6 Wave reflection, refraction and absorption

This unit will help you understand wave behaviour in terms of reflection, refraction and energy transfer.

In the exam, you will be asked to answer questions such as the one below.

Exam-style question

1 Figure 1 shows a light ray entering a semi-circular glass block from the air at point A and leaving at point B.

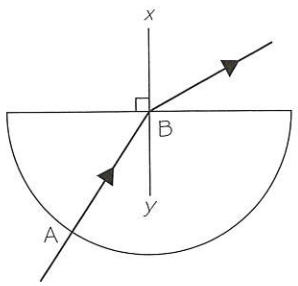


Figure 1

(a) Name the line labelled x–y on Figure 1. (1 mark)

.....

.....

(b) Describe what happens to the wavelength, frequency and speed of light as the ray enters the glass at A. (3 marks)

.....

(c) Explain why the ray of light leaving the glass block at point B carries less energy than the ray of light entering the block at point A. (3 marks)

.....

You will already have done some work on refraction, reflection and energy transfer by waves. Before starting the **skills boosts**, rate your confidence in each area. Colour in the bars.

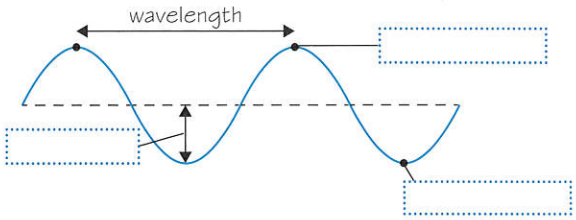
1 How do I explain what waves do at boundaries?

2 How do I apply ideas about absorption and emission of radiation?

3 How do I draw diagrams to explain refraction?

Get started

Waves are generated by an energy source and transfer the energy to the surroundings. Although a wave travels to transfer its energy, the particles that make up the wave only move a small amount by oscillating back and forth.



1 Label the diagram with the features of a wave shown in the word box. One has been done for you:

crest	trough	wavelength	amplitude

Wave speed describes how fast a wave travels. We can calculate wave speed from the distance a wave travels divided by the time it takes to travel that distance.

$$\text{wave speed} = \frac{\text{distance}}{\text{time}}, \quad v = \frac{x}{t}$$

2 A water wave in a ripple tank travels 0.5 m in 0.8 s.

Calculate the wave speed using $v = \frac{x}{t}$

Work out the answer.

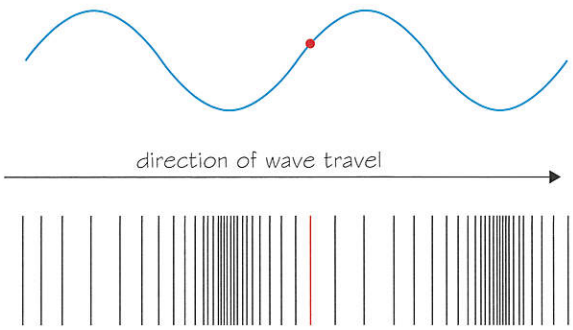
Wave frequency (f) is the number of waves passing a point each second and is measured in hertz (Hz). The relationship between frequency, wave speed and wavelength is given by the equation:

$$\text{wave speed} = \text{frequency} \times \text{wavelength}, \quad v = f \times \lambda$$

3 A sound wave has a frequency of 165 Hz and a wavelength of 2.00 m. Calculate the speed of sound using $v = f \times \lambda$.

Work out the answer.

There are two types of wave: transverse waves and longitudinal waves. The diagram shows the two types. The red dot and the red line represent wave particles within the waves.



4 Tick whether each statement about the waves is true or false. The first one has been done for you.

		true	false
a	Wave A is a transverse wave.	✓	
b	The particles in wave A move up and down at right angles to the direction of wave travel.		
c	Wave B is a longitudinal wave.		
d	The particles in wave B move back and forth in the same direction of wave travel.		
e	Wave A and B have different wavelengths.		

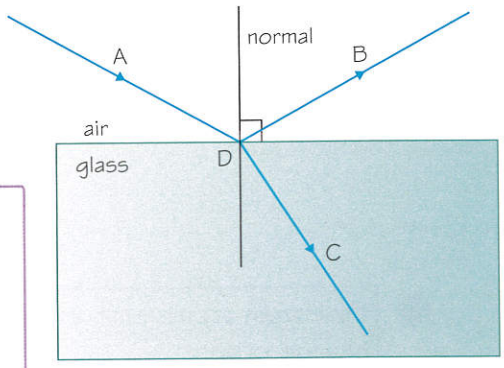
Longitudinal means 'lengthwise'; transverse means 'across'.

1 How do I explain what waves do at boundaries?

Waves transfer energy away from a source. This energy can pass through a substance (transmission) or may be transferred to the substance (absorption). For example, sound waves carry energy from a loudspeaker to your ears so you can hear the sound.

When incident (incoming) waves or rays meet a boundary between one substance and another, they can bounce off the substance (reflection) or they can move from one substance to the other and may change direction (refraction).

1 Look at the diagram of a light ray hitting a glass block. Complete these sentences using words from the box.



refracted	incident	absorbed	reflected

Light ray A is shone at a glass block. This is the ..... ray. Some energy from ray A enters the glass and is ..... to become ray C. Ray C is refracted towards the normal by the glass block because light slows down as it enters glass. Some energy from ray A does not enter the glass and is ..... to become ray B. A small percentage of energy may be ..... by the glass.

Remember When a wave changes speed as it moves from one substance to another, it is refracted.

A transparent medium (substance) transmits waves, but an opaque medium reflects and absorbs waves. Glass is transparent to light and infrared radiation but opaque to ultraviolet radiation.

2 Imagine you are sitting next to a glass window. Tick the **two** correct statements.

A You do get a suntan because ultraviolet light from the Sun is transmitted by the glass. ☐

B You don't get a suntan because ultraviolet light from the Sun is absorbed by the glass. ☐

C You don't get a suntan because ultraviolet light from the Sun is reflected by the glass. ☐

D You do feel warm because infrared radiation from the Sun is transmitted by the glass. ☐

E You don't feel warm because infrared radiation from the Sun is absorbed by the glass. ☐

F You don't feel warm because infrared radiation from the Sun is reflected by the glass. ☐

The further that waves travel through a substance, the greater the amount of energy that is absorbed and so less energy is transmitted.

3 At sea depths of 200 m or more, it is almost completely dark. Complete these sentences that explain why, using words from the box.

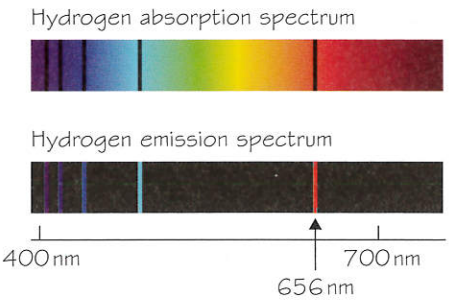
reflected	absorbed	transmitted	refracted

As light rays from the Sun reach the sea, a small percentage of light is ..... but most is ..... as it enters the water. As the light travels through the water, more and more light is ..... and less and less is .....

2 How do I apply ideas about absorption and emission of radiation?

In an atom, electrons orbit the nucleus in shells. An electron can jump into a higher orbit (electron shell) when it absorbs electromagnetic radiation of the correct frequency. This produces a black line at that frequency in the atom's electromagnetic spectrum. Electrons emit electromagnetic radiation at the same frequencies when they jump into a lower orbit. This produces coloured lines in the electromagnetic spectrum.

1 The diagram shows the emission and absorption spectra for hydrogen in the visible region of the electromagnetic spectrum. Tick ✓ whether each statement is **true** or **false**.



Each wavelength of light has a unique colour.

		true	false
a	Hydrogen atoms emit and absorb visible light when electrons change orbits.	☐	☐
b	Hydrogen emits visible light at four particular wavelengths.	☐	☐
c	The lowest energy visible light emitted is violet light.	☐	☐
d	The wavelengths of the lines in the emission spectrum exactly match the wavelengths of the lines in the absorption spectrum.	☐	☐
e	The emission spectrum is a continuous spectrum.	☐	☐

2 Which types of electromagnetic radiation are emitted by these devices?

Tick ✓ **one or more** boxes for each device.

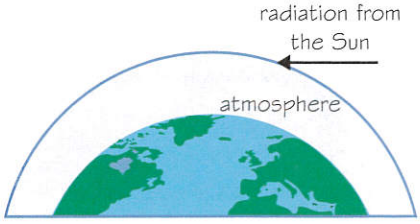
Think about the properties of different types of electromagnetic radiation and how they can be detected.

	Gamma ray	X-ray	Ultraviolet	Visible light	Infrared	Microwave	Radio wave
filament lamp							
mobile phone							
neon light							
radioactive tracer							

3 Complete these sentences about what can happen to radiation from the Sun when it reaches the Earth's atmosphere. Use words from the box.

reflected refracted absorbed

When the Sun's radiation reaches the atmosphere, it slows down slightly, and so it is ..... Some of the radiation is ..... back into space and some radiation is ..... by the atmosphere and clouds.



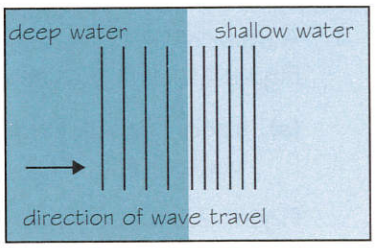
On Earth, about half the Sun's radiation that reaches the upper atmosphere reaches the surface. The rest is reflected or absorbed.

3 How do I draw diagrams to explain refraction?

Refraction happens as waves move from one substance into another and the wave speed changes. The frequency of the wave always remains constant. If the wave slows down, the wavelength decreases. The equation that links wave speed with frequency and wavelength is: wave speed = frequency × wavelength, $v = f \times \lambda$

We can represent a wave by a line called a wave front. You can imagine the wave front as the crest of a wave. Waves always travel at right angles to the wave front.

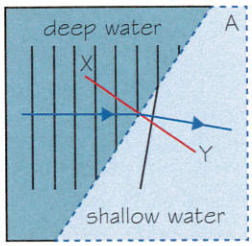
The diagram represents waves as wave fronts. It shows that water waves slow down as they reach shallower water. The frequency of the waves remains constant, but the wavelength decreases.



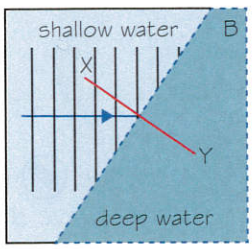
1 Water waves in deep water have a frequency of 2 Hz and a speed of 0.50 m/s. They reach shallow water and slow to 0.40 m/s. Calculate the wavelength of the waves in the deep water and in the shallow water. Use $\lambda = \frac{v}{f}$

The frequency of the waves must always remain constant.

If water waves reach shallow water at an angle, they slow down and change direction. Look at the diagrams A and B.
The blue line shows the direction the water waves are travelling. The red line X–Y shows the normal. Notice how the wave direction is refracted towards the normal as the wave slows down.



2 Some of the wave fronts in shallow water are incomplete. Draw lines to complete the wave fronts in diagram A.



3 Diagram B shows water waves reaching deep water at an angle.

a Complete these sentences.

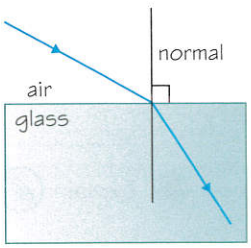
As waves travel from shallow water to deeper water, they ..... in speed. The direction of travel is refracted away from the .....

Remember The direction a wave travels is always at right angles to the wave front.

b Draw a line on diagram B to show the direction of travel in deep water.

c The wave fronts in deep water are incomplete. Draw lines to complete the wave fronts in diagram B..

4 Look at the diagram of water waves reaching shallow water at an angle and the diagram of the light ray entering glass. Write whether each statement is **true** or **false**.



a Both change speed at the boundary. .....

b Both change frequency at the boundary. .....

c Both change wavelength at the boundary. .....

d Both change direction of travel at the boundary. .....

Sample response

Use these example student responses to improve your understanding of how to gain more marks in questions about waves.

Exam-style question

1 A student investigates water waves using a ripple tank. Figure 1 shows a wave diagram.

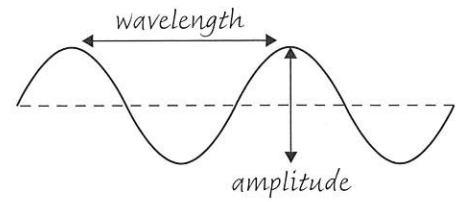


Figure 1

(a) Label the amplitude and wavelength. **(2 marks)**

Figure 2 shows the student's ripple tank. The wooden bar vibrates and makes ripples. The light source projects an image of the ripples onto the screen below the ripple tank.

(b) Calculate the wavelength of the waves as seen on the screen. **(2 marks)**

There are 11 waves in 55cm. $\lambda = \frac{55}{11} = 5\,cm$

(c) The student measures the frequency of the waves on the screen as 16Hz. Calculate the speed of the waves. **(3 marks)**

$v = f \times \lambda$

$v = 16 \times 5$

$v = 80\,m/s$

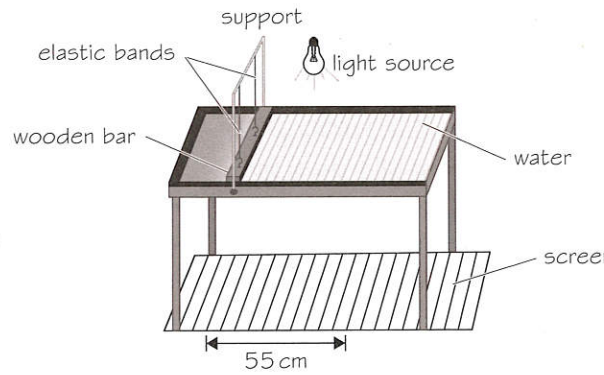


Figure 2

1 Describe the **two** mistakes the student has made in labelling the amplitude and wavelength on the wave diagram for part (a).

.....

.....

2 The student counted 11 waves for part (b). Write how many waves they should have counted.

.....

3 The answer to part (c) is incorrect but the student gained 2 marks.

a Describe what the 2 marks were awarded for.

.....

.....

b Explain why a mark was not awarded for the unit.

.....

.....

Your turn!

It is now time to use what you have learned to answer the exam-style question from page 153. Remember to read the question thoroughly, looking for information that may help you. Make good use of your knowledge from other areas of physics.

Exam-style question

1 Figure 1 shows a light ray entering a semi-circular glass block at point A and leaving at point B.

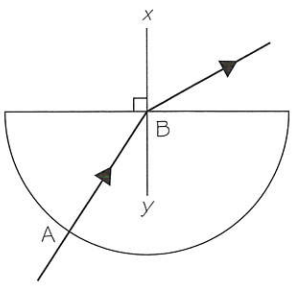


Figure 1

(a) Name the line labelled *x*–*y* on Figure 1. (1 mark)

.....

.....

(b) Describe what happens to the wavelength, frequency and speed of light as the ray enters the glass at A. (3 marks)

.....

.....

.....

.....

(c) Explain why the ray of light leaving the glass block at point B carries less energy than the ray of light entering the block at point A. (3 marks)

.....

.....

.....

Need more practice?

Exam questions may ask about different parts of a topic, or parts of more than one topic.

Questions about waves could occur as:

- questions about light, electromagnetic spectrum, sound or water waves
- part of a question on how energy is transferred
- part of a question about an experiment or investigation.

Have a go at this exam-style question.

Exam-style question

1 When a light ray is shone on a glass block, not all of the energy is transferred by reflection and refraction.

(a) Describe what happens to the remaining energy. (1 mark)

.....

.....

(b) Draw and label the normal line, reflected ray and refracted ray on Figure 1. (3 marks)

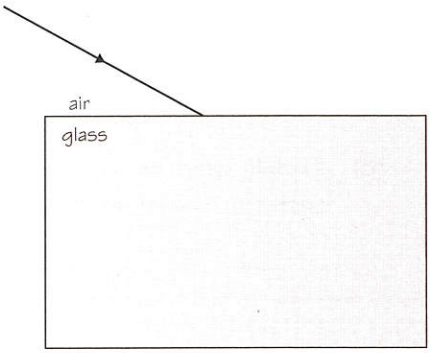


Figure 1

(c) Skiers need to wear special sunglasses or goggles.

Explain why, in terms of reflection and absorption of light. (3 marks)

.....

.....

.....

.....

Boost your grade

Make sure you practise labelling wave diagrams and learn these equations: $v = f \times \lambda$ and $v = \frac{x}{t}$

Learn the similarities and differences of longitudinal and transverse waves, including these common properties:

- waves transfer energy from a source to the surroundings
- energy from waves can be reflected, transmitted or absorbed by a substance
- waves may change direction by refraction as they move from one substance to another.

How confident do you feel about each of these **skills**? Colour in the bars.

1 **How do I explain what waves do at boundaries?**

2 **How do I apply ideas about absorption and emission of radiation?**

3 **How do I draw diagrams to explain refraction?**