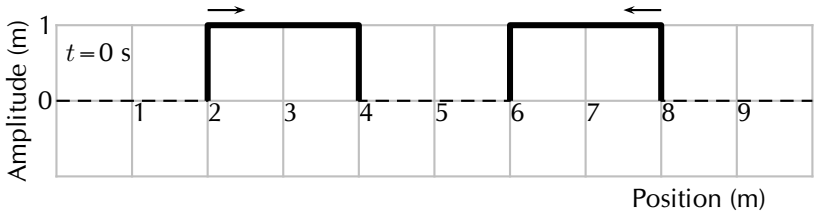
Method:

1. Set up the ripple tank
2. Produce a single pulse and observe what happens (you can do this any means, tapping the water with a finger, dropping a small object into the water, tapping a ruler or even using a electronic vibrator)
3. Produce two pulses simultaneously and observe what happens
4. Produce two pulses at slightly different times and observe what happens

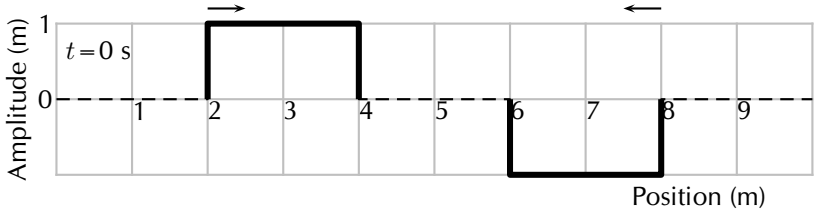
Results and conclusion: You should observe that when you produce two pulses simultaneously you see them interfere constructively and when you produce two pulses at slightly different times you see them interfere destructively.

Exercise 7 - 2

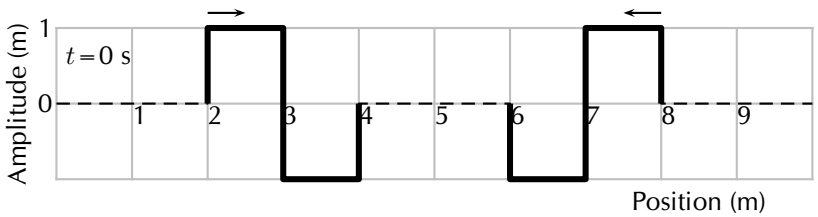
1. For the following pulse, draw the resulting wave forms after 1 s, 2 s, 3 s, 4 s and 5 s. Each pulse is travelling at $1\ \text{m}\cdot\text{s}^{-1}$. Each block represents 1 m. The pulses are shown as thick black lines and the undisplaced medium as dashed lines.



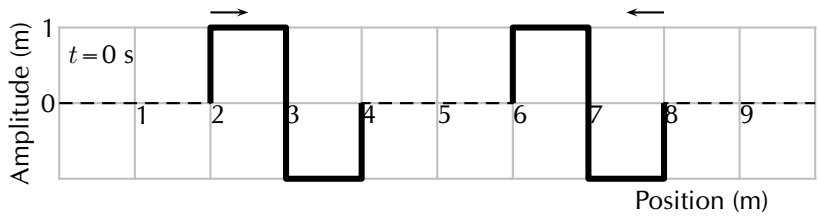
2. For the following pulse, draw the resulting wave forms after 1 s, 2 s, 3 s, 4 s and 5 s. Each pulse is travelling at $1\ \text{m}\cdot\text{s}^{-1}$. Each block represents 1 m. The pulses are shown as thick black lines and the undisplaced medium as dashed lines.



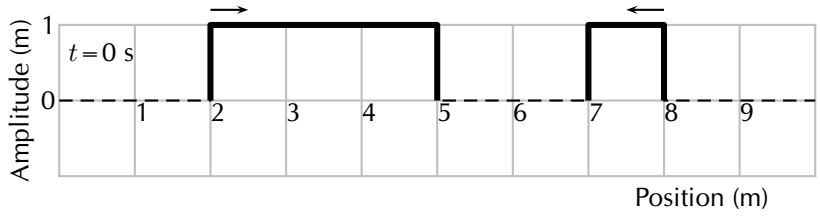
3. For the following pulse, draw the resulting wave forms after 1 s, 2 s, 3 s, 4 s and 5 s. Each pulse is travelling at $1\ \text{m}\cdot\text{s}^{-1}$. Each block represents 1 m. The pulses are shown as thick black lines and the undisplaced medium as dashed lines.



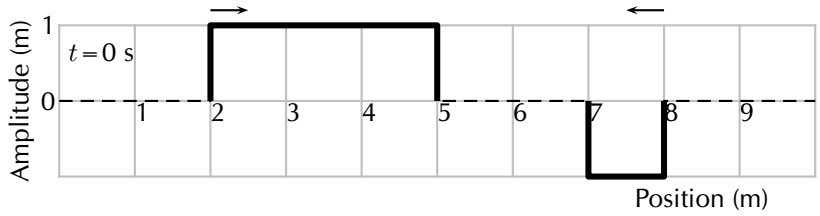
4. For the following pulse, draw the resulting wave forms after 1 s, 2 s, 3 s, 4 s and 5 s. Each pulse is travelling at $1\ \text{m} \cdot \text{s}^{-1}$. Each block represents 1 m. The pulses are shown as thick black lines and the undisplaced medium as dashed lines.



5. For the following pulse, draw the resulting wave forms after 1 s, 2 s, 3 s, 4 s and 5 s. Each pulse is travelling at $1\ \text{m} \cdot \text{s}^{-1}$. Each block represents 1 m. The pulses are shown as thick black lines and the undisplaced medium as dashed lines.



6. For the following pulse, draw the resulting wave forms after 1 s, 2 s, 3 s, 4 s and 5 s. Each pulse is travelling at $1\ \text{m} \cdot \text{s}^{-1}$. Each block represents 1 m. The pulses are shown as thick black lines and the undisplaced medium as dashed lines.



7. What is superposition of waves?

8. What is constructive interference?

9. What is destructive interference?

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(1.) 002v (2.) 002w (3.) 002x (4.) 002y (5.) 002z (6.) 0030
(7.) 0031 (8.) 0032 (9.) 0033

Chapter 7 | Summary

See the summary presentation (▶ Presentation: VPcjo at www.everythingscience.co.za)

- A medium is the substance or material in which a pulse will move.
- A pulse is a single disturbance that moves through a medium.
- The amplitude of a pulse is the maximum disturbance or distance the medium is displaced from its equilibrium position (rest).
- Pulse speed is the distance a pulse travels per unit time.
- Constructive interference is when two pulses meet and result in a bigger pulse.
- Destructive interference is when two pulses meet and and result in a smaller pulse.

Physical Quantities		
Quantity	**Unit name**	**Unit symbol**
Amplitude (A)	metre	m
Pulse speed (v)	metre per second	$m \cdot s^{-1}$

Table 7.1: Units used in **transverse pulses**

Chapter 7 End of chapter exercises

1. A heavy rope is flicked upwards, creating a single pulse in the rope. Make a drawing of the rope and indicate the following in your drawing:

a. The direction of motion of the pulse

b. Amplitude
c. Pulse length
d. Position of rest

2. A pulse has a speed of $2,5\,\text{m}\cdot\text{s}^{-1}$. How far will it have travelled in $6\,\text{s}$?

3. A pulse covers a distance of $75\,\text{cm}$ in $2,5\,\text{s}$. What is the speed of the pulse?

4. How long does it take a pulse to cover a distance of $200\,\text{mm}$ if its speed is $4\,\text{m}\cdot\text{s}^{-1}$?

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(1.) 0034 (2.) 0035 (3.) 0036 (4.) 0037