Wave Properties

Key Stage 4 Revision Programme

Pupil Name	
Handbook Designed by	Dr Y Hamidizadeh

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1 (Baseline)			
2			
3			
4			
5			
6 (Final Assignment)			
7 (Feedback)			

Timetable – Homework Assignments

Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

If you need more space for your answers please use "Notes" pages at the end of the workbook.

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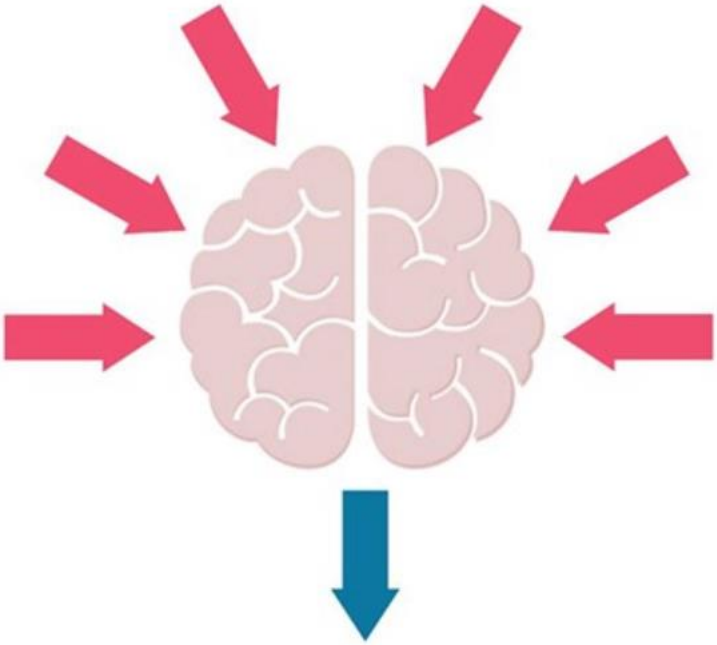
If you need more space for your answers please use "Notes" pages at the end of the workbook.

Course Rationale

The tutorials are planned to give a clear understanding of the essentials of the Wave properties and to teach exam techniques, so that students can use their knowledge to best effect.

In this course, we are going to explore the Wave properties. To do this, initial tutorial will assess students' initial level of attainment in this subject area. Pupils will then learn about the nature and properties of waves. Pupil will also learn about reflection and refraction. Finally, we will have more discussion about waves.

For the final assignment, pupil will be asked to do a research and design a concept map about waves based on what they've learned during the course. They will also be asked to think about study tips for each branch of their concept map.



Subject Vocabulary

Word	Definition	In a sentence

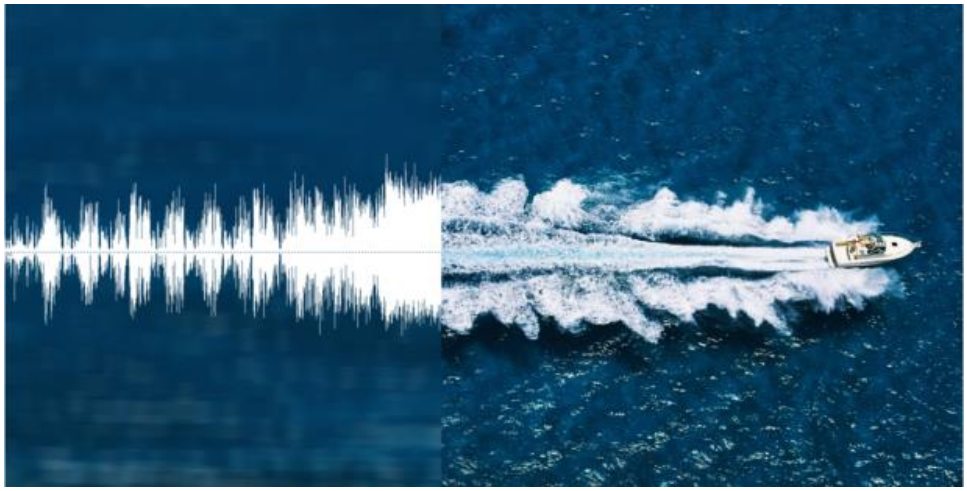
If you need more space for your answers please use "Notes" pages at the end of the workbook.

Tutorial 1 – Baseline test

What is the Purpose of Tutorial 1?

- Objective) A baseline test to see your initial level of attainment in this subject area.

Tutorial 2 – The nature of waves



What is the Purpose of Tutorial 2?

- Objective A) Defining the nature of waves
- Objective B) Describing the nature of longitudinal and transverse waves
- Objective C) Describing and explaining the difference between longitudinal and transverse waves using wave tests

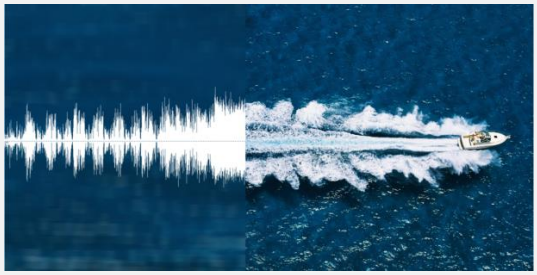
1. The nature of the waves

Keywords: waves, mechanical waves, electromagnetic waves, transverse, longitudinal, oscillates, compression, rarefaction

Objectives this tutorial:

A) Defining the nature of waves
B) Describing the nature of longitudinal and transverse waves
C) Describing and explaining the difference between longitudinal and transverse waves using wave tests

Starter: List as many types of waves as you can think of.



What does a wave do?

Objective A: Defining the nature of waves

Waves transfer energy without transferring matter. There are different types of waves:

- Mechanical waves: vibrations travel through a medium (a substance)
- Electromagnetic waves: can travel through a vacuum at the same speed of 300 000 km/s. No medium is needed

Note that these two types of waves can be further classified as transverse or longitudinal.

Practice A: Defining the nature of waves

1) State the name of different types of waves and give some examples for each type.

2) Write a sentence defining mechanical waves and give an example.

3) Describe the difference between the two types of waves.

4) Explain why would sound travels quicker in solids and liquids than gases. (Hint: Think about the arrangements of particles in solid and liquid compared to gases)

5) Explain why sound cannot travel through a vacuum like outer space.

Assessment A: Defining the nature of waves

What do waves transfer and does microwave travel through a medium?

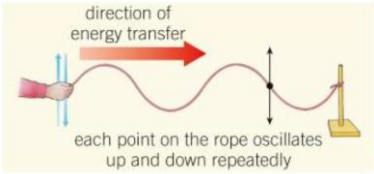
A	Energy, No
B	Information, Yes
C	Energy, Yes
D	Information, No

Objective B: Describing the nature of longitudinal and transverse waves

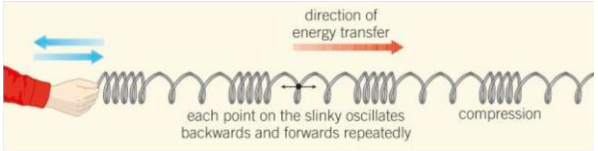
Worked example 1

Waves may be either transverse or longitudinal waves. Describe the difference between them using diagrams and examples.

Diagrams →



Transverse waves



Making longitudinal waves

Oscillations perpendicular to direction of energy transfer in transverse wave but parallel in a longitudinal wave ← Difference

Transverse wave : electromagnetic wave or waves on stretched string / wire
longitudinal wave: sound waves ← Examples

Study tip
Make sure you know how to describe the difference between these two waves. Don't forget to draw diagrams and give examples!

Worked example 2

Fill in the gaps in the sentences below:

Study tip
Transverse waves oscillate perpendicular to the direction of energy transfer of the waves and longitudinal waves oscillate parallel to the direction of energy transfer of the waves!

a …… Longitudinal…….. waves travel parallel to the direction of vibration.
b ……Transverse …… waves are made when the disturbance is at 90 degrees to the direction of wave motion.
c …… Longitudinal …….. waves can be 'heard' by the brain as sound.
d …… Transverse …….. waves can be processed by the brain to allow us to 'see'.

Worked example 3

For the following statement, state whether the wave being described is most likely to be a longitudinal wave, a transverse wave, or both. Then explain your answer.

'I noticed that when I dropped a stone into water, that ripples were formed.'

Transverse ; ← Wave type

Study tip
Ripples on the surface of water are transverse waves. So are all electromagnetic waves.

Ripples are transverse as the disturbance is at 90° to the direction of the wave's energy transfer outwards along the surface of the water. ← Explanation

Practice B: Describing the nature of longitudinal and transverse waves

1) A football is stuck, floating, in the middle of a pond. The owner finds a stick and hopes to use it to retrieve the ball. He can't decide whether to throw the stick at the ball , or use the stick to made waves in the water. Which would you recommend and why?

2) Fill in the table below to show if the observations apply to longitudinal waves, transverse waves or both. Tick the correct box(es) in columns two and three and then explain your answer in column four.

Observation	Transverse wave	Longitudinal wave	Explanation
transfer energy			
travel at speed of light			
can be heard			
travel through a vacuum			

3) For the following statements, state whether the wave being described is most likely to be a longitudinal wave, a transverse wave, or both. Then explain your answer.

a 'It is possible to detect these waves from beyond our own galaxy.'

b 'These waves will travel faster through solids than through air.'

c 'These waves can be described in terms of their wavelength, frequency, and velocity.'

4) Transverse X-rays and longitudinal ultrasound waves are both used in hospitals. Consider the properties, uses and dangers of these two different types of radiation by filling in the table below.

	X-rays	Ultrasound
Type of wave	transverse	longitudinal
Speed in air		
Typical wavelengths		
Typical frequencies		
Uses		
Dangers		
Properties	can be transmitted, reflected, absorbed and refracted	

5) A baby monitor has a sensor unit that transmits an image of the baby and the noises the baby makes to a monitor unit. The monitor unit then displays an image of the baby and emits the noises the baby makes. Compare the properties of the waves that transmit images and noises from the monitor unit.

Assessment B: Describing the nature of longitudinal and transverse waves

Which line gives an example of longitudinal wave and describes its vibrations.

	Example of longitudinal wave	vibrations
A	Light wave	At right angles to the direction the wave travels
B	Light wave	In the same direction as the wave travels
C	Sound wave	At right angles to the direction the wave travels
D	Sound wave	In the same direction as the wave travels

Objective C: Describing and explaining the difference between longitudinal and transverse waves using wave tests

Worked example 1

A long rope with a knot tied in the middle lies straight along a smooth floor. A student pics up one end of the rope. This send waves along the rope. State whether the waves on the rope are transverse or longitudinal waves, describe the direction of energy transfer along the rope and the movement of the knot.

Study tip
You will see that the waves move along the rope but the knot doesn't move along the rope.

Wave type
transverse

Direction of energy
along rope from one end to the other

Movement of the knot
Oscillates in a direction perpendicular to energy transfer

Worked example 2
Describe how to use a slinky spring to demonstrate to a friend the difference between longitudinal waves and transverse waves.

Stretch slinky out, move one end at right angles to slinky for transverse waves or parallel to slinky for longitudinal waves

Worked example 3
Describe and explain the motion of a small ball floating on a pond when waves travel across the pond.

Ball moves up and down repeatedly on surface because waves consist of successive crests and troughs moving across surface, each crest pushes ball up and each trough allows it to move down

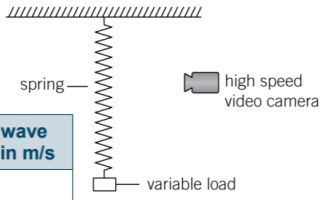
Study tip: Make sure to know the different wave tests!

Practice C: Describing and explaining the difference between longitudinal and transverse waves using wave tests

1) Describe the movement of the ribbon on the spring as a longitudinal wave passes through it, comparing the direction of the motion of the particles with the direction of the wave motion. Then describe what happens to the wave pulse if the spring is shaken back and forth more rapidly.

2) A student proposes that the tension in the spring (how much it is stretched) has an effect on the speed of the wave pulses which pass through it and makes this prediction: "Prediction: The greater the tension in the spring the greater the speed of the wave will be." Describe an experiment that would test this prediction for both transverse and longitudinal waves.

3) A student set up apparatus to measure the speed of a longitudinal wave pulse in a stretched spring as shown in the diagram below. They collected results as shown in the table.

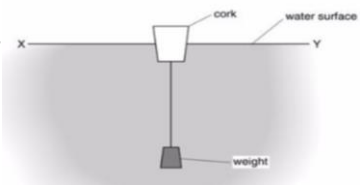


Calculate the mean wave speed for each tension using the data in the table. Complete the final column in the table. Describe the relationship between the wave speed and the tension in the spring.

Tension in N	Wave speed test 1 in m/s	Wave speed test 2 in m/s	Wave speed test 3 in m/s	Mean wave speed in m/s
1.0	1.08	1.01	0.92	
2.0	1.34	1.32	1.32	
3.0	1.63	1.79	1.79	
4.0	2.08	2.06	2.03	
5.0	2.14	2.34	2.24	

Assessment C: Describing and explaining the difference between longitudinal and transverse waves using wave tests

The diagram shows a cork with a weight attached so that the cork floats upright.
Transverse waves travel across the water from X to Y.
Which way do the waves make the cork move?



A	Right and left	B	Up and down	C	Only to the right	D	Only to the left

Plenary: Explain the differences between longitudinal and transverse waves. Your explanation should refer to ultraviolet, ultrasound and seismic waves.

Tutorial 3 – The properties of waves

What is the Purpose of Tutorial 3?

- Objective A) Defining what is meant by the amplitude, frequency, period and wavelength of a wave
- Objective B) Describing the relationship between the speed, wavelength, and frequency of a wave
- Objective C) Performing and explaining multi-stage calculations linking period, frequency, wave speed, and wavelength

2. The properties of the waves

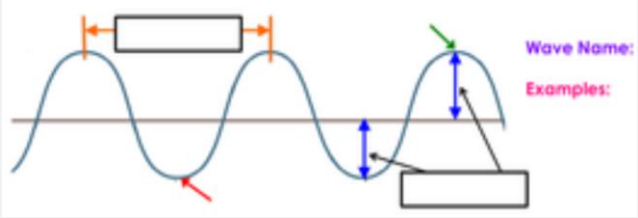
Keywords: wavelength, frequency, velocity, period , wave speed, amplitude

Objectives this tutorial:

A) Defining what is meant by the amplitude, frequency, period and wavelength of a wave
B) Describing the relationship between the speed, wavelength, and frequency of a wave
C) Performing and explaining multi-stage calculations linking period, frequency, wave speed, and wavelength

Starter: What type of wave can you see below:

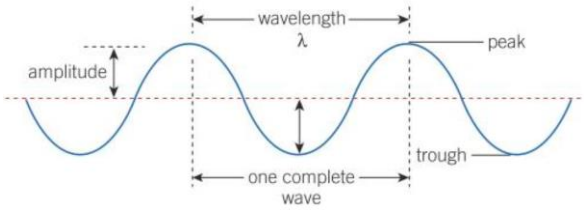
List as many properties of waves as you can think of.



Objective A: Defining what is meant by the amplitude, frequency, period and wavelength of a wave

If you want to find out how much energy or information waves carry you need to measure them:

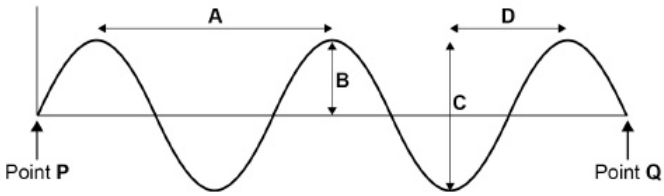
- The ***amplitude*** of a wave is the maximum displacement of a point on the wave from its undisturbed position.
- The ***wavelength*** of a wave is the distance from a point on the wave to the equivalent point on the adjacent wave.
- The number of waves passing a fixed point every second is called the ***frequency*** of the waves. (Unit of frequency: Hz)
- The ***period*** of a wave is the time taken from each wave to pass a fixed point.



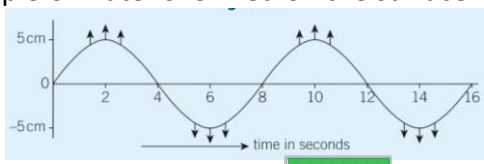
Practice A: Defining what is meant by the amplitude, frequency, period and wavelength of a wave

1) State what is meant by frequency of a wave.

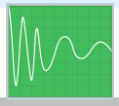
2) The diagram shows a wave:
(a) Which arrow shows the amplitude of the wave?
(b) Which arrow shows the wavelength of the wave?



3) A student observes a large stone falling into a pool water. A ripple of water s formed on the surface. the difference between the two types of waves.
Determine the amplitude of the wave.



4) A microphone connected to an oscilloscope picks up the sound from a siren. The trace produced on the oscilloscope screen is shown below. Describe how the wave changes as it goes across the screen from left to right.



Assessment A: Defining what is meant by the amplitude, frequency, period and wavelength of a wave

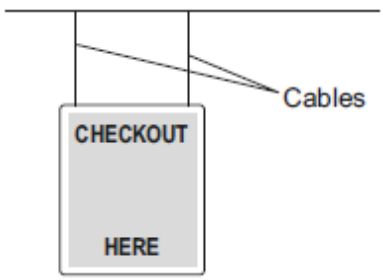
'The displacement from rest position to crest' is a definition of what?

A	frequency
B	phase
C	amplitude
D	wavelength

Objective B: Describing the relationship between the speed, wavelength, and frequency of a wave

Worked example 1

Waves A sign hangs from the ceiling using two cables, as shown below:



A breeze made the sign swing forwards and backwards like a pendulum. The frequency of oscillations of the sign was 2 hertz.
Calculate the periodic time for the sign.

$$period, T(s) = \frac{1}{frequency, f(Hz)}$$ ← Equation

T = 1/2

T= 0.5 s ← units

Worked example 2

A man counts 6 waves on a pond in 10 seconds. The distance between them is 40 cm. What is their speed?

$$wave\ speed, v\left(\frac{m}{s}\right) = frequency, f\ (Hz) \times\ wavelenght, \lambda(m)$$

$v = f \times \lambda$

6 waves in 10 seconds = 0.6 waves per second
So f =0.6 Hz
And λ = 0.4m ← conversion

Hence v= 0.6 × 0.4 = 0.24 m/s ← unit

Study tip
Don't forget to convert non-standard units into standard units!

Worked example 3

A bird on a post out at sea is exposed to a series of water waves, each travelling at 3.3 m/s, that periodically splash its feet when the crest of the wave hits the post. Each crest is 4.5 m apart. For how long do the bird's feet dry for between each drenching? .

λ = 4.5 m; v = 3.3 m/s
f = v / λ= 3.3 /4.5= 0.733 Hz (to 3 s.f.) ← rearrange
Time between each drenching is T = 1/ f
T = 1/ 0.733 = 1.364 so 1.36 s (to 3 s.f.)

Study tip
Don't forget to rearrange equations!

Practice B: Describing the relationship between the speed, wavelength, and frequency of a wave

1) A water wave passes a boat. An observer on the boat notices that 120 water waves pass the boat in a time of 1 minute. The boat is at anchor (it is not moving).
(a) Calculate the frequency of the water waves in hertz, Hz. (b) The water waves have a wavelength of 1.8 m. Calculate the wave speed of the water waves.

2) A stationary car horn emits a sound wave of frequency 400 Hz. The wavelength of the wave is 0.85 m. Calculate the speed of sound.

3) A radio station RadioDJJazzy broadcasts on a frequency of 102 MHz. Radio waves have a speed of 3 x 10^8 m/s. (a) What is the wavelength of RadioDJJazzy? (b) What is the period of this wave?

4) Jasmine plays a note of wavelength 22 cm on her clarinet. The speed of sound in air is 340 m/s. What is the frequency of this note? Give your answer to 3 significant figures.

5) The label on the back of a microwave oven displays: frequency = 2450 MHz
If v = 3 x 10^8 m/s, what is the wavelength of the microwaves?

6) A girl stands on a boat and feels the boat rise and fall 7 times in 1 minute. What is the period of the water wave?

7) Describe what happens to the speed of the waves as you increase the frequency of the vibrations.

8) The table below shows values for wavelength, frequency, time period, and wave speed. Fill in the missing values in the table and identify what the wave might be:

Wavelength in m	Frequency in Hz	Time period in s	Wave speed in m/s	Type of wave
5.0	2.0			water wave
6.0×10^{-7}			3.0×10^{8}	
	26 000		1570	
		3.3×10^{-7}		radio wave

Assessment B: Describing the relationship between the speed, wavelength, and frequency of a wave

A wave motion has period *T*, frequency *f*, wavelength *λ*, and speed *v*. which one of the following equations is incorrect?

A	*1=Tf*	B	*T=v/λ*	C	*λ=v/f*	D	*Tv=λ*

Objective C: Performing and explaining multi-stage calculations linking period, frequency, wave speed, and wavelength

Worked example 1
A group of students investigate the speed of sound in air. Two students stand a distance apart with one holding an air horn and the other a stop watch.
- The first student drops his arm and at the same time sounds the horn
- The second student starts the stop watch as the arm drops
- The second student then stops the stopwatch when she hears the horn

Describe how the speed of sound in the air can be calculated from the results.

The speed of sound = the measured distance / the mean value of the 3 timings

Worked example 2

The diagram shows how ultrasound is used to measure the depth of water below a ship. A pulse of ultrasound is sent out from an electronic system on-board the ship. It takes 0. 80 seconds for the emitted ultrasound to be received back at the ship. Calculate the depth of the water. (Speed of ultrasound in water = 1600m/s)

The speed of ultrasound = the measured distance / time

Distance = speed x time

= 1600 x 0. 80

=1280 m

Depth of water: Distance /2

=1280/2=640 m

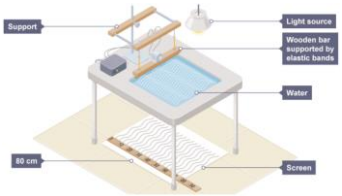
Study tip: Make sure to calculate the depth!

Worked example 3

The figure below shows a ripple tank which is used to study the behaviour of water waves:

Water waves are produced in the tank. The shadow of the waves is projected onto the screen below the tank. The waves appear to move in the direction of the arrow.

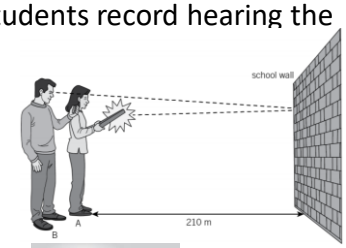
Describe how to determine the frequency of the waves.



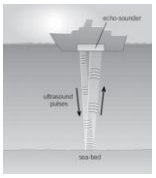
Measure the time for a certain number of waves to pass a fixed point and then calculate frequency = number of waves ÷ time taken

Practice C: Performing and explaining multi-stage calculations linking period, frequency, wave speed, and wavelength

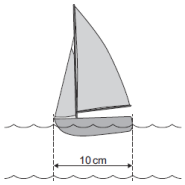
1) A sound wave is generated by clapping two wooden sticks together. The students record hearing the echo 1.2 seconds later. The students are standing 210 m from the wall.
   (a) Use this information and the diagram to determine a value for the speed of sound in air. (b) Explain how the investigation could be changed so that the value for the speed of sound obtained would be more accurate.



2) An ultrasound signal is sent out by a ship to detect how far beneath the surface the sea bed is. The process is called 'echo-ranging'. The ultrasound signal has a frequency of 24 000 Hz and a wavelength of 0.63 m. The time between sending the signal and detecting the reflected wave is 0.42 s.



(a) Explain why the equation used to find the distance of the sea bed beneath the surface can be written as d = 1/ 2 (v x t) (b) Calculate the distance from the surface of the water to the sea bed.



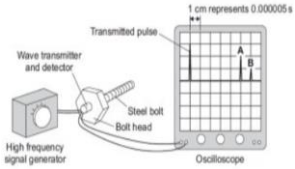
3)) A scientist tests a design for a sailing boat using a scale model in a tank of water. Waves are produced on the surface of the water. Calculate the wavelength of one wave. The waves at sea have a wavelength of 6 m. The frequency of the waves is 0.5 Hz. Calculate the speed of the water waves.

Assessment C: Performing and explaining multi-stage calculations linking period, frequency, wave speed, and wavelength

The diagram shows how a very high frequency sound wave can be used to check for internal cracks in a large steel bolt.

The oscilloscope trace shows that the bolt does have an internal crack.

Speed of sound through steel = 6000 m/s. Calculate the distance from the head of the bolt to the internal crack.



A	7.5 cm	B	18 cm	C	15 cm	D	9 cm

Plenary: Use the words frequency, wavelength, and wave speed to write an equation which shows the relationship between them and explain their relationship.

Tutorial 4 – Reflection and refraction

What is the Purpose of Tutorial 4?

- Objective A) Defining refraction and reflection using wave-front model
- Objective B) Describing the relationship between the angle of incidence and angle of refraction
- Objective C) Explaining refraction in terms of changes in the speed of waves when they move between one medium and another.

3. Reflection and refraction

Keywords: reflection, refraction, incident waves, transmitted wave, plane wave

Objectives this tutorial:

A) Defining refraction and reflection using wave-front model

B) Describing the relationship between the angle of incidence and angle of refraction

C) Explaining refraction in terms of changes in the speed of waves when they move between one medium and another.

Starter: Look at a pencil in a beaker of water. What does it look like?

Why does it look broken?

Objective A: Defining refraction and reflection using wavefront model

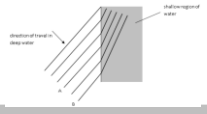
what happens to a wave when it hits a surface or crosses a boundary into a different depth of water?

- ***Reflection*** is the change in direction of a wavefront at an interface between two different media so that the wavefront returns into the medium from which it originated.
- ***Refraction***, the change in direction of a wave passing from one medium to another caused by its change in speed. For example, waves in deep water travel faster than in shallow.

Practice A: Defining refraction and reflection using wave-front model

1) When plane waves reflect from a straight barrier describe the angle of each reflected wavefront to the barrier and the angle of each incident wavefront to the barrier.

2) The diagram shows a water wave in deep water being refracted as it passes into a region of shallow water. The arrow shows the direction of the incident wave. (a) Draw an arrow on the diagram to show the direction of the wave in the shallow water. (b) Angles of incidence and refraction are defined in terms of the angle between the direction of the wave and the normal. Is the angle of refraction of the wave in the shallow water greater than, smaller than or equal to the angle of incidence in the deep water? (c) As the wave enters the shallow water, what happens to the wavelength of the wave? (d) The wavefront labelled B was at the position labelled A one second before. i What is the frequency of the wave? ii Explain why the frequency of the wave in the deep and shallow regions is the same. iii State what happens to the speed of the wave as it enters the shallow region.



3) State one similarity and one difference between refraction and diffraction.

Assessment A: Defining refraction and reflection using wave-front model

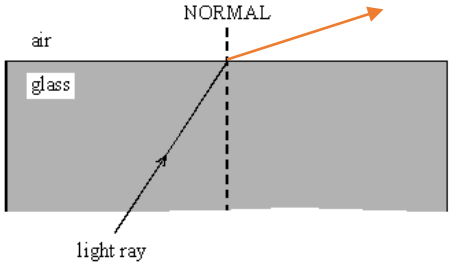
When refraction of a wave occurs, there is a change in?

A	Both frequency and speed
B	Both frequency and wavelength
C	Both speed and wavelength
D	Frequency, speed, and wavelength

Objective B: Describing the relationship between the angle of incidence and angle of refraction

Worked example 1

The diagram shows a ray of light travelling through a glass block.



(a) Complete the diagram to show what happens to the ray of light when it comes out of the glass.

(b) Explain why this happens to the ray of light.

Study tip
Make sure to draw the ray!

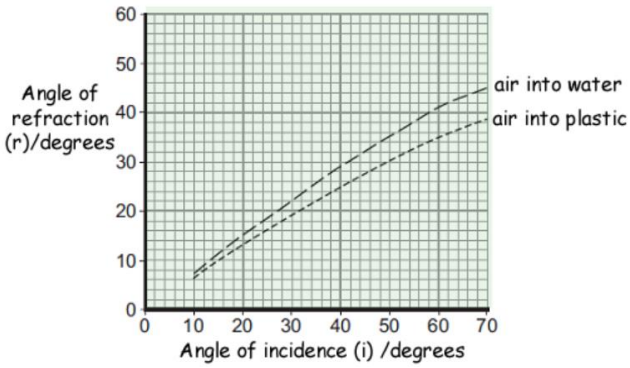
(a) ray shown refracted (to rhs or along normal)

but
ray shown refracted away from normal

(b) travels at a different speed
(allow refracted / travels slower in air / air is less dense) (do not allow bent)
but travels more quickly in air ← Other possible answers

Worked example 2
The graph below shows the student's results for light passing from air into plastic. This graph also shows the results for light passing from air into water. How does the refraction of light passing from air into water compare to the refraction of light passing from air into plastic?

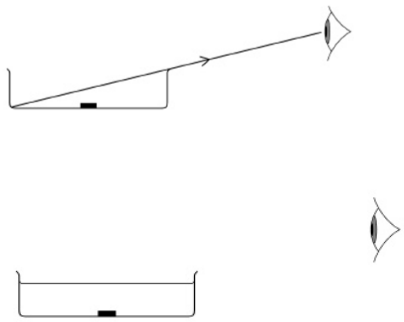
Light is refracted to a smaller degree by water than plastic



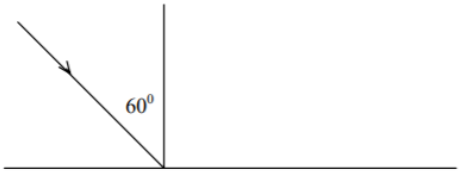
Practice B: Describing the relationship between the angle of incidence and angle of refraction

1) A coin is glued to the bottom of a bowl and an observer stands where they cannot see the coin

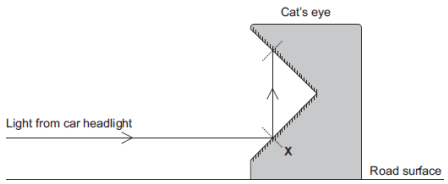
Another person fills the bowl with water.
The observer and the coin do not move.
After the water is added the observer can see the coin.
Explain why the observer can now see the coin in .



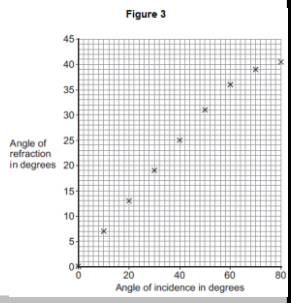
2) The wave fronts which are the crests of waves can be represented in diagrams as a series of straight lines. (i) How do the wave fronts relate to the direction of travel of the wave? (ii) On the diagram below, draw the direction of travel of the reflected wave and show the wave fronts.
(iii) What is the angle of the reflected wave?



3) 'Cat's eyes' are used on roads as markers. They reflect light from car headlights.
Diagram below shows the path of a ray of light entering a 'cat's eye'. Continue the path of the ray of light on Diagram. Show the direction of the ray. What is the name given to the dotted line on Diagram labelled X?



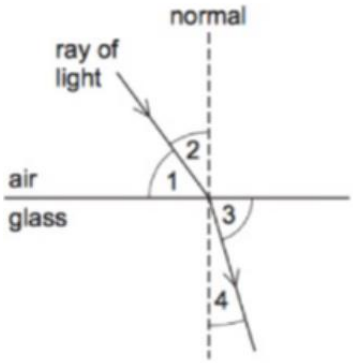
4) A student investigated the relationship between the angle of incidence and the angle of refraction as light passes from air into glass. Her results are shown below:
Describe the relationship between the angle of incidence and the angle of refraction.



Assessment B: Describing the relationship between the angle of incidence and angle of refraction

The diagram shows a ray of light entering a block of glass. Which numbered angles are the angles of incidence and of refraction?

	Angle of incidence	Angle of refraction
A	1	3
B	1	4
C	2	3
D	2	4



Objective C: Explaining refraction in terms of changes in the speed of waves when they move between one medium and another.

Worked example 1
Snell's Law can be expressed as: $\frac{sin\theta_1}{sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$

A student suggests that it may also be expressed as: $\frac{sin\theta_1}{sin\theta_2} = \frac{\lambda_1}{\lambda_2}$
Is this student correct? Justify your answer.

Study tip
Remember this equation!

v1 = f1λ1 and v2 = f1λ2. Frequency is unchanged as the light travels between the media, therefore f1 = f2.
v1/λ1=v2/λ2. This means that v1/v2=λ1/λ2=sinθ1/sinθ2.
The student is correct.

Worked example 2

Red light of wavelength 6.5x10−7m enters diamond with an index of refraction of n = 2.419 from air, with an angle of incidence of θ = 50°. Calculate:

(a) The angle of refraction (b) The wavelength of light in the diamond.

(a) $\frac{sin 50^o}{sin\theta_2} = 2.419$ and thus $\theta_2 = 18.5^o$

(b) $\frac{\lambda_1}{\lambda_2} = n$ and thus $\lambda_2 = \frac{6.5x10^{-7}}{2.419} = 269nm$

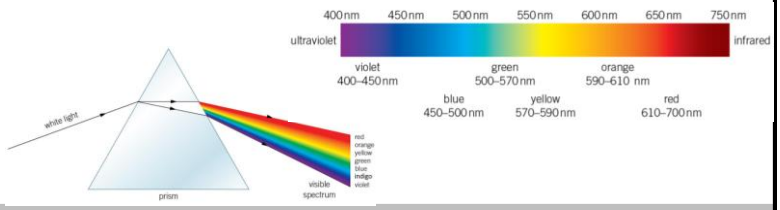
Study tip: Be careful with angle of incidence and angle of refraction when calculating index of refraction. It can make a big difference to the answer!

Worked example 3

When white light passes through a prism it splits into the visible spectrum. Use these 2 Figures to answer the following questions: (a) For which end of the visible spectrum and wavelengths of visible light is the refractive index of the glass of the prism the highest? (b) For which end of the visible spectrum and wavelengths of visible light is the refractive index of the glass of the prism the lowest?

(a) For the violet end of the spectrum, i.e., between 400 and 450 nm

(b) For the red end of the spectrum, i.e., between 610 and 700 nm



Practice C: Explaining refraction in terms of changes in the speed of waves when they move between one medium and another

1) The diagram below shows a layer of oil that is floating on water in a glass jar. A ray of light is shone through the glass. The refractive indices of the materials are as follows:

(a) Calculate the angle of refraction, θo, of the light ray as it passes from the oil into the water. (b) Explain why the light ray does not change direction when it passes from air into the glass.

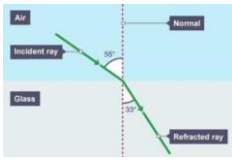
Refractive index of oil: = 1.47
Refractive index of water: = 1.33
Refractive index of glass: = 1.47

2) Calculate the critical angle for red light incident on a water-air interface. The refractive index of water is 1.33 for this colour of light.

3) (a) A ray of blue light of frequency 4. 8 x 10^{14}Hz is incident as shown on the surface of a piece of clear plastic. For this light the refractive index of the plastic is 1.48. Calculate the angle of refraction. (b) The refractive index for red light is 1.46. Calculate the angle of refraction for red light.

Assessment C: Explaining refraction in terms of changes in the speed of waves when they move between one medium and another

Diagram shows light refracting between the interface of air and glass. Calculate the refractive index.



A	1.67	B	1.5	C	0.6	D	0.67

Plenary: Explain why a pool of water appears to be shallower than it really is.

Tutorial 5 – More about waves

What is the Purpose of Tutorial 5?

- Objective A) Defining how sound waves are produced when objects vibrate.
- Objective B) Describing the properties of sound waves.
- Objective C) Evaluating data from speed of sound experiments to discuss the range of possible speeds for speed.

4. More about waves

Keywords: waves, sound waves, oscillates, echo, rarefaction

Objectives this tutorial:

A) Defining how sound waves are produced when objects vibrate.
B) Describing the properties of sound waves.
C) Evaluating data from speed of sound experiments to discuss the range of possible speeds for speed.

Starter: How do different musical instruments produce sound?

Objective A: Defining how sound waves are produced when objects vibrate

- Vocal cords vibrate and produce sound waves every time we speak.
- Any object vibrating in air makes the layers of air near the object vibrate which make the layers of air next to them vibrate.
- The vibrating object pushes and pulls repeatedly on the air.
- This sends out vibrations of air in waves of compressions and rarefactions.
- When the waves reach your ears they make your eardrums vibrate in and out so that out hear sound.

Note: the vibrations travelling through air are sound waves. The waves are longitudinal. The speed of sound waves in air is 330 m/s.

Practice A: Defining how sound waves are produced when objects vibrate

1) A sound wave is an example of a longitudinal wave.

(a) Figure below shows the air particles in a sound wave as the wave travels from a loudspeaker to an ear.

Write a letter R on Figure to show an area of rarefaction.

(b) Complete the sentence about longitudinal waves.

The vibrations of the air particles are _____ to the direction of energy transfer.

(c) Label the diagram to show one complete wavelength.

2) Explain how a vibration becomes a sound that is heard.

3) Sound waves can be reflected from a wall. What name is given to reflected sound waves?

4) What type of wave is a sound wave? electromagnetic | longitudinal | transverse

5) A lorry has an air horn. The air horn produces sound waves in the air. Use one word to complete the following sentence: Sound waves cause air particles to _____ .

Assessment A: Defining how sound waves are produced when objects vibrate

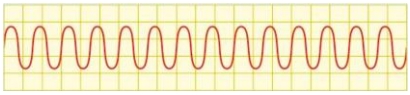
What Joe plucks a string on his guitar. How does this make a sound?

A	The string vibrates which vibrates the air which vibrates your eardrum.
B	The air vibrates which string the air which vibrates your eardrum.
C	His hand vibrates which vibrates the guitar which vibrates your eardrum.
D	The soundwaves vibrates the air.

Objective B: Describing the properties of sound waves.

Worked example 1

A loudspeaker is used to produced sound waves. (a) In terms of the amplitude of the waves explain why the sound is fainter further away from the loudspeaker. (b) a microscope is connected to an oscilloscope. Figure below shows the display on the screen of the oscilloscope when the microphone detects sound waves from a loudspeaker which is connected to a signal generator. Describe how the waveform displayed on the oscilloscope screen changes if the sound from the speaker is: (i) made louder (ii) reduced in pitch



(a) sound waves spread out so their amplitude becomes smaller

(b) (i) Same number of waves but taller (higher amplitude) (ii) same height of waves but stretched so fewer waves on screen

Worked example 2

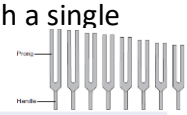
The signal generator produces one single frequency at a time. (a) State what happens to the trace on the oscilloscope when the frequency of the signal is increased. (b) State what happens to the trace on the oscilloscope when the volume of the signal is increased.

(a) The peaks become closer together.

(b) The wave trace height increases

Worked example 3

Figure below shows a set of tuning forks. A tuning fork has a handle and two prongs. It is made from metal. When the prongs are struck on a hard object, the tuning fork makes a sound wave with a single frequency. The frequency depends on the length of the prongs.



(a) Use the correct answer from the box to complete each sentence.

direction	loudness	Pitch	speed

The frequency of a sound wave determines its _____pitch_____ .

The amplitude of a sound wave determines its _____loudness_____ .

(b) Each tuning fork has its frequency engraved on it. A student measured the length of the prongs for each tuning fork. Some of her data is shown in the table.

Describe the pattern shown in the table.

as length (of prongs) decreases frequency / pitch increases

Frequency in hertz	Length of prongs in cm
320	9.5
384	8.7
480	7.8
512	7.5

Practice B: Describing the properties of sound waves.

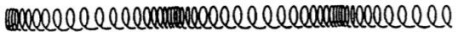
1) The strings on a guitar have a natural frequency of vibration. When plucked they vibrate and give out a note of that frequency. (a) What would a musician call the frequency of a note? (b) Shortening a string changes its frequency of vibration. (i) How do musicians shorten guitar strings? (ii) How does the frequency of the note change when the string is shortened? (c) The string's natural frequency can be changed by changing its tension. How is the tension of a guitar string changed? (d) The velocity of a sound wave is calculated from the equation: $V = f\lambda$ Where f = frequency, and λ = wavelength. λ for middle C is 1.3 m. The speed of sound in air is 330 m/s. Calculate the frequency of middle C. (e) How do two musical notes relate to each other if the frequency of note A is twice that of note B?
2) (a) All objects have a natural frequency of vibration. This vibration can be started and increased by another object vibrating at the same frequency. (i) What is this effect called? (ii) Give two examples of places where this effect is useful. (iii) Give two examples of places where this effect is a nuisance (b) What is meant by an overtone? (c) Use ideas about waves to explain the terms (i) loudness (ii) pitch (iii) quality (timbre) of a musical note.

3) A Sound waves with frequencies greater than 20 kHz are called 'Ultrasonics' (a) Explain how a fishing boat uses ultrasonics to detect shoals of fish. (b) How is ultrasound used in pregnancy? (c) A dentist may use ultrasound to descale teeth. Explain how this works. (d) How can ultrasound detect flaws in welded joints?

4) (a) A ship sends out a pulse of sound and receives an echo back one second later. If the water is 750 m deep, what is the speed of sound in water? (b) Katie ties a silver spoon to a piece of string and holds the ends to her ears. When her friend Hazel, strikes the spoon with a pencil, Katie hears a sound like a bell. Explain the reason for this. (c) Explain why we do not hear explosions on the Sun, although they must be very loud.

5) Choose words from the list below to complete the following sentences: Higher, Lower, Louder, Quieter
(i) A musical note with a high frequency sounds _____ than a musical note played at a low frequency.
(ii) A musical note with large amplitude sounds _____ _ than a musical note with small amplitude.

6) The diagram below shows a guitar. (i) Describe how the guitar produces sounds. (ii) Describe how the guitar can be made to produce louder sounds. (iii) State two ways that the guitar can be made to produce higher pitch sounds. (c) Look again at the diagram of the slinky spring. Explain why the wave travelling along the spring represents a sound wave but not a light wave.



Assessment B: Describing properties of sound waves.

Low frequency sound waves sound ……..

A	High pitched	B	Low pitched	C	Loud	D	Quit

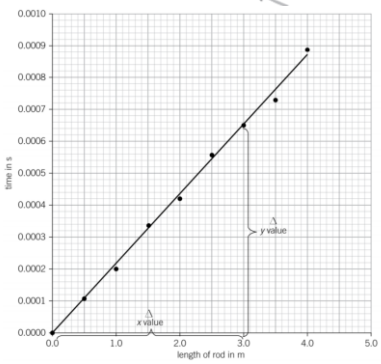
Objective C: Evaluating data from speed of sound experiments to discuss the range of possible speeds for speed

Worked example 1

The apparatus in the diagram is used to measure the time taken by a sound wave to travel through a copper rod. Two microphones attached at either end of the rod are set up to record signals. Signals are recorded by an audio recording app on the computer. One end of the rod is hit by a hammer and the time difference between the two signals recorded by the microphones is displayed on the software. By knowing the length of the rod we can calculate the speed of the sound wave in the copper rod. Below is a graph of the different lengths of copper rod against the time taken by the sound wave to travel through the rods.

What is the speed of sound in copper according to the graph above?

$$\text{Gradient} = \frac{\text{change in y value (time)}}{\text{change in x value (length)}} = \frac{6.5 \times 10^{-4}}{3.000} = 0.000217 = 2.17 \times 10^{-4}$$



But we need to know rod $\frac{length}{time} = \frac{s}{t}$ to give the speed of the sound wave.

So we need to do an extra calculation to get the value we want:

$$speed = \frac{1}{\text{gradient}}$$

$$v = \frac{1}{gradient} = \frac{1}{2.17 \times 10^{-4}} = 4615\ m/s$$

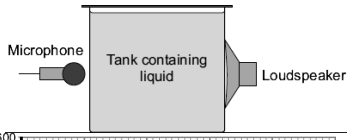
2) A student does an experiment to investigate the speed of sound in different liquids. The student uses the apparatus shown.

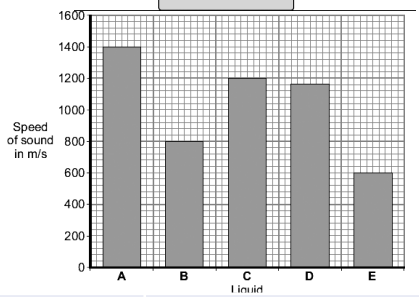
(a) A loudspeaker makes a sound wave. The sound wave travels through the liquid in the tank. The time it takes to travel this distance is used to calculate the speed of sound.

The bar chart shows the student's results.

When a sound wave with a frequency of 4800 hertz passes through one of the liquids, it has a wavelength of 0.25 m.

Calculate the speed of the wave and identify the liquid used.





Speed of wave= 4800 x 0.25= 1200(m/s) / (liquid) C

(b) The student's hypothesis was:

'There is a link between the density of a liquid and the speed of sound in the same liquid.' Use the information in the table to decide whether the student's hypothesis was completely correct or not.

Was the student's hypothesis completely correct?

speed increases as density increases
but, mercury should have a (much) greater speed given the higher density

Liquid	Density in g/cm³	Speed of sound in m/s
Ethoxyethane	0.71	985
Ethanol	0.80	1150
Kerosene	0.82	1300
Water	1.00	1500
Mercury	13.50	1450

Practice C: Evaluating data from speed of sound experiments to discuss the range of possible speeds for speed

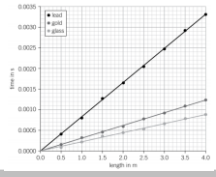
1) The graphs below show the time taken for a sound wave to travel through three different materials. Each measurement was taken following the same procedure as in the worked example. Lead, gold, and glass rods were used to record the time taken by the sound wave to travel along rods of increasing length. (a) Use the three graphs to calculate the speed of sound in lead, gold and glass respectively.

Look at the graph in the task and use the values of the speed of sound in different materials you found to answer the following questions:

2) A trusted source of information gives the speed of sound in lead as 1210m/s. Does your calculation of the speed of sound in lead from the graph in the task agree with this accepted value? Explain your answer.

3) The students investigating the speed of sound in gold declared that their value of speed of sound in gold (from the graph in the task) is accurate within a range of 25 m/s. A reliable source of information gives the value of speed of sound in gold as 3240 m/s. Are the results of the group of students in agreement with the accepted value? Explain your answer.

4) A reliable source of information gives the value of speed of sound in glass as 4540 m/s. Calculate the percentage difference between the accepted value and the value of speed of sound in glass you calculated from graph in the task. Is this difference significant?



Assessment C: Evaluating data from speed of sound experiments to discuss the range of possible speeds for speed

Sound travel faster in:

A	Vacuum	B	water	C	air	D	wall

Plenary: Write a paragraph describing some properties of sound waves in the context of this tutorial's objectives.

Tutorial 6 – Final Assignment

Your task is to research and design a concept map about waves based on what you've learned during the course. Also think about study tips for each branch of your concept map.

If you need more space for your answers please use "Notes" pages at the end of the workbook.

Tutorial 7 - Feedback

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well...	What I could have improved on...
•	•
•	•
•	•

My target for future work is...

If you need more space for your answers please use "Notes" pages at the end of the workbook.

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
•   •   •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

If you need more space for your answers please use "Notes" pages at the end of the workbook.

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Wave Properties

Key Stage 4 Programme

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