Edexcel GCSE Physics

Your notes

Properties of Waves

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Introduction to Waves

Waves & Energy

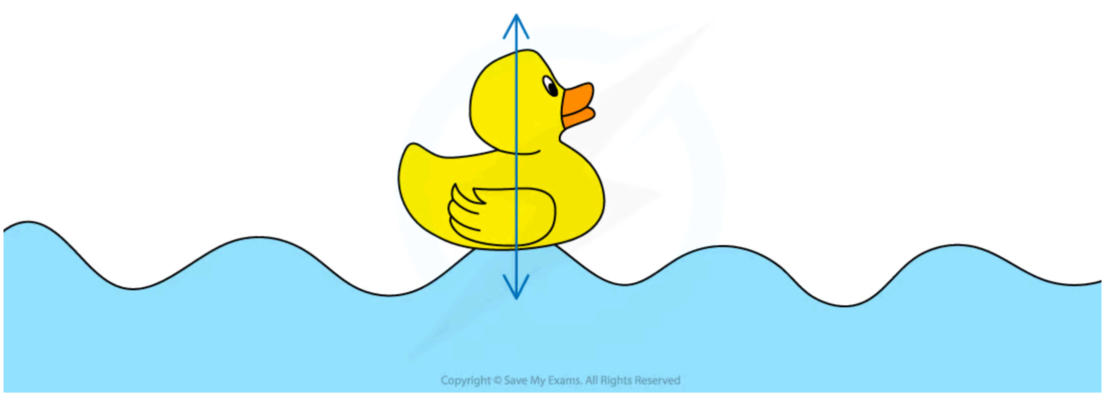
- Waves transfer **energy** and **information**
- Waves are described as **oscillations** or **vibrations** about a fixed point
  - For example, **ripples** cause particles of water to oscillate up and down
  - **Sound** waves cause particles of air to vibrate back and forth
- In all cases, waves transfer **energy** without transferring **matter**

Examples of Waves

- Objects floating on water provide evidence that waves only transfer energy and **not** matter

Worked Example

The diagram below shows a toy duck bobbing up and down on top of the surface of some water, as waves pass it underneath.



Explain how the toy duck demonstrates that waves do not transfer matter.

Answer:

Step 1: Identify the type of wave

- The type of wave on the surface of a body of water is a **transverse** wave

- This is because the duck is moving **perpendicular** to the direction of the wave

Step 2: Describe the motion of the toy duck

- The plastic duck moves up and down but does not travel with the wave

Step 3: Explain how this motion demonstrates that waves do not transfer matter

- Both transverse and longitudinal waves transfer **energy**, but not the particles of the medium
- This means when a wave travels between two points, no matter actually travels with it, the points on the wave just vibrate back and forth about **fixed** positions
- Objects floating on the water simply bob up and down when waves pass under them, demonstrating that there is **no movement of matter** in the direction of the wave, only **energy**

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Describing Wave Motion

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Describing Wave Motion

- When describing wave motion, there are several terms which are important to know, including:
  - Amplitude
  - Wavelength
  - Frequency
  - Time Period
  - Wave velocity
  - Wavefront

Amplitude

- Amplitude is defined as:

  The distance from the undisturbed position to the peak or trough of a wave

- It is given the symbol **A** and is measured in **metres (m)**
- Amplitude is the maximum or minimum **displacement** from the **undisturbed position**

Wavelength

- Wavelength is defined as

  The distance from one point on the wave to the same point on the next wave.

- In a transverse wave:
  - The wavelength can be measured from one peak to the next peak
- In a longitudinal wave
  - The wavelength can be measured from the centre of one compression to the centre of the next
- The wavelength is given the symbol **λ** (lambda) and is measured in **metres (m)**
- The distance along a wave is typically put on the x-axis of a wave diagram

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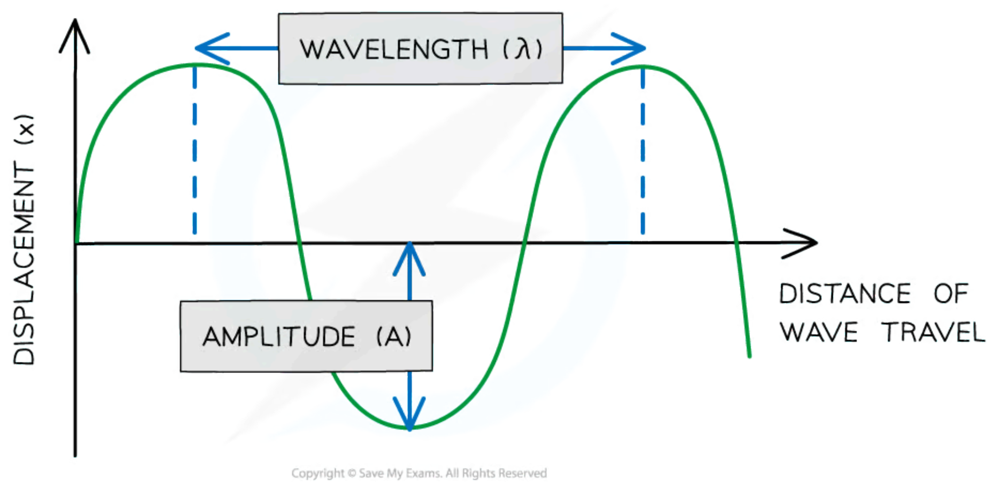


Diagram showing the amplitude and wavelength of a wave

Frequency

- Frequency is defined as:

  The number of waves passing a point in a second

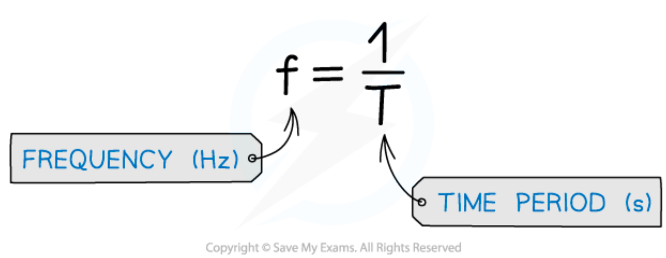
- Frequency is given the symbol ***f*** and is measured in **Hertz (Hz)**

Time Period

- The time period (or sometimes just '**period**') of a wave is defined as:

  The time taken for a single wave to pass a point

- The time period is given the symbol **T** and is measured in **seconds (s)**



Wave Velocity

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- Wave velocity (or wave speed) is defined as:

  The distance travelled by a wave each second

Wavefront

- Wavefronts are a useful way of picturing waves from above: each wavefront is used to represent a single wave
- The image below illustrates how wavefronts are visualised:
  - The arrow shows the direction the wave is moving and is sometimes called a **ray**
  - The space between each wavefront represents the **wavelength**
  - When the wavefronts are **close together**, this represents a wave with a **short** wavelength
  - When the wavefronts are **far apart**, this represents a wave with a **long** wavelength

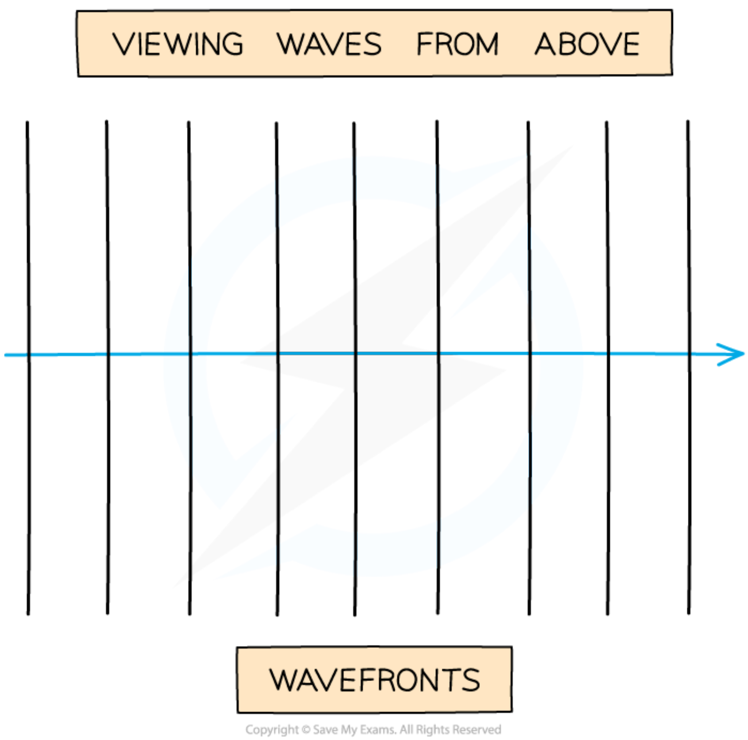

Diagram showing a wave moving to the right, drawn as a series of wavefronts

Transverse & Longitudinal Waves

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Transverse & Longitudinal Waves

- Waves are repeated vibrations that transfer **energy**
- Energy is transferred by parts of the wave knocking nearby parts
  - This is similar to the effect of people knocking into one another in a crowd, or a "Mexican Wave" at football matches
- Waves can exist as one of two types:
  - **Transverse**
  - **Longitudinal**

Transverse Waves

- Transverse waves are defined as:

  Waves where the points along its length vibrate at 90 degrees to the direction of energy transfer

- For a transverse wave:
  - The energy transfer is **perpendicular** to wave motion
  - They transfer energy, but not the particles of the medium
  - They can move in **solids** and on the **surfaces of liquids** but **not** inside liquids or gases
  - Some transverse waves (electromagnetic waves) can move in solids, liquids and gases and in a **vacuum**
- The point on the wave that is:
  - The highest above the rest position is called the **peak**, or **crest**
  - The lowest below the rest position is called the **trough**

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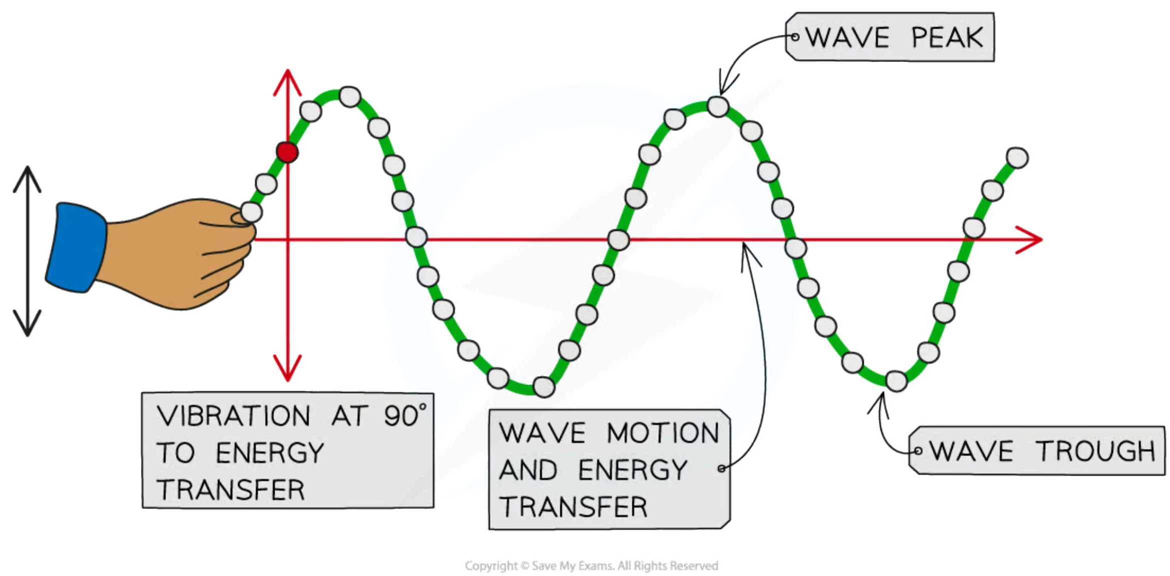

Transverse waves can be seen in a rope when it is moved quickly up and down

- Examples of transverse waves are:
  - Ripples on the surface of water
  - Vibrations in a guitar string
  - S-waves (a type of seismic wave)
  - Electromagnetic waves (such as radio, light, X-rays etc)

Representing Transverse Waves

- Transverse waves are drawn as a single continuous line, usually with a central line showing the **undisturbed position**
- The curves are drawn so that they are **perpendicular** to the direction of energy transfer
  - These represent the peaks and troughs

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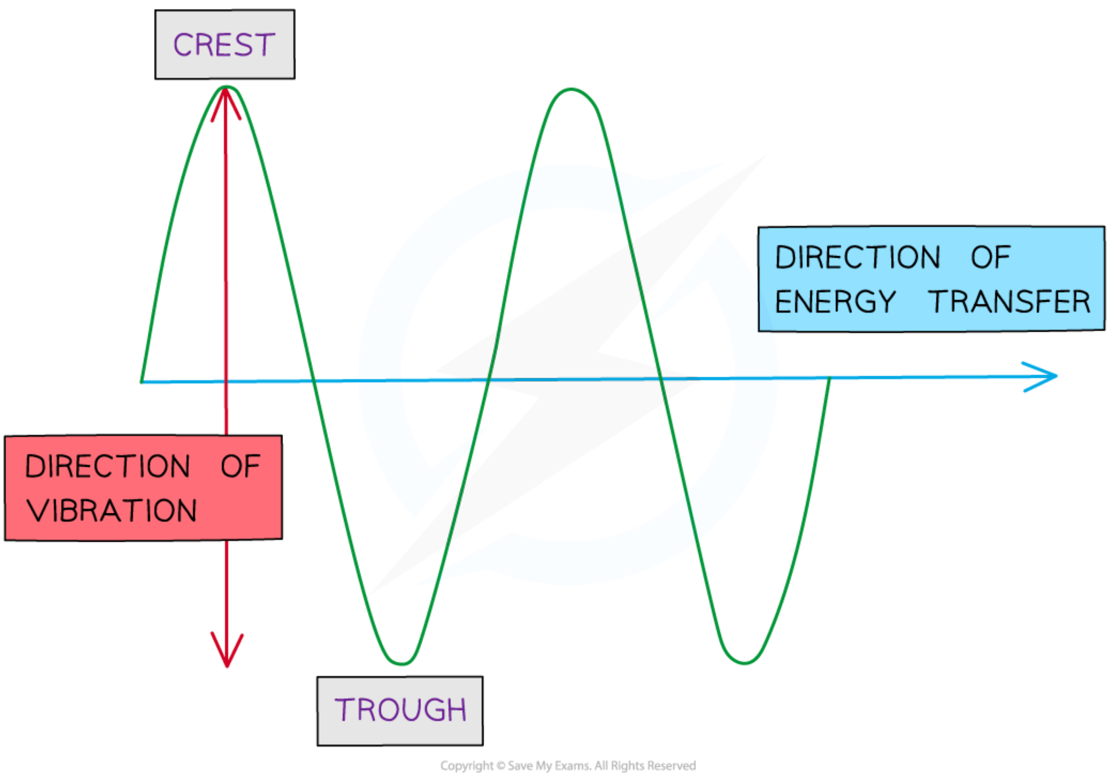

Transverse waves are represented as a continuous solid line

Longitudinal Waves

- Longitudinal waves are defined as:

  Waves where the points along its length vibrate parallel to the direction of energy transfer

- For a longitudinal wave:
  - The energy transfer is in the **same direction** as the wave motion
  - They transfer energy, but not the particles of the medium
  - They can move in solids, liquids and gases
  - They can **not** move in a vacuum (since there are no particles)
- The key features of a longitudinal wave are where the points are:
  - Close together, called **compressions**
  - Spaced apart, called **rarefactions**

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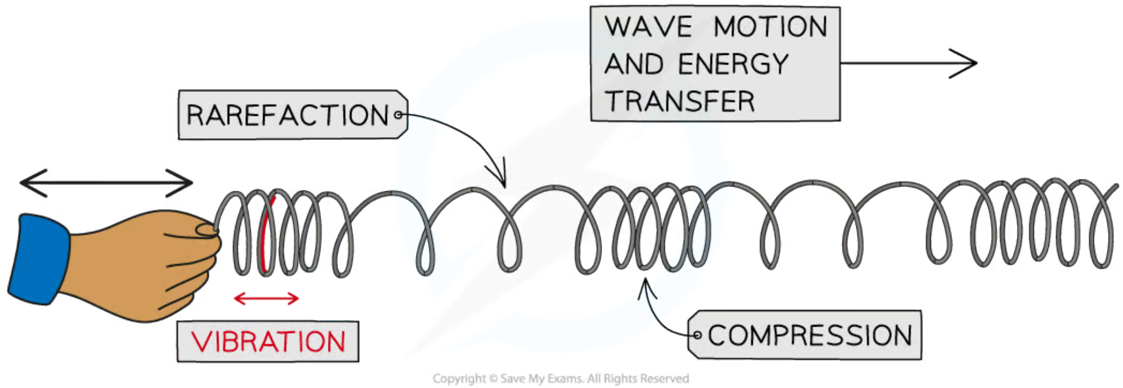
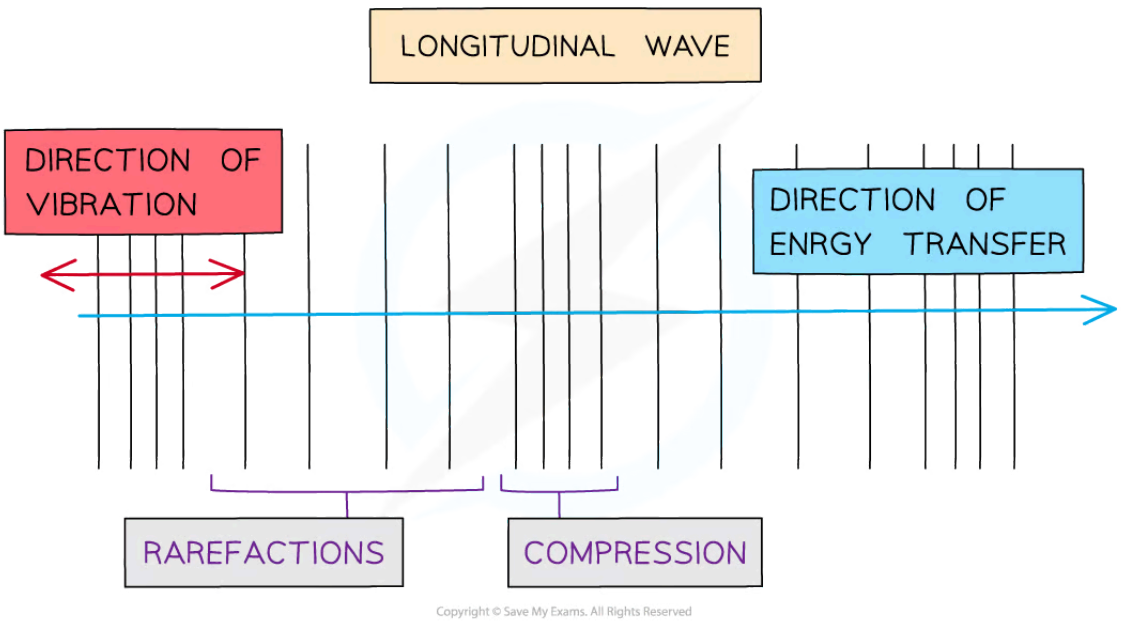


Longitudinal waves can be seen in a slinky spring when it is moved quickly backwards and forwards

- Examples of longitudinal waves are:
    - Sound waves
    - P-waves (a type of seismic wave)
    - Pressure waves caused by repeated movements in a liquid or gas

Representing Longitudinal Waves

- Longitudinal waves are usually drawn as several lines to show that the wave is moving **parallel** to the direction of energy transfer
    - Drawing the lines closer together represents the **compressions**
    - Drawing the lines further apart represents the **rarefactions**



Longitudinal waves are represented as sets of lines with rarefactions and compressions

Comparing Transverse & Longitudinal Waves

- Wave vibrations can be shown on **ropes** (transverse) and **springs** (longitudinal)

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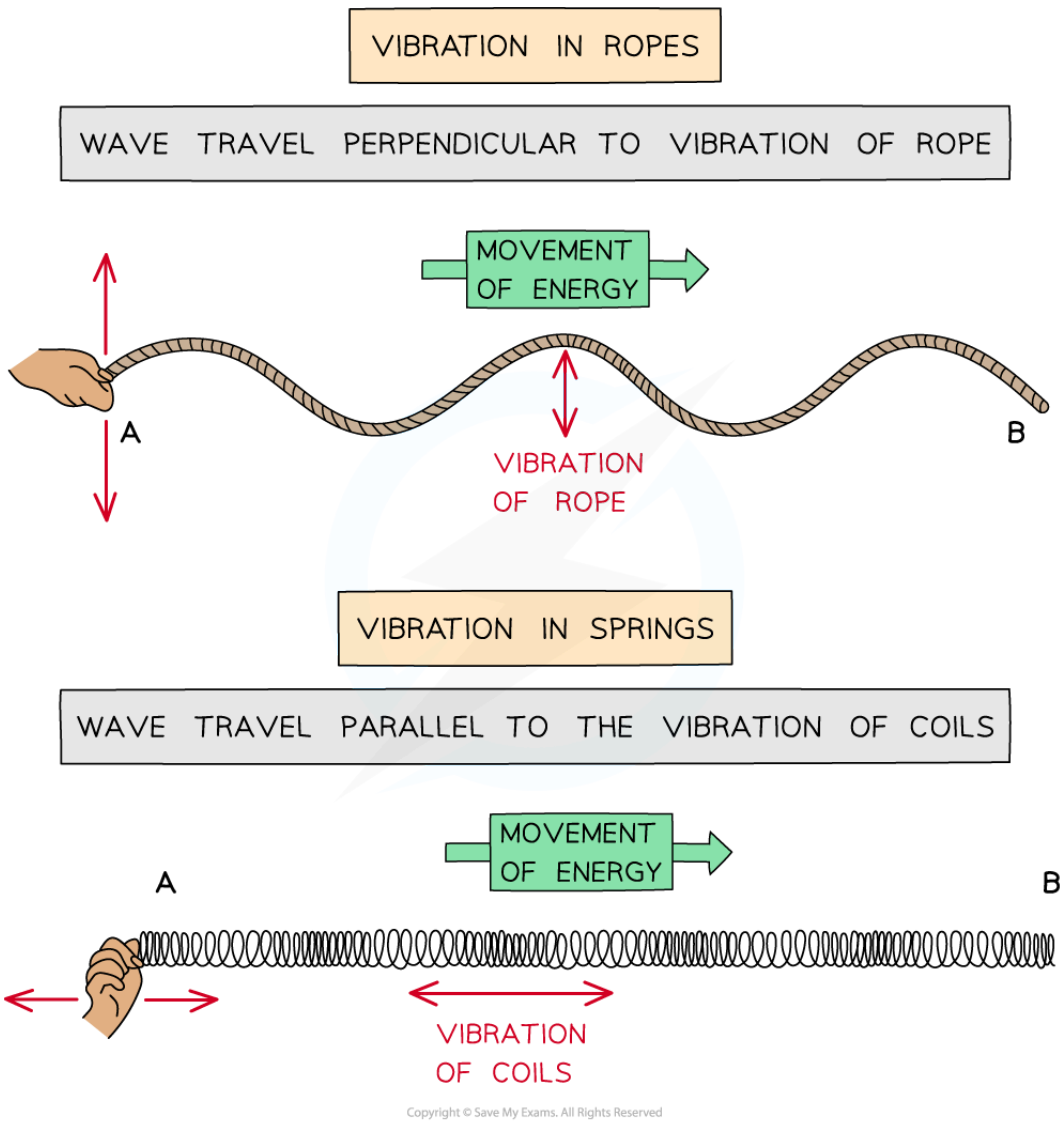

Waves can be shown through vibrations in ropes or springs

- The different properties of transverse and longitudinal waves are shown in the table:

Transverse Waves v Longitudinal Waves Table

Property	**Transverse waves**	**Longitudinal waves**
Structure	Peaks and troughs	Compressions and rarefactions

Vibration	Right angles to the direction of energy transfer	Parallel to the direction of energy transfer
Vacuum	Only electromagnetic waves can travel in a vacuum	Cannot travel in a vacuum
Material	Can move in solids and the surfaces of liquids	Can move in solids, liquids and gases
Density	A constant density	The density of the wave changes
Pressure	Has a constant pressure	Pressure in the wave changes
Speed of wave	Depends on the material the wave is travelling in	Depends on the material the wave is travelling in

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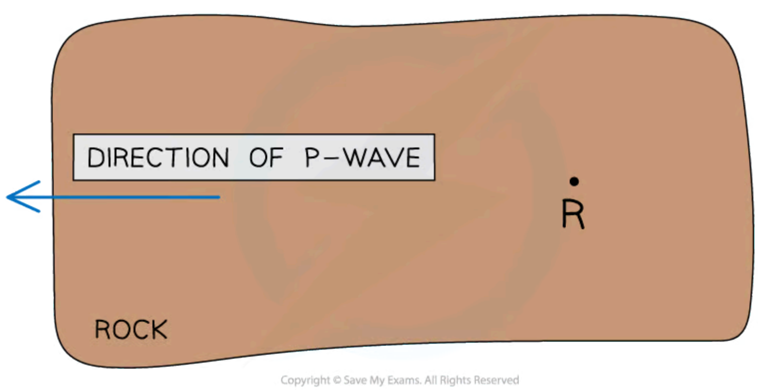
Worked Example

The diagram below shows the direction of a P-wave in a sample of rock during an earthquake.



Draw arrows on the diagram to show how the piece of rock, labelled R, moves as the P-wave passes through it.

Answer:

Step 1: Recall if a P-wave is transverse or longitudinal

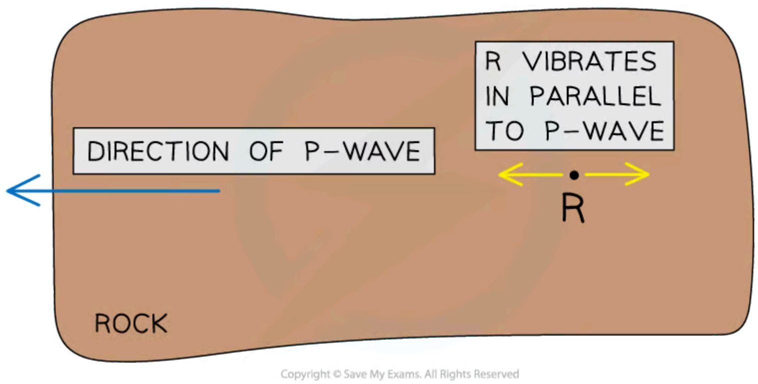
- P-waves are **longitudinal** waves

Step 2: Recall the definition of longitudinal waves

- Points along longitudinal waves vibrate **parallel** to the direction of energy transfer
- This means the rock vibrates in a line **parallel** to the direction of the P-wave drawn

Step 3: Draw arrows at the point labelled R to show it vibrating in parallel to the direction of the P-wave

- This is shown in the image below



Examiner Tips and Tricks

Exam questions may ask you to describe waves and this is most easily done by drawing a diagram of the wave and then describing the parts of the wave - a good, clearly labelled diagram can earn you full marks! Make sure you know the difference between the wavefront diagram and the longitudinal wave diagram, do not confuse the two!

Your notes

The Wave Equation

Your notes

The Wave Equation

- Wave speed is defined as:

The distance travelled by a wave each second

- The wave speed can be calculated in a similar way to calculating the speed of moving objects:

$$\text{wave speed} = \frac{\text{distance}}{\text{time}}$$

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

- Where:
  - v = wave speed in **metres per second** (m/s)
  - x = distance travelled by the wave in **metres** (m)
  - t = time taken in **seconds** (s)
- All waves obey the **wave equation**, which is another way to calculate the wave speed:

$$\text{wave speed} = \text{frequency} \times \text{wavelength}$$

$$v = f \times \lambda$$

- Where:
  - v = wave speed in **metres per second** (m/s)
  - f = frequency in **Hertz** (Hz)
  - λ = wavelength in **metres** (m)
- The wave speed equation may need to be rearranged, which can be done using this formula triangle:

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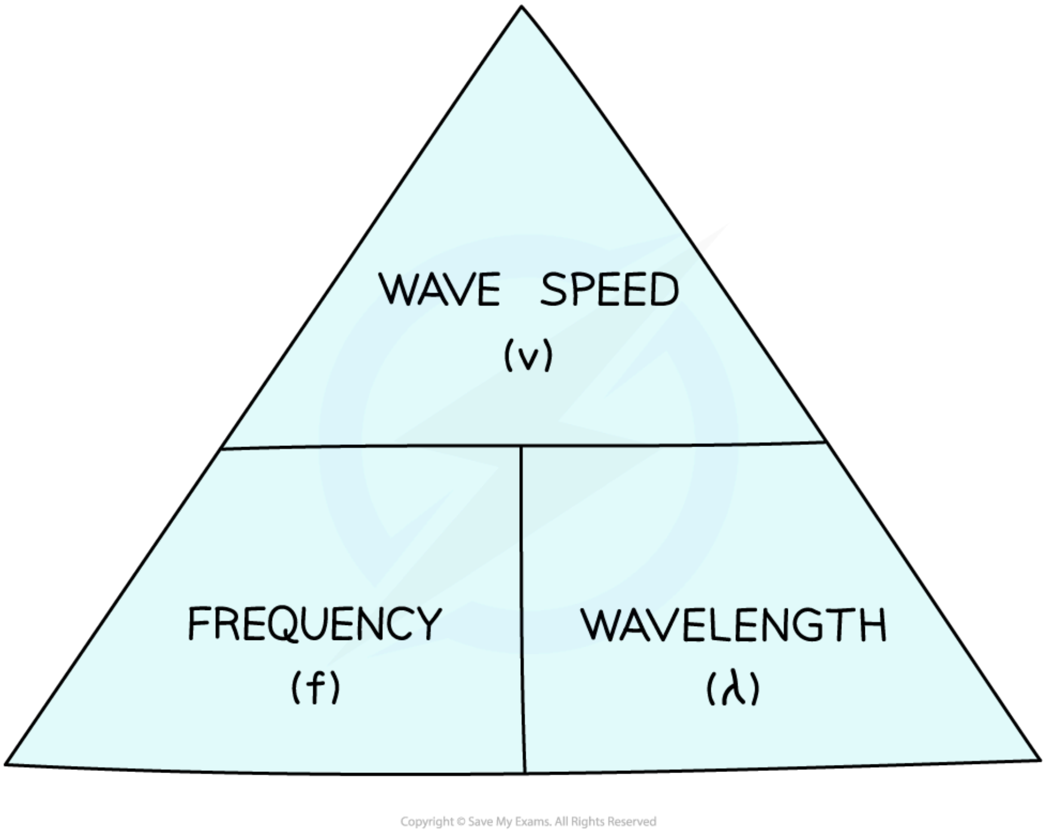

Worked Example

A wave in a pond has a speed of 0.15 m/s and a time period of 2 seconds. Calculate:

a) The frequency of the wave

b) The wavelength of the wave

Answer:

Part (a)

Step 1: List the known quantities

- Time period, T = 2 s

Step 2: Write out the equation relating time period and frequency

$$T = \frac{1}{f}$$

Step 3: Rearrange for frequency *f* and calculate the answer

$$f = \frac{1}{T} = \frac{1}{2}$$

Frequency, f = **0.5 Hz**

Part (b)

Step 1: List the known quantities

- Wave speed, v = 0.15 m/s
- Frequency, f = 0.5 Hz

Step 2: Write out the wave speed equation

$$v = f \times \lambda$$

Step 3: Rearrange for wavelength λ and calculate the answer

$$\lambda = \frac{v}{f} = \frac{0.15}{0.5}$$

Wavelength, λ = **0.30 m**

Examiner Tips and Tricks

When stating equations make sure you use the right letters:

For example, use λ for wavelength, not L or W

If you can't remember the correct letters, then just state the word equations

Be careful with units: wavelength is usually measured in metres and speed in m/s, but if the wavelength is given in cm you might have to give the speed in cm/s

Likewise, watch out for frequency given in kHz: 1 kHz = 1000 Hz

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Measuring Wave Speed

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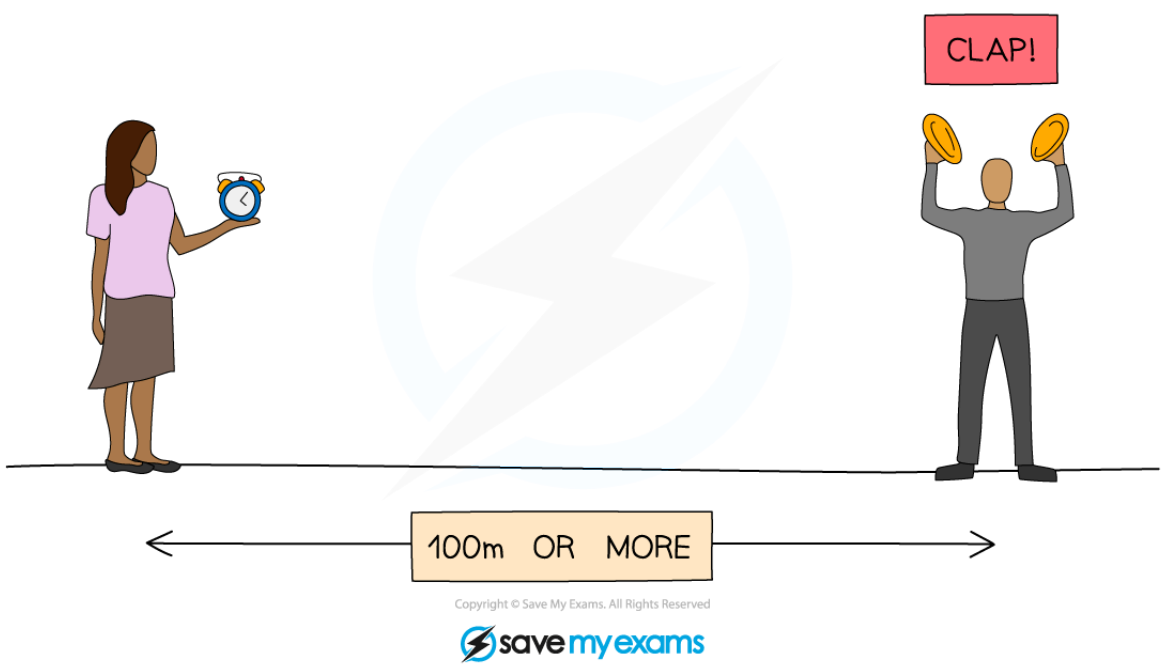
Measuring Wave Speed

Experiments to Determine the Speed of Sound in Air

- There are several experiments that can be carried out to determine the speed of sound
- Three methods are described below
  - The apparatus for each experiment is given in **bold**

Method 1: Measuring Sound Between Two Points



Measuring the speed of sound directly between two points

1. Two people stand a distance of around 100 m apart
2. The distance between them is measured using a **trundle wheel**
3. One person has **two wooden blocks**, which they bang together above their head

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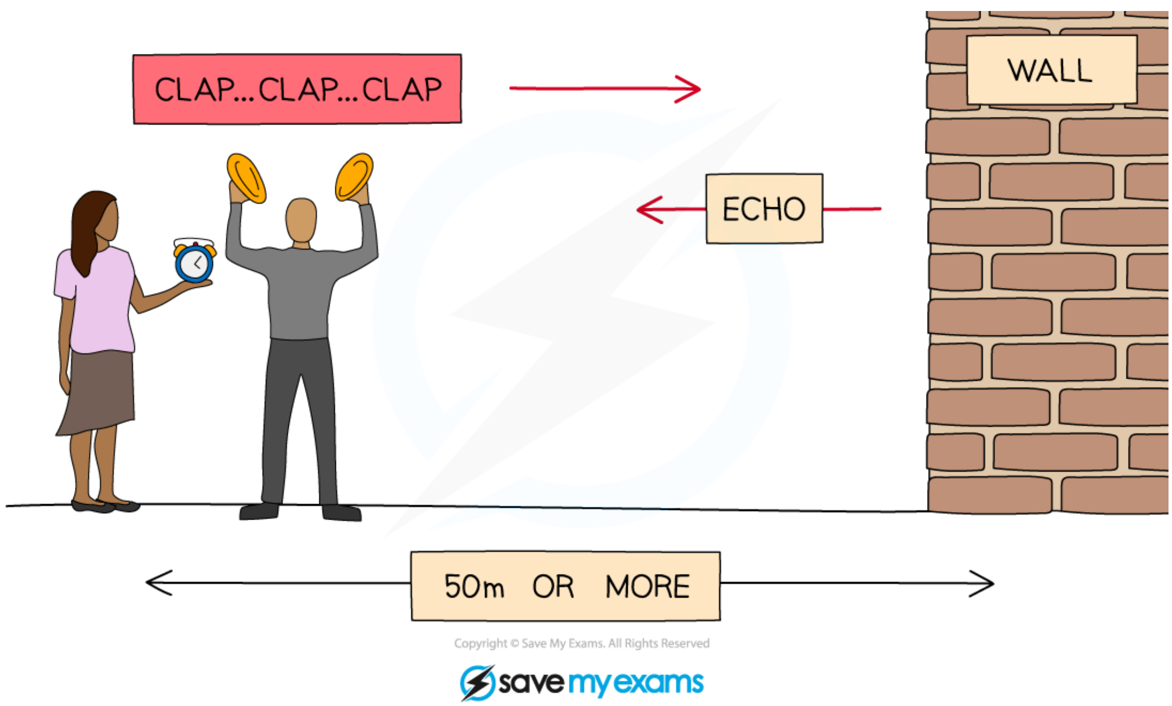
4. The second person has a **stopwatch** which they start when they see the first person banging the blocks together and stops when they hear the sound
5. This is then repeated several times and an average value is taken for the time
6. The speed of sound can then be calculated using the equation:

$$\text{SPEED OF SOUND} = \frac{\text{DISTANCE TRAVELED BY SOUND}}{\text{TIME TAKEN}}$$

Method 2: Using Echoes



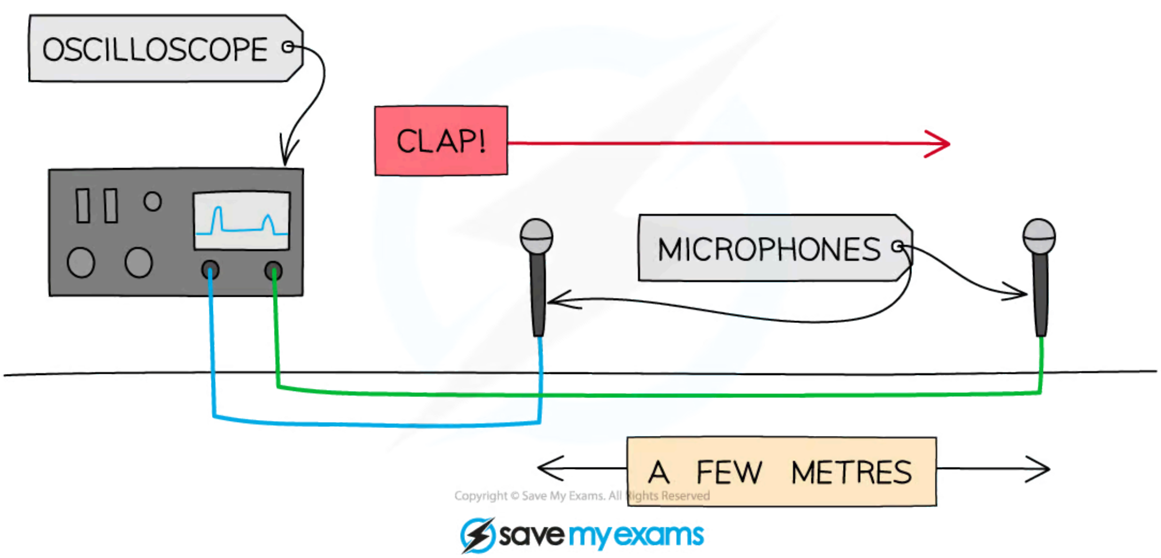
Measuring the speed of sound using echoes

1. A person stands about 50 m away from a wall (or cliff) using a **trundle wheel** to measure this distance
2. The person claps **two wooden blocks** together and listens for the echo
3. The person then starts to clap the blocks together repeatedly, in rhythm with the echoes

4. A second person has a **stopwatch** and starts timing when they hear one of the claps and stops timing 20 claps later
5. The process is then repeated and an average time calculated
6. The distance travelled by the sound between each clap and echo will be (2 × 50) m
7. The total distance travelled by sound during the 20 claps will be (20 × 2 × 50) m
8. The speed of sound can be calculated from this distance and the time using the equation:

$$\text{SPEED OF SOUND} = \frac{2 \times \text{DISTANCE TO THE WALL}}{\text{TIME TAKEN}}$$

Method 3: Using an Oscilloscope



Measuring the speed of sound using an oscilloscope

1. Two **microphones** are connected to an **oscilloscope** and placed about 5 m apart using a **tape measure** to measure the distance
2. The oscilloscope is set up so that it triggers when the first microphone detects a sound, and the time base is adjusted so that the sound arriving at both microphones can be seen on the screen

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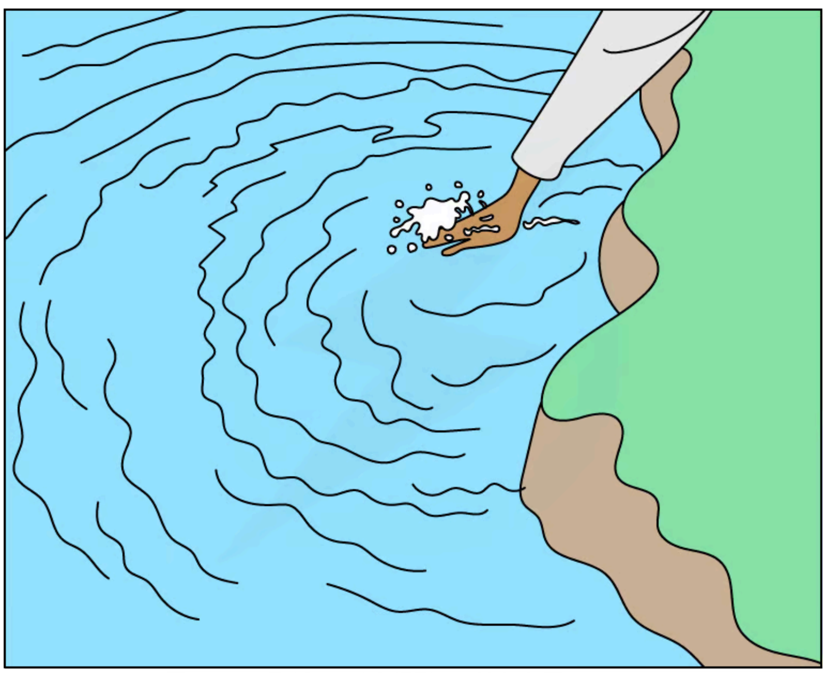
3. Two wooden blocks are used to make a large clap next to the first microphone
4. The oscilloscope is then used to determine the time at which the clap reaches each microphone and the time difference between them
5. This is repeated several times and an average time difference calculated
6. The speed can then be calculated using the equation:

$$\text{SPEED OF SOUND} = \frac{\text{DISTANCE BETWEEN MICROPHONES}}{\text{TIME BETWEEN PEAKS}}$$

Measuring the Speed of Ripples on Water Surfaces



Creating ripples in water

1. Choose a calm flat water surface such as a lake or a swimming pool
2. Two people stand a few metres apart using a **tape measure** to measure this distance

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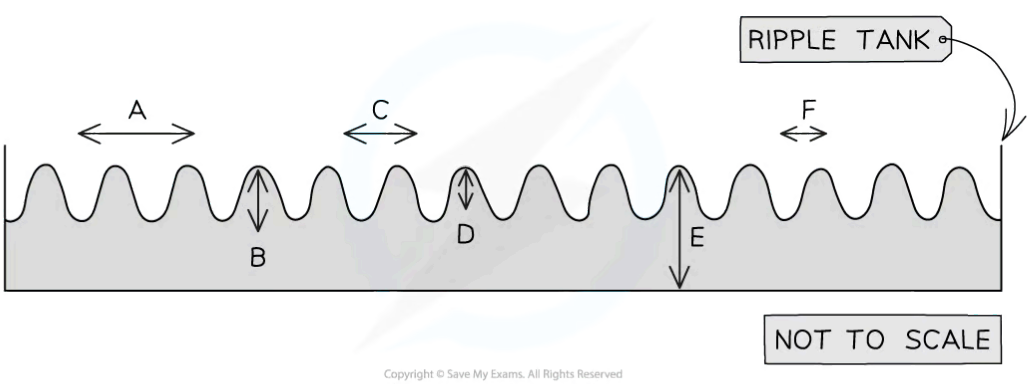
3. One person counts down from three and then disturbs the water surface (using their hand, for example) to create a ripple
4. The second person then starts a **stopwatch** to time how long it takes for the first ripple to get to them
5. The experiment is then repeated 10 times and an average value for the time is calculated
6. The average time and distance can then be used to calculate the wave speed using the equation:

$$\text{AVERAGE SPEED} = \frac{\text{DISTANCE MOVED}}{\text{TIME TAKEN}}$$

Your notes

Worked Example

Small water waves are created in a ripple tank by a wooden bar. The wooden bar vibrates up and down hitting the surface of the water. The diagram below shows a cross-section of the ripple tank and water.



Which letter shows:

a) The amplitude of a water wave?

b) The wavelength of the water wave?

Answer:

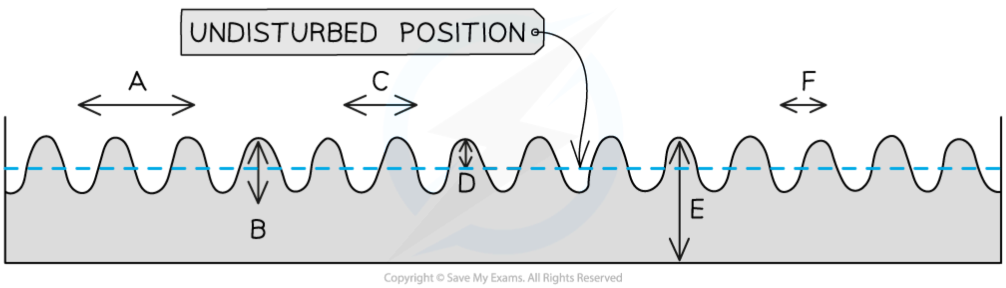
Part (a)

Step 1: Recall the definition of amplitude

- Amplitude = The distance from the undisturbed position to the peak or trough of a wave

Step 2: Mark the undisturbed position on the wave

- This is the centre of the wave



Step 3: Identify the arrow between the undisturbed position and a peak

- The amplitude is arrow **D**

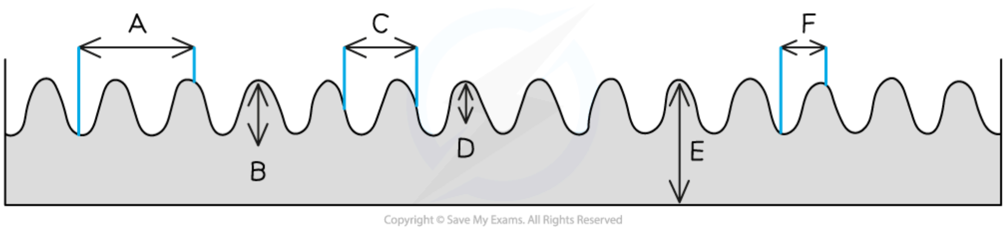
Part (b)

Step 1: Recall the definition of wavelength

- Wavelength = The distance from one point on the wave to the same point on the next wave

Step 2: Draw lines on each horizontal arrow

- This helps to identify the points on the wave the arrows are referring to



Step 3: Identify the arrow between two of the same points on the wave

- The wavelength is arrow **C**

Examiner Tips and Tricks

Your notes

Your notes

When you are answering questions about methods to measure waves, the question could ask you to comment on the accuracy of the measurements

- In the case of measuring the speed of sound:
  - Method 3 is the **most** accurate because the timing is done automatically
  - Method 1 is the **least** accurate because the time interval is very short

Whilst this may not be too important when giving a method, you should be able to explain why each method is accurate or inaccurate and suggest ways of making them better (use bigger distances)

- For example, if a manual stopwatch is being used there could be variation in the time measured which can be up to 0.2 seconds due to a person's reaction time
- The time interval could be as little as 0.3 seconds for sound travelling in air
- This means that the variation due to the stopwatch readings has a big influence on the results and they may not be reliable

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Calculating Depth & Distance

Higher Tier Only

- If the speed of a wave is known, it can be used to calculate the distance to an object, or the depth of an object - say, underwater

Calculating Distance

- The worked example below demonstrates how the **speed of sound in air** can be used to determine how **far away** objects are from an observer

Worked Example

A clap of thunder is heard 4 seconds after the corresponding flash of lightning. How far away is the thunderstorm? (The speed of sound in air is 330 m/s)

Answer:

Step 1: List the known quantities

- Wave speed, v = 330 m/s
- Time, t = 4 s

Step 2: Write out the wave speed, distance and time formula

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

Step 3: Re-arrange the equation to make distance (x) the subject

$$x = v \times t$$

Step 4: Put known values into the equation

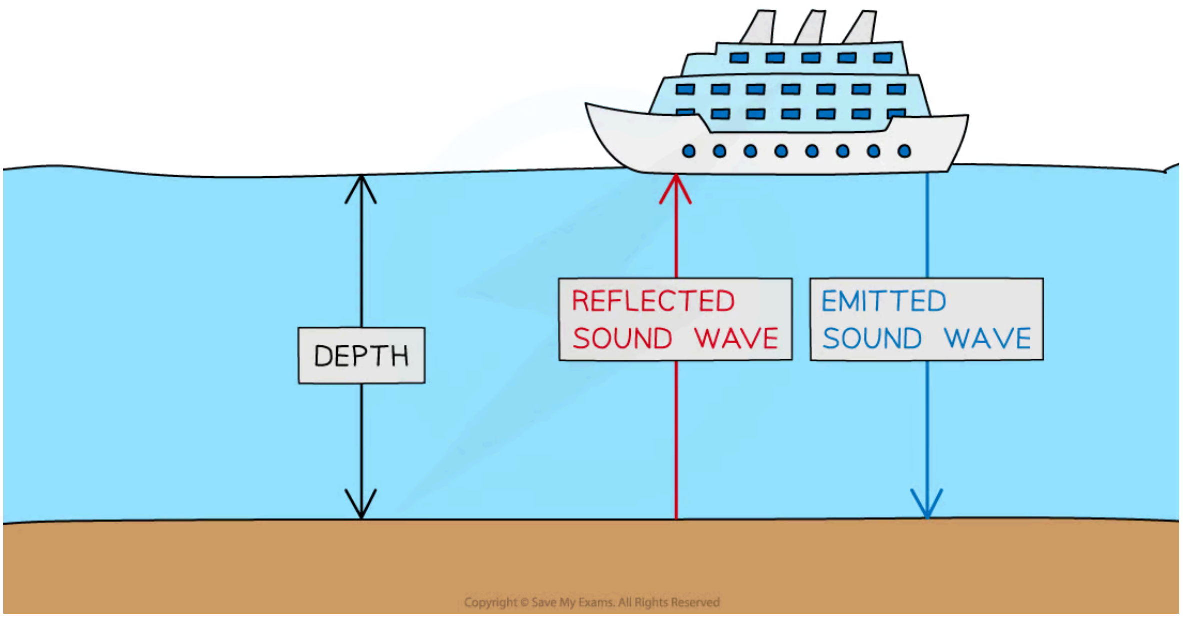
$$x = 330 \times 4 = 1320 \text{ m}$$

- So the distance to the thunderstorm is **1320 m**

Calculating Depth

Your notes

- Echo sounding uses **ultrasound** to detect objects underwater
- The sound wave is reflected off the ocean bottom
- The **time** it takes for the sound wave to **return** is used to calculate the **depth** of the water
- The distance the wave travels is **twice** the depth of the ocean
  - This is the distance to the ocean floor plus the distance for the wave to return



Echo sounding is used to determine water depth

Worked Example

The sound wave released from a ship took 0.12 seconds to return. The speed of sound in water is 1500 m/s. What was the depth of the sea?

Answer:

Step 1: List the known quantities

- Wave speed, v = 1500 m/s
- Time, t = 0.12 s

Step 2: Write out the wave speed, distance and time formula

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

Step 3: Rearrange the equation to make distance (x) the subject

$$x = v \times t$$

Step 4: Put known values into the equation

$$x = 1500 \times 0.12 = 180 \text{ m}$$

Step 5: Half the distance to obtain the depth

$$d = 180 \div 2$$

Depth, d = **90 m**

Examiner Tips and Tricks

Don't forget to take into account if a sound wave has travelled **twice** the distance You can do this one of two ways:

- Halve the time at the beginning, **or**
- Halve the distance at the end

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Wave Interactions

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Wave Interactions

- When a wave reaches an **interface** (or boundary) between two materials - for example, air and water - the wave may be:
  - Reflected
  - Refracted
  - Transmitted
  - Absorbed

Reflection

- Reflection occurs when:

  A wave hits a boundary between two media and does not pass through, but instead stays in the original medium

- Some of the wave may also be absorbed or transmitted
  - **Echos** are examples of sound waves being reflected off a surface
- **Flat** surfaces are the **most** reflective
  - The smoother the surface, the stronger the reflected wave is
- **Rough** surfaces are the **least** reflective
  - This is because the light scatters in all directions
- **Opaque** surfaces will reflect light which is not absorbed by the material
  - The electrons will absorb the light energy, then reemit it as a reflected wave

Refraction

- Refraction occurs when:

  A wave changes speed at the boundary between two materials of different densities

- Glass and water are both **denser** than air, so light waves passing from air into them will slow down (and speed up if going from them into air)
- The **change in speed** at the boundary can **sometimes** causes the wave to change **direction**
  - **Lenses** make use of refraction to bend light waves and help focus it in glasses and cameras

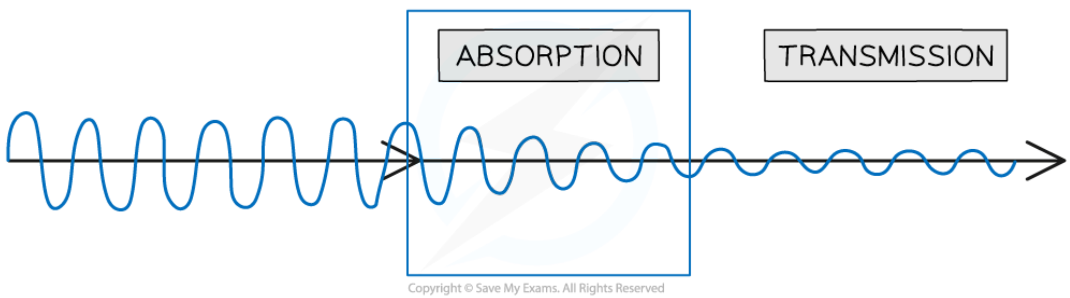
- Sound, water, electromagnetic and seismic waves can all be refracted

Transmission

- Transmission occurs when:

  A wave passes through a substance

- For light waves, the more **transparent** the material, the more light will pass through
- Transmission can involve **refraction** but is not exactly the same
- For the process to count as transmission, the wave must pass through the material and emerge from the other side
- When passing through a material, waves are usually partially absorbed
- The transmitted wave may have a lower **amplitude** because of some absorption
  - For example, sound waves are **quieter** after they pass through a wall



When a wave passes through a boundary it may be absorbed and transmitted

Absorption

- Absorption occurs when:

  Energy is transferred from the wave into the particles of a substance

- Waves can be partially or completely absorbed
  - Sound waves are absorbed by brick or concrete in houses
- Light will be absorbed if the frequency of light matches the energy levels of the electrons
  - The light will be absorbed, and then reemitted over time as heat
- If an object appears red, this means:
  - Only red light has been **reflected**

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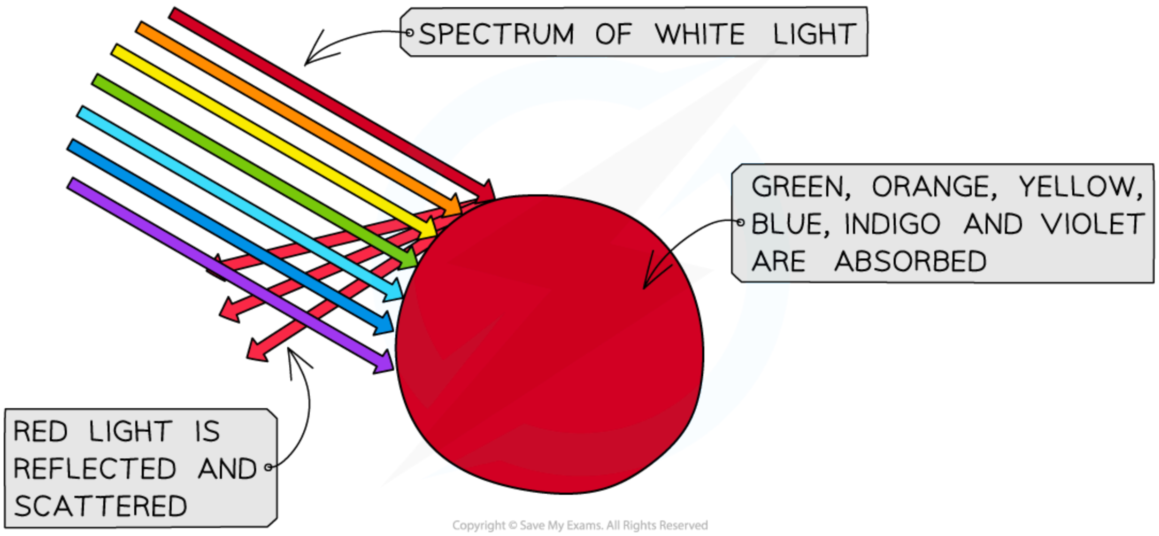
- All the other frequencies of visible light have been **absorbed**



The object is seen as red since the red light is reflected whilst the other colours are absorbed

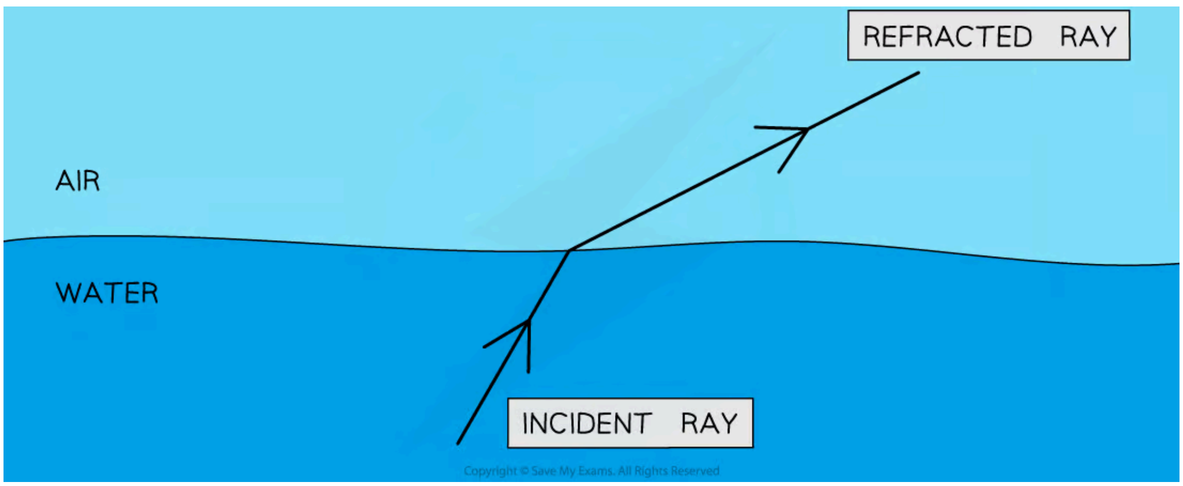
Your notes

Your notes

Refraction

Refraction

- Refraction can occur when a wave crosses a boundary between two materials with **different densities**
- In some cases, the wave will **change direction**
- The ray diagram below illustrates the change of direction of a light ray at a water-air boundary:

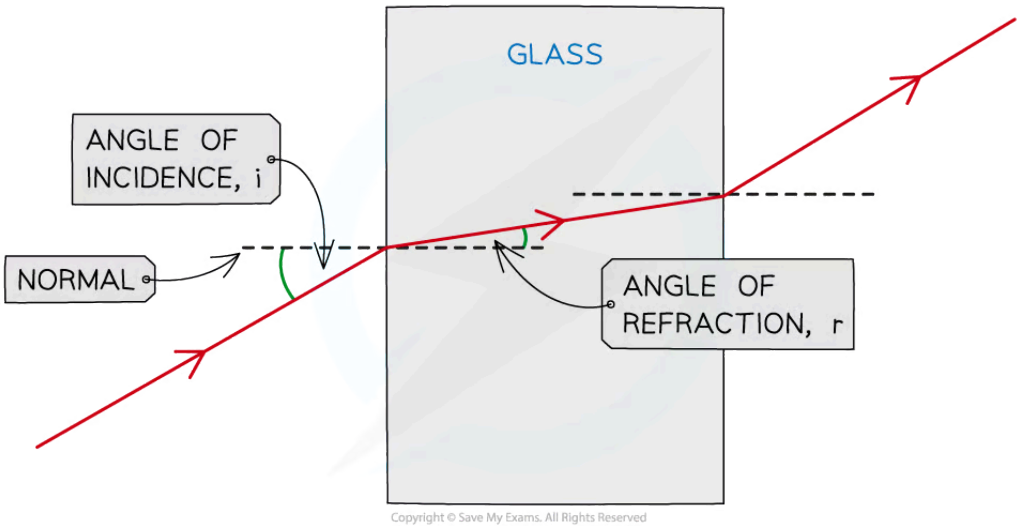


Waves can change direction when moving between materials with different densities

Refraction of light

- Refraction also occurs when light passes a boundary between two different transparent media
- At the boundary, the rays of light undergo a **change in direction**
- The direction is taken as the angle from the normal
- The change in direction depends on the difference in density between the two media:
  - From less dense to more dense (e.g air to glass), light bends **towards** the normal
  - From more dense to less dense (e.g. glass to air), light bends **away** from the normal
  - When passing along the normal (perpendicular) the light **does not bend** at all

Refraction of Light Through a Glass Block



Light enters the glass where the light ray bends towards the normal. Light bends away from the normal as it exits the glass

- The change in direction occurs due to the change in speed when travelling in different substances
  - When light passes into a **denser** substance the rays will **slow down**, hence they bend towards the normal
- As with refraction of water waves, the only properties that change during refraction of light are speed and wavelength – the **frequency** of waves **does not change**
  - Different frequencies account for different **colours** of light (red has a low frequency, whilst blue has a high frequency)
  - When light refracts, **it does not change colour** (think of a pencil in a glass of water), therefore, the frequency does not change

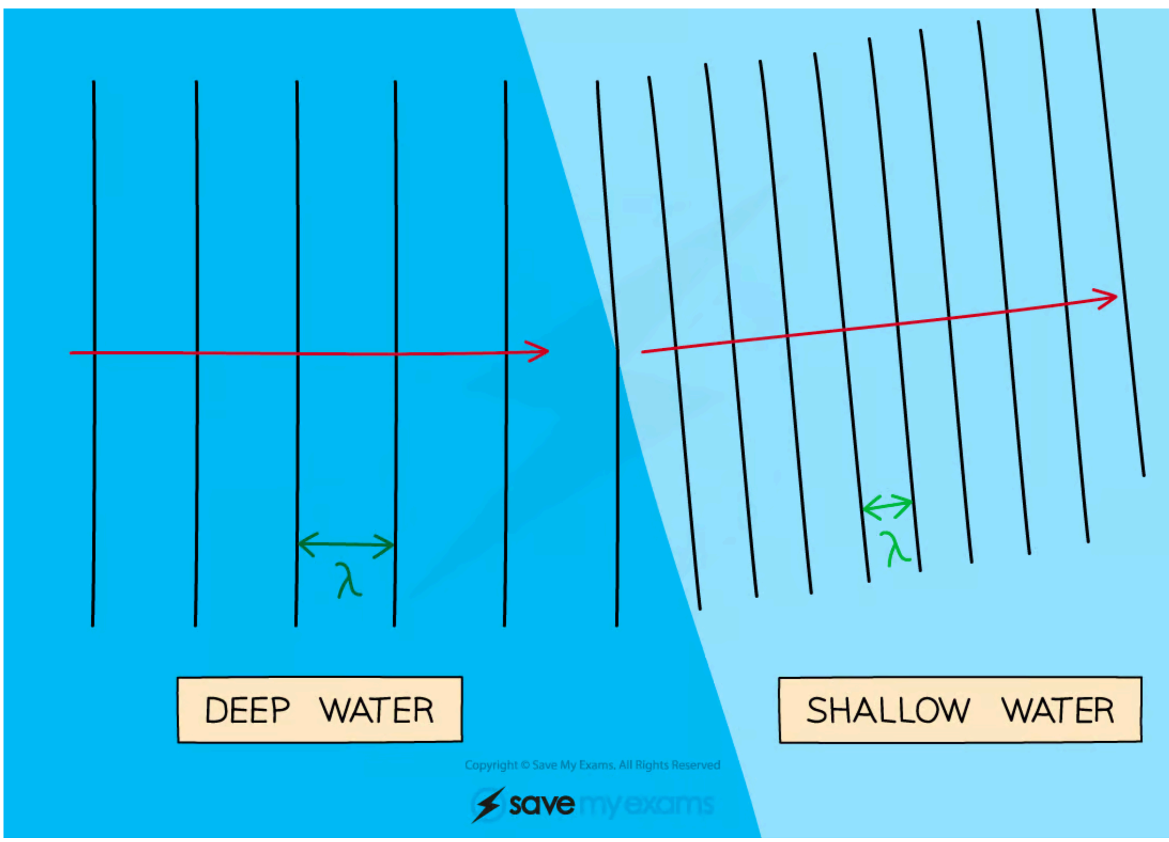
Refraction & Speed

Your notes

Refraction & Speed

Higher Tier Only

- When a wave hits a different medium the different parts of the wave enter the medium at different times
  - Hence, this leads to a **change in speed**
- The difference in speed between the parts of the wave in the first medium and the parts in the second medium causes the wave to **bend**
  - Hence, this leads to a **change in direction**
- Refraction can be represented using **wavefront diagrams**, as shown below:



The different parts of the wave enter the second medium at different times causing the wave to bend

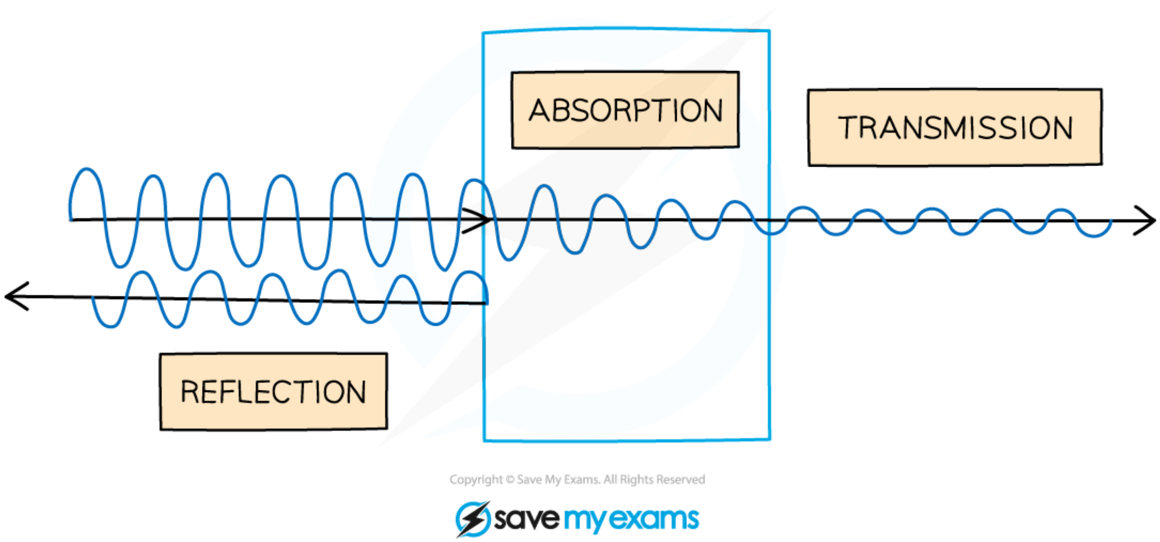
Wave Interactions & Wavelength

Your notes

Wave Interactions & Wavelength

Higher Tier Only

- When waves move from one substance to another the waves might be:
  - Transmitted
  - Absorbed
  - Reflected
  - Refracted



When waves move from one medium to another they can be transmitted, reflected, refracted or absorbed

- Materials interact differently with waves depending on their **wavelength**
- Whilst some wavelengths might be transmitted, others might be reflected, refracted or absorbed
- For example, glass will:
  - **Transmit** and/or **refract** visible light
  - **Absorb** UV radiation

- **Reflect** IR radiation

Your notes

Your notes

Core Practical 2: Investigating Wave Properties

Equipment List

Equipment	Purpose
Ripple Tank	To create small waves in water
Light Source	To illuminate the waves to create shadows
Strobe light	To make the waves appear stationary so that wavelength can be measured
Metre Rule	To measure distance
Large Sheet of paper	To provide a white background to act as a screen for the wavefront shadows
Stopwatch	To time the movement of the waves
Signal generator	To operate the vibration generator and to measure the frequency of the stationary wave

Pulley	To provide a smooth track to connect the horizontal string to vertical masses
Clamp	To attach the pulley to the table
Vibration Generator	To vibrate the string
Retort Stand	To clamp the vibration generator in place to stop it moving on the table
String	Used to observe the stationary wave
Wooden Bridge	To change the vibration length of the string
Slotted masses with hook	To provide tension in the string

- **Resolution** of measuring equipment:
  - Metre ruler = 1 mm
  - Stopwatch = 0.01 s
  - Signal generator ~ 10 nHz

Experiment 1: Water Waves in a Ripple Tank

Aims of the Experiment

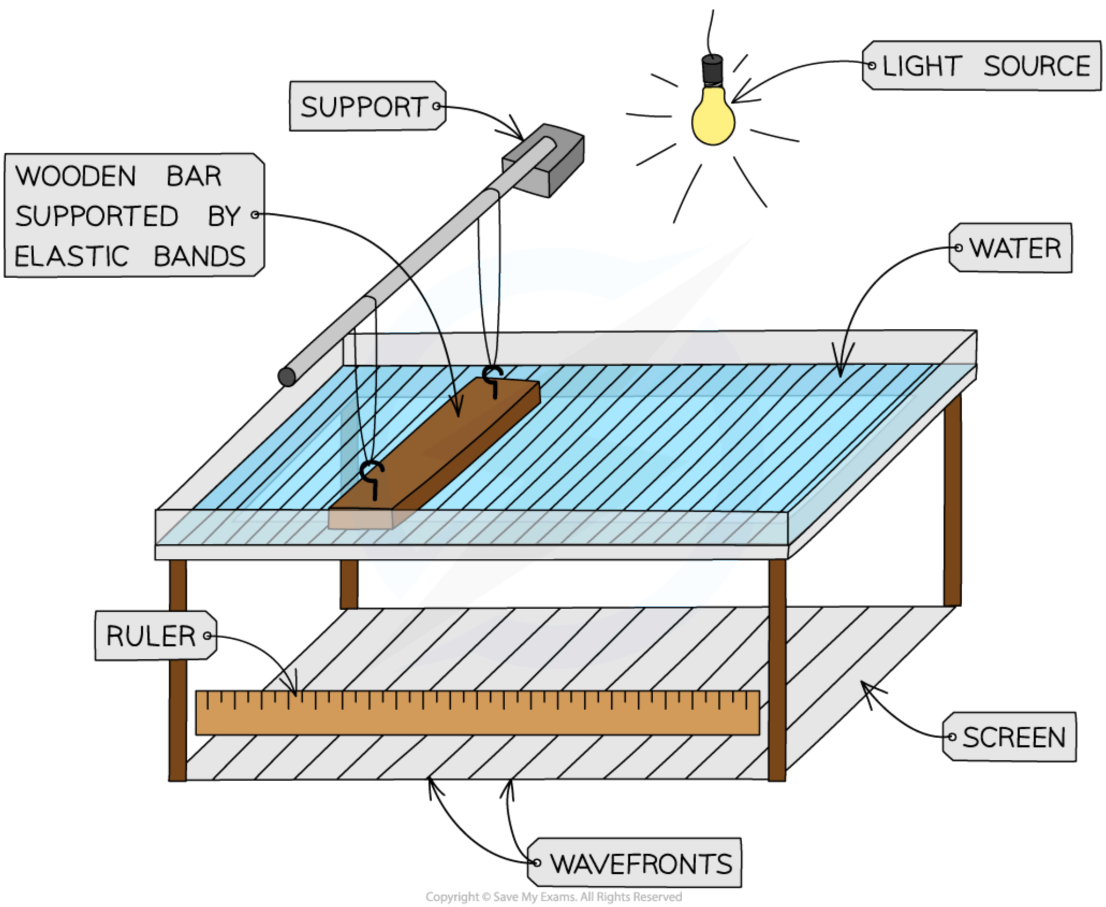
- To measure frequency, wavelength and wave speed by observing water waves in a ripple tank

Variables

- Independent variable = frequency, f
- Dependent variable = wavelength, λ
- Control variables:
  - Same depth of water

- Same temperature of water

Method

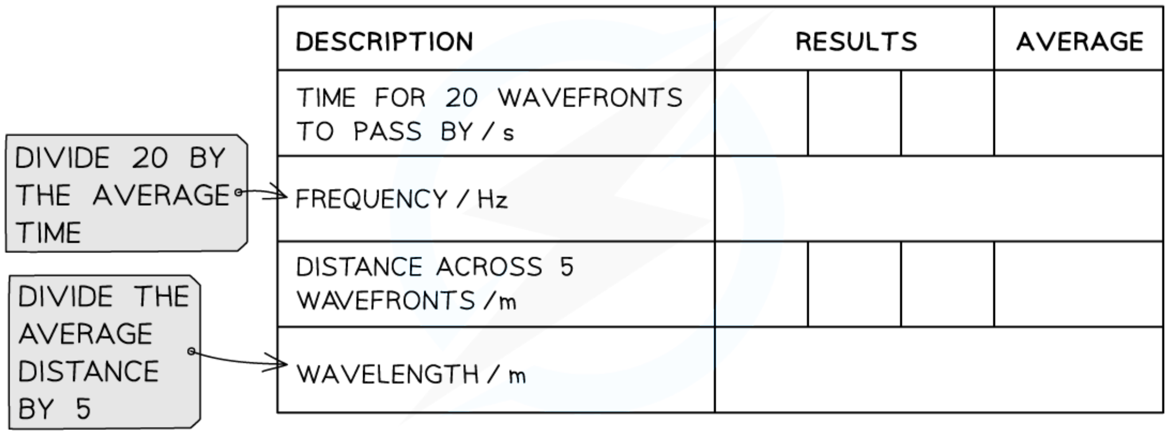


Set up of ripple tank to investigate wave properties

1. Set up the apparatus as shown and fill the ripple tank with water to a depth of no more than 1 cm
2. Turn on the power supply and the light source to produce a wave pattern on the screen
3. The wavelength of the waves can be determined by using a ruler to measure the length of the screen and dividing this distance by the number of wavefronts
4. The frequency can be determined by timing how long it takes for a given number of waves to pass a particular point and dividing the number of wavefronts by the time taken
5. Record the frequency and wavelength in a table and repeat the measurements

- An example of the data collection table is shown below:

Your notes



Analysis of Results

- The speed of the waves can be determined using the equation:

Wave Speed = Frequency × Wavelength

$$v = f\lambda$$

- Where:
  - v = wave speed in metres per second (m/s)
  - f = frequency in Hertz (Hz)
  - λ = wavelength in metres (m)

Experiment 2: Stationary Waves on a Vibrating String

Aim of the Experiment

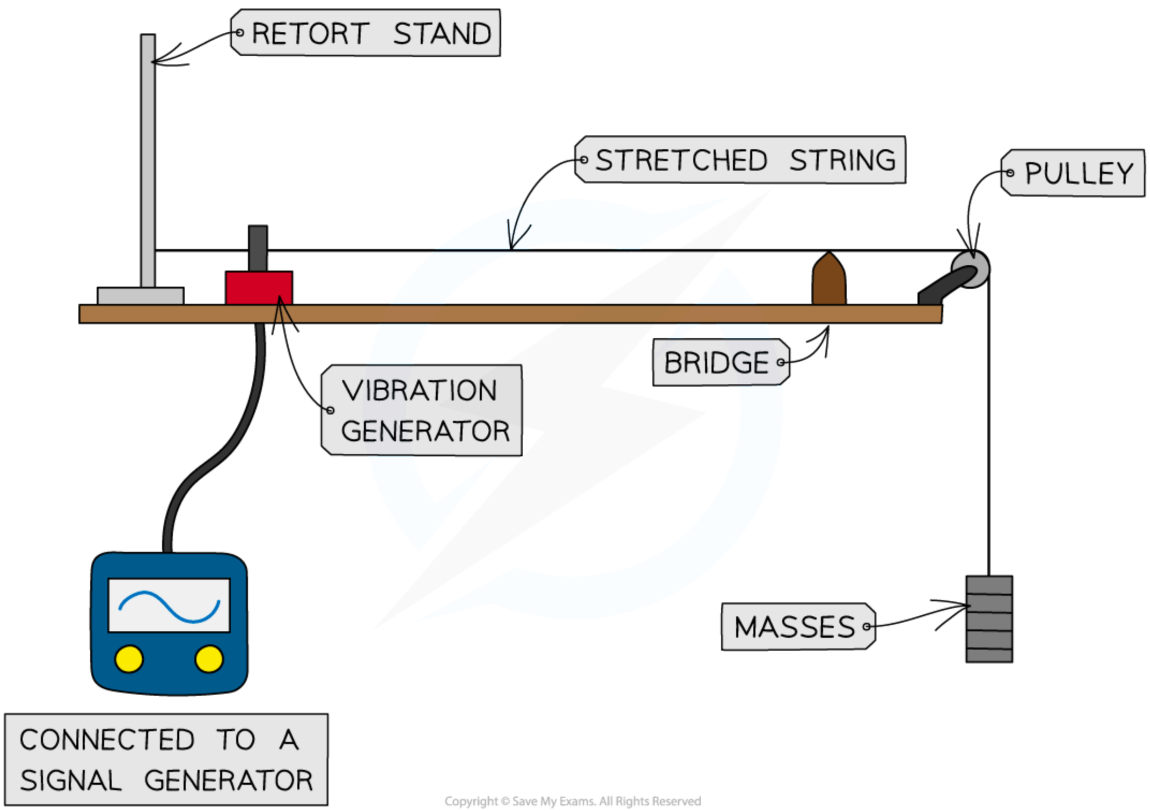
- To measure frequency, wavelength and wave speed by observing waves on a stretched string or elastic cord

Variables

- Independent variable = frequency, f
- Dependent variable = wavelength, λ
- Control variables:
  - Same string
  - Same masses attached to string

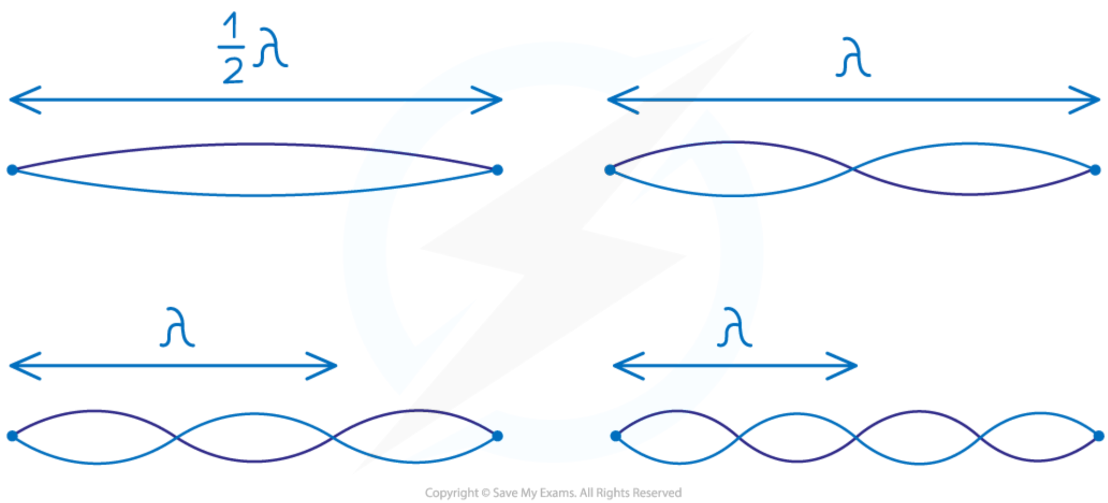
- Same length of string

Method



Set up of apparatus to investigate wave properties of a vibrating string

1. Set up the apparatus as shown, then adjust the frequency of the signal generator until a stationary wave is produced
2. Once the stationary wave is produced, record the frequency shown on the signal generator
3. Use a ruler to measure the wavelength, the length to measure will depend on the number of stationary waves produced. Or measure the length of multiple wavelengths, and divide by the number of wavelengths seen
4. Repeat the procedure by adjusting the frequency until another stationary wave is produced



Guide to measuring the wavelength of stationary waves

- An example of the data collection table is shown below:

	DESCRIPTION		RESULTS			AVERAGE
WAVELENGTH = 2 × THE LENGTH OF THE STRING		FIRST FREQUENCY / Hz				
		WAVELENGHT / m				
WAVELENGTH = THE LENGTH OF THE STRING		SECOND FREQUENCY / Hz				
		WAVELENGHT / m				
WAVELENGTH = $\frac{2}{3}$ × THE LENGTH OF THE STRING		THIRD FREQUENCY / Hz				
		WAVELENGHT / m				

Analysis of Results

- The speed of each wave can be determined using the equation:

Wave Speed = Frequency × Wavelength

Your notes

Your notes

$$v = f\lambda$$

Evaluating the Experiment

Systematic Errors:

- It can be difficult to identify the wavefronts while they are moving
  - Use a stroboscope (flashing light) matched to the same frequency of the waves, this will be indicated by the waves appearing to be stationary
  - The frequency can be read from the frequency setting of the stroboscope, and the wavelength will be easier to determine while the waves appear still

Random Errors:

- To improve the accuracy of the wavelength measurement in the ripple tank:
  - Measure across a number of waves (e.g. 5 of them) and then divide the distance by the number of waves
- To improve the accuracy of the frequency measurement in the ripple tank:
  - Measure across a longer time period (e.g. a minute) and then divide the number of waves by the time
- When taking repeat measurements of the frequency of the stationary wave, the best procedure is as follows:
  - Determine the frequency of the stationary wave when the largest vibration is observed and note down the frequency at this point
  - Increase the frequency and then gradually reduce it until the stationary wave is clearly observed again and note down the frequency of this
  - If taking three repeat readings, repeat this procedure again
  - Average the three readings and move onto the next measurement

Safety Considerations

- Care should be taken when working with water and electricity in close proximity
  - Carelessness could lead to electric shock
- No food or drink should be consumed near the experiment
- If using strobe lighting to see the wavefronts more clearly, ensure no one in the room has photosensitive epilepsy
- Make sure to stand up during the whole experiment, to react quickly to any spills

- Use a rubber string instead of a metal wire, in case it snaps under tension
- Wear safety goggles to protect the eyes in case the string or cord snaps
- Stand well away from the masses in case they fall onto the floor
  - Place a crash mat or any soft surface under the masses to break their fall

Your notes