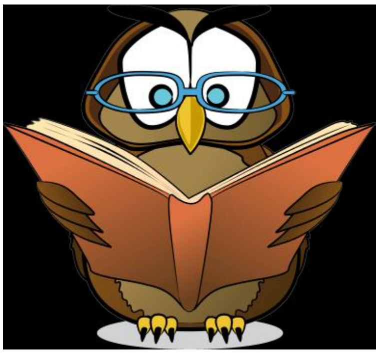


KNOWLEDGE

ST MARY'S SCIENCE DEPARTMENT:

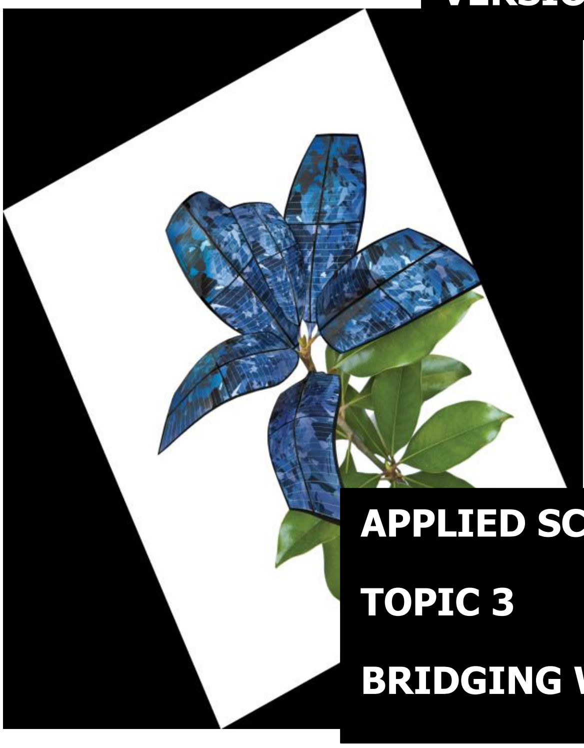
APPLIED SCIENCE

APPLIED SCIENCE BRIDGING COURSE WAVES

WEEK 3

NAME	
CLASS	

VERSION 1.1



APPLIED SCIENCE

TOPIC 3

BRIDGING WORK

THIS MUST BE BROUGHT TO LESSONS AT THE START OF YEAR 12.

WEEK 3

Contents

Overview

This bridging course will provide you with a mixture of information about Extended Certificate Applied Science and what to expect from the course, as well as key work to complete. Students who are expecting to study Extended Certificate Applied Science, and are likely to meet the entry requirements, must complete the bridging course fully and thoroughly, to the best of their ability.
You should complete all work on paper and keep it in a file, in an ordered way. You will submit it to your teacher in September.

All of the work will be reviewed, and selected work will be assessed, and you will be given feedback on it. This work will be signalled to you. If you do not have access to the internet, please contact the school and appropriate resources will be sent to you.

If you are thinking about studying Extended Certificate Applied Science, you should attempt this work to see whether or not you think studying a subject like this is right for you. If you later decide to study Extended Certificate Applied Science, you must ensure you complete this work in full.

This work should be completed after you have read and completed the Study Skills work that all of Year 12 should complete.

Introduction

Welcome to the Science Department at St Mary's Catholic School. I am delighted that you have chosen to study this qualification and hope you feel comfortable with your study environment, and that you value the support you will be given by your teaching staff. This book has been designed to inform you about your programme of study; including the ways you will be assessed and how to fully understand the grade you can achieve on completion.

BTEC courses do work differently to other subjects and you will be expected to work hard both in and out of your lesson to meet coursework deadlines. You will also be presented with many different opportunities to broaden your vocational learning, as this qualification contains a wide range of contemporary topics pertaining to Applied Science. A variety of assessment methods are used, ranging from external exams to course work. Additionally, this BTEC qualification has been designed with employers and representatives from higher education and professional bodies. In this way, the qualification is up to date and covers all of the knowledge, skills and attributes that are required across a range of technical science sectors.

I have high expectations of all students studying this BTEC qualification and all of the teachers in the department have researched and prepared in great depth to ensure that you receive quality teaching. Please use this book to get a feel of what the course is about and to ensure you are fully aware of what is expected of you. The Science Department has planned lots of innovative and creative ways to deliver the programme. This will help to promote your learning and successfully prepare you for the various assessments.

The Science Department has planned an exciting year ahead. We wish you the absolute best in your academic pathway and we look forward to working with you to achieve great success!

Course Overview

The BTEC Applied Science Extended Cerifiicate is a 2 year course comprising of 4 units.

Year 12

Unit 1 – 90 GLH

Unit 2 – 90 GLH

Year 13

Unit 3 – 120 GLH

Unit 10 – 60 GLH

GLH stands for Guideline Learning Hours, and represents the amount of time you will spend on each part of the course, and also how much each unit contributes to the final grade. You will see that Year 12 and 13 contribute equally to the final grade. In Year 12 Units, 1 and 2 are equally split and will take the same amount of time. In Year 13 Unit 3 contributes 66% of the mark and will take 66% of the time.

Each unit is awarded a grade (Distinction, Merit, Pass or Unclassified). Each grade is worth a certain number of marks.

	Unit 1*	**Unit 2**	**Unit 3***	**Unit 10**
Distinction	24	24	32	16
Merit	15	15	20	10
Pass	9	9	12	6
Unclassified	0	0	0	0

*These units are examined. For examined units marks may be awarded between these boundries. These marks are the minimum you need for a grade.

To arrive at your final grade your marks are added together. The final grade boundries are shown in the table.

Grade	**Points**	**A-Level Equivelent Grade**
Distinction*	90	A*
Distinction	74	A
Merit	52	C
Pass	36	E

To gain a pass you must achieve a pass in all units. If you fail a unit you will fail the course regardless of your score.

In units 2 and 10, a numbes of assignments contribute to each unit. Your grade for that unit will be the lowest grade you achieve. For example if you achieved a P, M, D, D in Unit 2, your grade for that unit would be a Pass.

Assessment Schedule

In Year 12 you will complete Unit 1 and Unit 2

Unit 2

This will be taught between the start of the year and Christmas.

You will complete 4 assignments

Assignment A – Titration and Colorimetry.
You will investigate methods to determine the pH of a solution. You will also use colorimetry to determine the concentration of a solution.

Assignment B – Calorimetry.
You will investigate different methods of measuring temperature. You will also use a cooling curve to determine the rate of cooling, and the melting point of different substances.

Assignment C – Chromatography.
You will use chromatography techniques to identify substances in a plant leaf extract and a mixture of amino acids.

Assignment D – Personal Review.
You will produce an assignment evaluating the personal and technical skills that you have developed over the unit.

This unit will be assessed by your teacher. All work must be submitted by the given deadline. A sample of assignments will be moderated by a Pearson moderator. Remember that you must pass the unit to pass the course, and that the grade awarded will be the lowest one you achieve.

You will be given interim and final deadlines for each assignment which must be met.

Unit 1

Unit 1 is made up of Biology, Chemistry and Physics theory, and will be taught by specialist teachers.
The level of difficulty is around that of A-level.

This will be taught between Christmas and May.

You will complete a Biology, Chemistry and Physics exam, each of which are worth 30 marks and last 40 minutes.

Biology

Chemistry

Physics

You are allowed to resit each exam once.

Aim

In this bridging course, we will outline the basic principles of the key topics covered in Unit 1.

In each topic, we will start by reviewing the understanding which you gained in GCSE Science and apply it to more advanced applications found in Extended Certificate Applied Science.

This is not a comprehensive overview of the Extended Certificate Applied Science specification, rather a taster on what is covered throughout the course.
This bridging course should give you an experience of the level you will be expected to study at, at the start of Year 12

Important

Please remember to look after your own wellbeing as you work through this bridging course.

Please take regular breaks as you go through this work.

This work should take approximately 5 hours, so should not be completed in one sitting.

Do not worry or panic if there is something challenging or which you do not understand at first. This is completely normal.

If you do not understand a concept after reviewing this work, please contact Mr. Turnbull on his school e-mail address.

WEEK 3: PHYSICS 1

RECAP TASK

In the previous week, we looked at key concepts in the Biology found in Unit 1 of Applied Science.

This included looking at the principles of cell theory, cell specialisation and gram staining.

To recap and assess your understanding, answer the following questions on these topics.

1. Draw lines to identify the cell type to which each of these organelles belongs.
Some organelles may be present in multiple cell types.

[6 Marks]

Organelle		Cell type
Nucleoid		Prokaryote
Golgi apparatus		Eukaryote (Animal)
70S ribosome		Eukaryote (Plant)
Centriole		
80S ribosome		
Tonoplast		

Reference: Zig Zag Educational Resources

2. Eukaryotic cells and prokaryotic cells have similarities and differences in their ultrastructure. Compare and contrast the ultrastructures of eukaryotic cells and prokaryotic cells.

[4 Marks]

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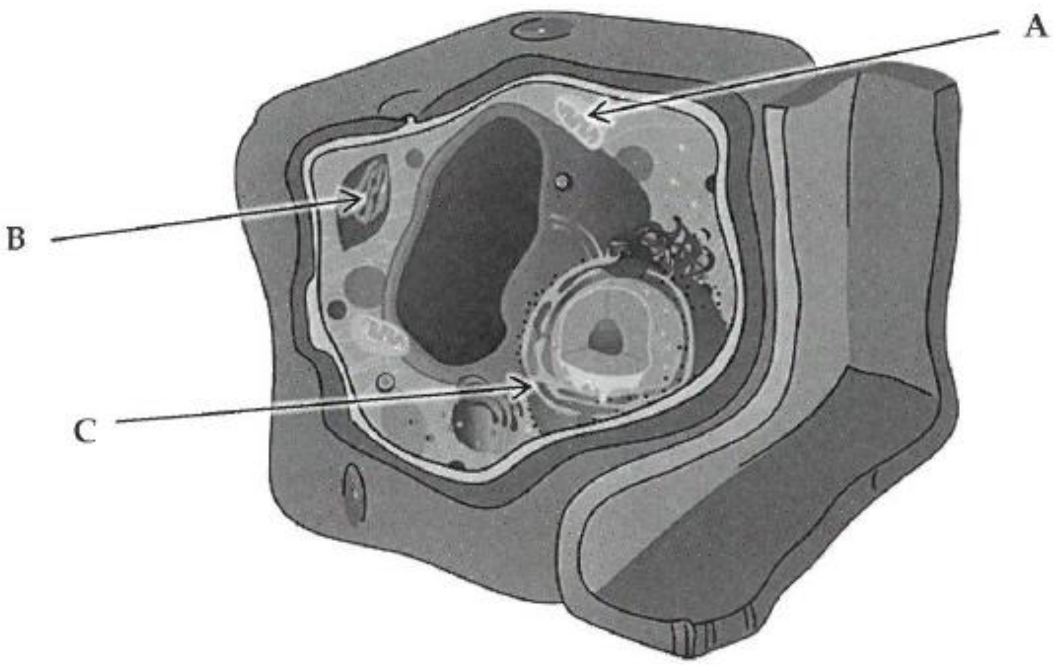
Reference: EdExcel A-Level Biology Examination Resources

3. A drawing of a plant cell is shown below



1.1 What is the function of the organelles labelled **A, B and C?**

[1 Mark]

A

....

....

B

[1 Mark]

....

....

C

[1 Mark]

....

....

Reference: Zig Zag Educational Resources

4. A microbiologist studies microscopic lifeforms such as bacteria in order to learn more about their structure and function.
4.1 Name the type of ribosome found in bacteria.

[1 Mark]

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4.2 Explain how the ultrastructure of a bacterium capsule prevents dehydration.

[2 Marks]

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A microbiologist measures an electron micrograph image of a bacterium to be 4.5 cm in length.
The magnification used to view the bacterium was 22 500×.
4.3 Calculate the actual size of the bacterium.

[3 Marks]

Show your working.

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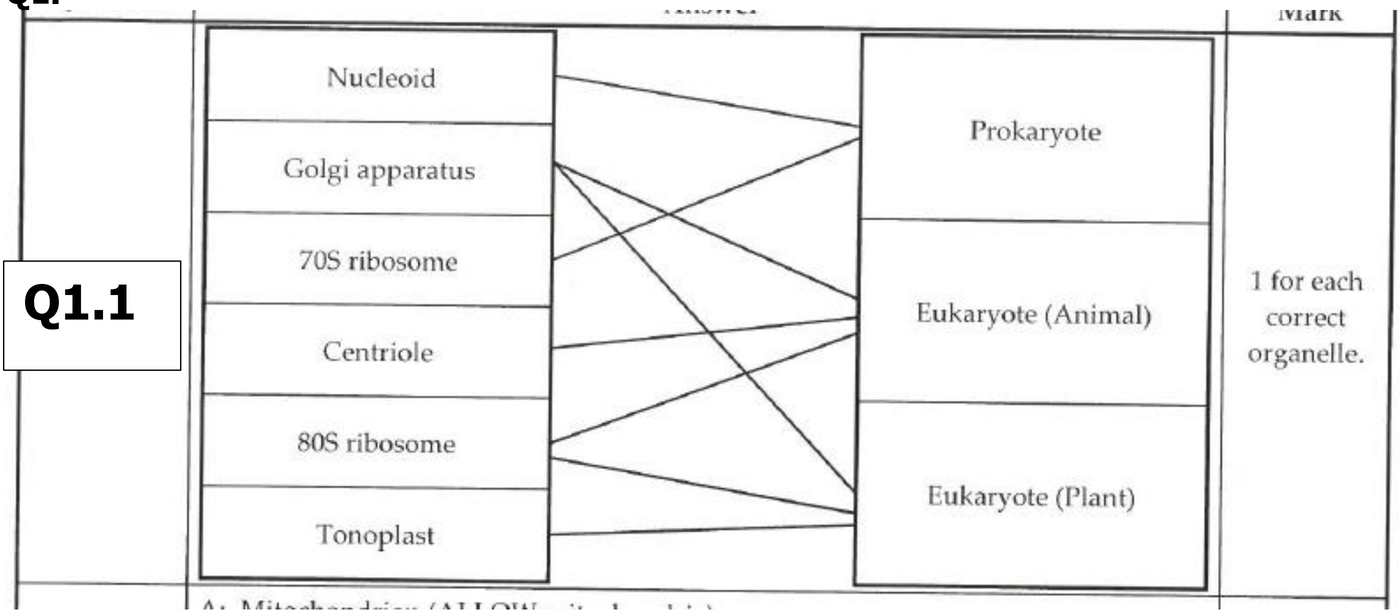
.... μm

Reference: BTEC Applied Science Specimen Materials 2

ANSWERS

Q1.

Q1.1



Q2.

Question Number	Answer	Additional Guidance	Mark
Q2.1	An answer that makes reference to the following: **Similarities** • cytoplasm **(1)** • cell membrane **(1)** • ribosomes **(1)** **Differences** • eukaryotic cells contain {Membrane-bound organelles / named example e.g. mitochondria }, prokaryotic cells do not **(1)** • eukaryotic cells have 80S ribosomes, prokaryotic cells have 70S ribosomes **(1)** • eukaryotic cells have {a nucleus / nuclear envelope }, prokaryotic cells {have a nucleoid / do not have a nucleus} **(1)** • some eukaryotic cells have a cellulose cell wall and prokaryotic cells have a {murein / peptidoglycan} cell wall **(1)**	Max of 3 marks if only differences given **ACCEPT** eukaryotic cells have larger ribosomes **ACCEPT** as comparison: prokaryotes have free-floating genetic material (in the cytoplasm)	**(4)**

Q3.

	- Adjust magnification as necessary	
Q3.1	A: Site of respiration AND produces energy for cell	1
	B: Site of photosynthesis AND produces glucose for respiration from CO_2 and water (and sunlight)	1
	C: Site of protein synthesis AND receives template from nucleus and creates the polypeptide from template	1

Q4.

Question Number	Answer	Additional Guidance	Mark
Q4.1	70S		1
Q4.2	bacterium capsules are made of polysaccharides (1) which are hydrophilic (1)		2
Q4.3	Conversion (1) 45 000 (μm) substitution **(1)** 45 000 ÷ 22 500 evaluation **(1)** 2 (μm)	2 (μm) alone gains all 3 marks ECF from first MP Conversion and substitution can be in any order	3
			Total Marks 6

TOPIC 1: WAVE PROPERTIES
SPEC CHECK

This the key specification points of the Applied Science course for this part of the topic.

Specification	Learning Outcomes	Completed?
Understand the features common to all waves and use the following terms as applied to waves:		
Periodic Time	Know that a period of a wave, vibration or oscillation is the time required to complete a full cycle, e.g. the time taken to produce a complete wave or complete one full oscillation Know that the symbol T is used to represent periodic time/time period and the unit for T is the second (s) Know that time period, T and frequency (f) are linked by the equation $T = 1/f$ Be able to substitute a value for either T or f into this equation and calculate a value of the other term Be able to use the term period T, the unit (s), for this quantity and the equation $T= 1/f$	
Speed	Know that the speed of a wave is also referred to as wave speed or wave velocity Know that wave speed is the distance in metres (m) travelled by the wave in one second (s) Be able to use information about the distance travelled by a wave in a given amount of time to calculate wave speed/velocity in ms^{-1}	
Wavelength	Know that the wavelength of a wave is the distance between two points on a wave that have the same amplitude and are moving in the same direction, e.g. between two consecutive crests or troughs	

	Be able to determine the wavelength of a wave from a graphical representation of the wave Know that wavelength is given the symbol λ (lambda) and has the unit metre (m)	
Frequency	Know that the frequency of a wave is the number of waves produced in one second (s) or the number of waves that pass a point each second Be able to use the unit hertz (Hz) or s^{-1} for frequency Be able to use information about the number of waves produced in a given amount of time to calculate frequency in hertz (Hz)	
Amplitude	Know that the amplitude of a wave is its maximum displacement from its undisturbed position Be able to determine the amplitude of a wave from a graphical representation of the wave	
Oscillation	Know that an oscillation is a regular repetitive motion, e.g. a weight on a spring bouncing up and down, a pendulum swinging backwards and forwards or a string on a guitar vibrating to and fro Understand that one complete oscillation is a vibration of a particle or wave or source through one complete cycle, e.g. for a pendulum to swing from its maximum displacement on the left to its maximum displacement on the right AND back to the maximum displacement on the left	
Graphical representation of wave features	Be able to identify and/or determine displacement, amplitude, wavelength, period and frequency of waves or oscillations from information supplied on graphs and diagrams	
Understand the difference between the two main types of wave:	Be able to describe the differences between transverse and longitudinal waves in terms of the motion of their particles	

	Understand the production of transverse and longitudinal waves using a slinky Be able to identify examples of transverse and longitudinal waves	
Transverse	Know examples of transverse waves including all electromagnetic waves, seismic S-waves and surface water waves Be able to describe the motion of the particles in a transverse wave	
Longitudinal	Know examples of longitudinal waves including sound, ultrasound and seismic P-waves Be able to describe the motion of the particles in a longitudinal wave Know the term and use the terms compression and rarefaction to describe longitudinal waves Understand the applications of longitudinal waves, to include ultra sound in diagnostic medicine and echo-location	

KEY INFORMATION

Read the information found in the key information to understand the concepts of this topic.

Waves

All waves are caused by oscillations and all transfer energy without transferring matter (there is no net transfer of matter). This means that a sound wave can transfer energy to your eardrum from a far speaker without the air particles by the speaker moving into your ear.

In a wave, the displacement oscillates. The displacement could be physical movement of a particle, or it may be the change of another quantity, for example of the electric field for electromagnetic waves.
Oscillations occur around a mean rest of the displacement – this is called the equilibrium.

We will now look at the two types of waves and how they are different

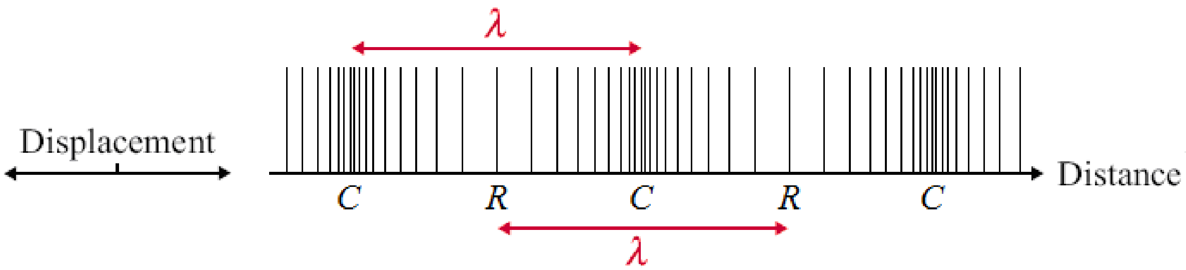
Longitudinal Waves

A longitudinal wave is a wave where the oscillations of the wave are parallel (the same direction) to the **direction of propagation (travel).**

Where the particles are close together, we call a compression (labelled **C** on the diagram) and where they are spread we call a rarefaction (labelled **R** on the diagram).

The wavelength is the distance from one compression or rarefaction to the next corresponding compression or rarefaction.

The amplitude is the maximum distance the particle moves from its equilibrium position to the right of left.



Example:
Sound waves, P- seismic waves, Water waves

For a longitudinal wave, the wavelength is the distance between compressions or rarefactions instead of between crests or troughs in transverse waves.
Microphone detects pressure variations caused by compressions and rarefactions of the air in a sound wave.

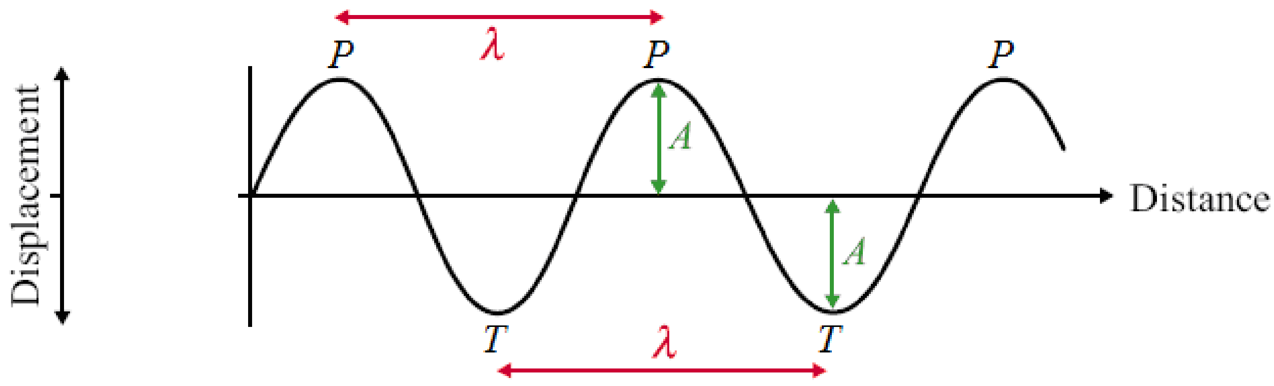
Transverse Waves

In a transverse wave the oscillations of the wave are perpendicular (right angles) **to the direction of propagation (energy transfer).**

Where the particles are displaced above the equilibrium position, we call a peak and below we call a trough.

The wavelength is the distance from one peak or trough to the corresponding peak or trough on the next wave.

The amplitude is the maximum distance the particle moves from its equilibrium position up or down.



<u>Examples</u>: Water waves, Mexican waves, S-seismic waves and waves of the EM spectrum

Electromagnetic waves are produced from varying electric and magnetic field in a material.

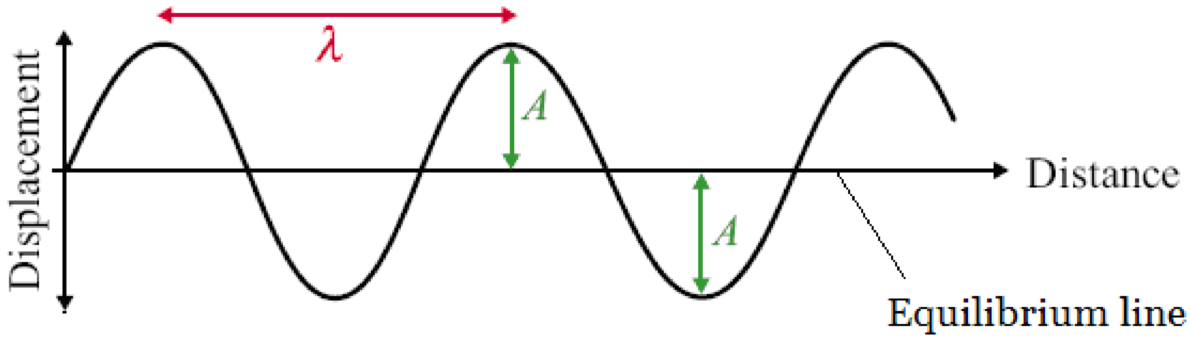
Transverse waves drawn on a displacement-time graph or displacement-distance graph look like they only vibrate in one direction (up and down). But transverse wavs actually vibrate in all directions on the plane perpendicular to the direction of motion.

Transverse waves in water or in stretched strings can be visible as travelling ripples or as standing waves.
Detectors for transverse waves must be aligned at right angles to the direction of propagation – this includes TV and radio antennas.

Wave Properties

All waves are caused by oscillations and all transfer energy without transferring matter. This means that a water wave can transfer energy to you sitting on the shore without the water particles far out to sea moving to the beach.

Here is a diagram of a wave; it is one type of wave called a transverse wave.
A wave consists of something (usually particles) oscillating from an equilibrium point. The wave can be described as progressive; this means it is moving outwards from the source.



Here are some basic measurements and characteristics or waves.

Amplitude, *A*

Amplitude is measured in metres, m

The amplitude of a wave is the maximum displacement of the particles from the equilibrium position.

Wavelength, λ

Wavelength is measured in metres, m

The wavelength of a wave is the length of one whole cycle. It can be measured between two adjacent peaks, troughs or any point on a wave and the same point one wave later.

Time Period, T

Time Period is measured in seconds, s

This is the time is takes for one complete wave to happen. It can be measured as the time it takes between two adjacent peaks, troughs or to get back to the same point on the wave.

Frequency, f

Frequency is measured in Hertz, Hz

Frequency is a measure of how often something happens, in this case how many complete waves occur in every second.
It is linked to time-period of the wave by the following equations:

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

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

REVISION SHEET

Highlight or underline the key information on the revision sheet to consolidate your understanding.

Definitions

Wave	a regular backwards and forwards motion of a medium which transfers energy from one location to another
Medium	the material a wave moves through
Oscillation	the backwards and forwards motion of a wave
Frequency	how often an oscillation of a wave occurs

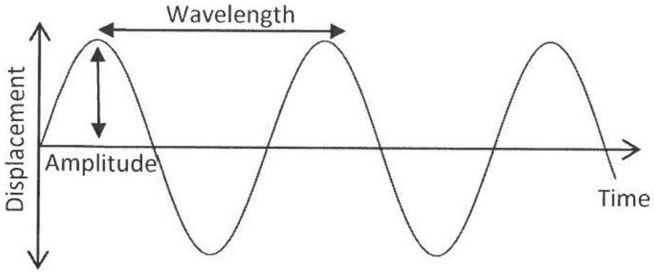
In this chapter you will learn about the different features of a wave and the different types of wave. You'll also learn about some of the applications of waves in industry, and how the features of a wave are used in these applications.

Features of waves

There are many different types of wave. Some waves, such as sound waves or the waves you'll see on the surface of water, move the particles that make up the material the wave is travelling through, called the **medium**. Other waves, such as light waves, occur in fields.

The repeated backwards and forwards motion of particles or field in a wave is called an **oscillation**. All waves have similar features and can be described in similar ways.

Waves are generally described in terms of their **displacement** of the medium or field as a function of **time**. The graph on the following page shows the displacement of a single particle as a wave passes through the medium the particle is a part of.



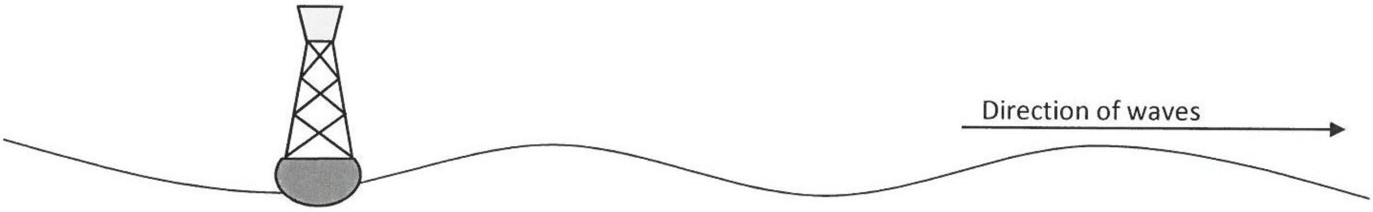
This graph shows how the particle moves with constant motion, up and down in a regular oscillation, always returning to a central point before moving in the opposite direction. This central point is the position the particle would rest in if there were no wave.

Exam tip

This is how a wave appears on an oscilloscope, or CRO (cathode-ray oscilloscope).

Oscilloscopes display the displacement of a wave (vertically) against time (horizontally).

The display settings of the oscilloscope determine what scale the displacement and time will be seen on.



The diagram above shows a buoy on the ocean. The buoy moves up and down as each wave passes it, but otherwise stays in the same position. It is only the waves themselves that move.

The amplitude of the wave is the height of the wave above the surface of the water if it were completely still.

The distance between one peak of the wave and another is the **wavelength**. The time taken for a single wavelength is the **periodic time** of the wave.

The **frequency** of the wave is the number of wavelengths that pass through a point in a second. Frequency and periodic time are linked by the equation:

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

f = frequency, in Hz
T = periodic time, in s

The maximum displacement of the particle from its central equilibrium point is the **amplitude** of the wave.

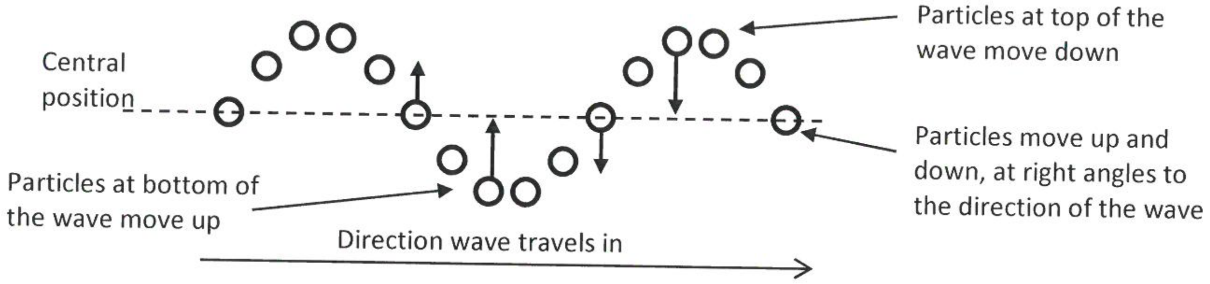
The **speed** of the wave is how fast it appears to move and how fast it transfers energy from one place to another.

Types of wave

Waves can be grouped into two main types: **transverse** and **longitudinal**.

Looking at a wave on the sea surface, it can seem like it's the water that's moving towards the shore. In fact, the water is only moving up and down, while it is the wave and the **energy** it transfers that are moving towards the shore.

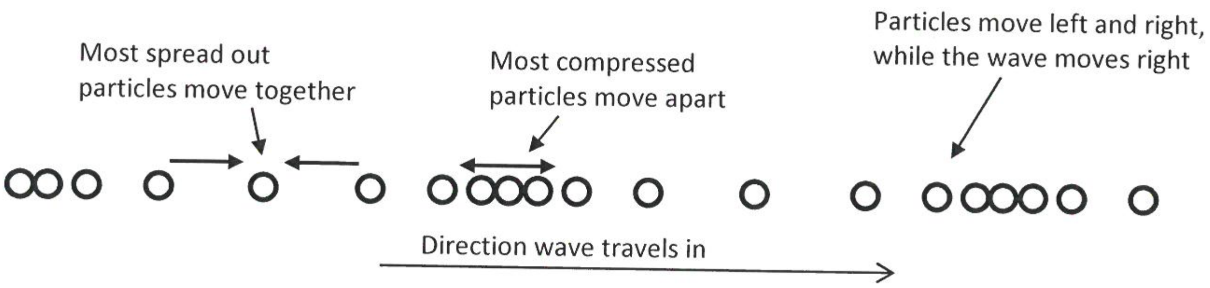
- The oscillations in a **transverse wave** are at right angles to the direction the wave is travelling in and transferring energy in.



- Examples of transverse waves include **light waves** and **water waves**.

Not all waves have particles moving in different directions to the wave. Sound waves are made of periodic pressure increases and decreases, compressing particles along the direction of propagation.

- The oscillations in a **longitudinal wave** are in the same direction as the direction the wave is travelling in and transferring energy.



- An example of a longitudinal wave is a **sound wave**.

Credit: Zig Zag Resources Revision Guide Editions

VIDEO

To watch a video looking at this concept, please scan one of the following codes with your smartphone.

SCAN ME

Note

All rights to this video belong to the creator of the video.

This external third-party content – please check the contents are appropriate.

SELF ASSESSMENT

To practice your understanding, answer the following questions.

DO NOT WORRY IF YOU STRUGGLE AT FIRST.

The answers are found after the questions.

A1. Sketch a graph of displacement against time for a wave.

A2. What is meant by each of the following terms: wavelength, frequency, amplitude, periodic time?

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A3. A wave has a frequency of 12 kHz. Calculate the periodic time of the wave.

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A4. Describe the main difference between transverse and longitudinal waves.

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A5. Give one example each of a transverse wave and a longitudinal wave.

....

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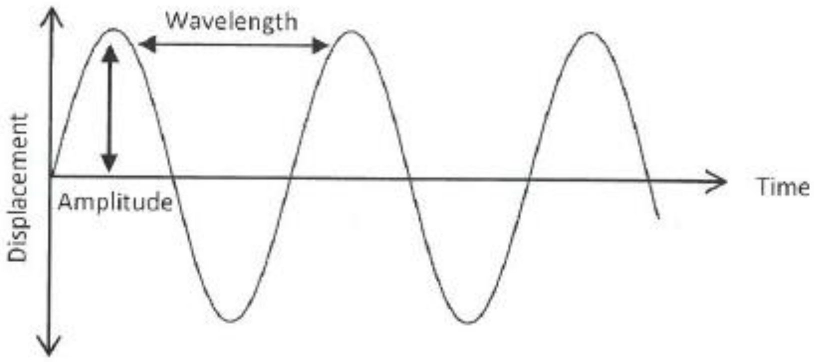
ANSWERS

A1.



A2. Wavelength is the distance between peaks on a wave.
Frequency is how many peaks of a wave pass a point in a second.
Amplitude is the maximum displacement of a particle in a wave from its equilibrium position.
Periodic time is the time between waves passing a point.

A3.

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

$$T = \frac{1}{12 \times 10^3}$$

$$T = 8.3 \times 10^{-5} \text{ s}$$

A4. Transverse waves oscillate at right angles to the direction of propagation.
Longitudinal waves oscillate in the same direction as propagation.

A5. Transverse: Light waves, electromagnetic waves, water waves, S-seismic waves.
Longitudinal: Sound waves, P-seismic waves.

KEYWORDS

To assess your understanding on this topic, complete this table with the keywords of this topic.

An oscillation which carries energy	
The time it takes for a single wave to pass a point	
The rate at which a wave travels	
The substance a wave travels through	
The smallest distance between two equal consecutive points on a wave oscillating in phase	
The number of complete oscillations per unit time	
Unit of frequency	
The maximum displacement of an oscillation measured from its rest position	
The motion of a particle that is repeated back and forth from its rest position	
Instrument which allows waves to be seen	
A wave where the displacement of the medium is perpendicular to the direction of the wave propagation	
A wave where the displacement of the medium is in the same direction as the wave propagation	
The distance travelled in a certain direction	
A unit of measurement of angles related to the circumference of a circle	
A formula which links wave speed, frequency and wavelength	
A unit of measurement of angles	

ANSWERS

Wave	An oscillation which carries energy
Periodic time	The time it takes for a single wave to pass a point
Speed	The rate at which a wave travels
Medium	The substance a wave travels through
Wavelength	The smallest distance between two equal consecutive points on a wave oscillating in phase
Frequency	The number of complete oscillations per unit time
Hertz	Unit of frequency
Amplitude	The maximum displacement of an oscillation measured from its rest position
Oscillation	The motion of a particle that is repeated back and forth from its rest position
Oscilloscope	Instrument which allows waves to be seen
Transverse	A wave where the displacement of the medium is perpendicular to the direction of the wave propagation
Longitudinal	A wave where the displacement of the medium is in the same direction as the wave propagation
Displacement	The distance travelled in a certain direction
Radian	A unit of measurement of angles related to the circumference of a circle
Wave equation	A formula which links wave speed, frequency and wavelength
Degree	A unit of measurement of angles

ASSESSMENT QUESTION

Please answer this assessment question on this topic in Applied Science.

This work will be formally assessed with feedback given.

This work will be submitted at the start of the KS5 course in Year 12.

If we require any help or you wish to receive immediate feedback, please e-mail Mr. Turnbull.

1. Oceanographers can understand the effects of coastal erosion by studying water waves in tanks. They collect information about the behaviour of a wave.
The graphs show two sets of information about the same water wave.

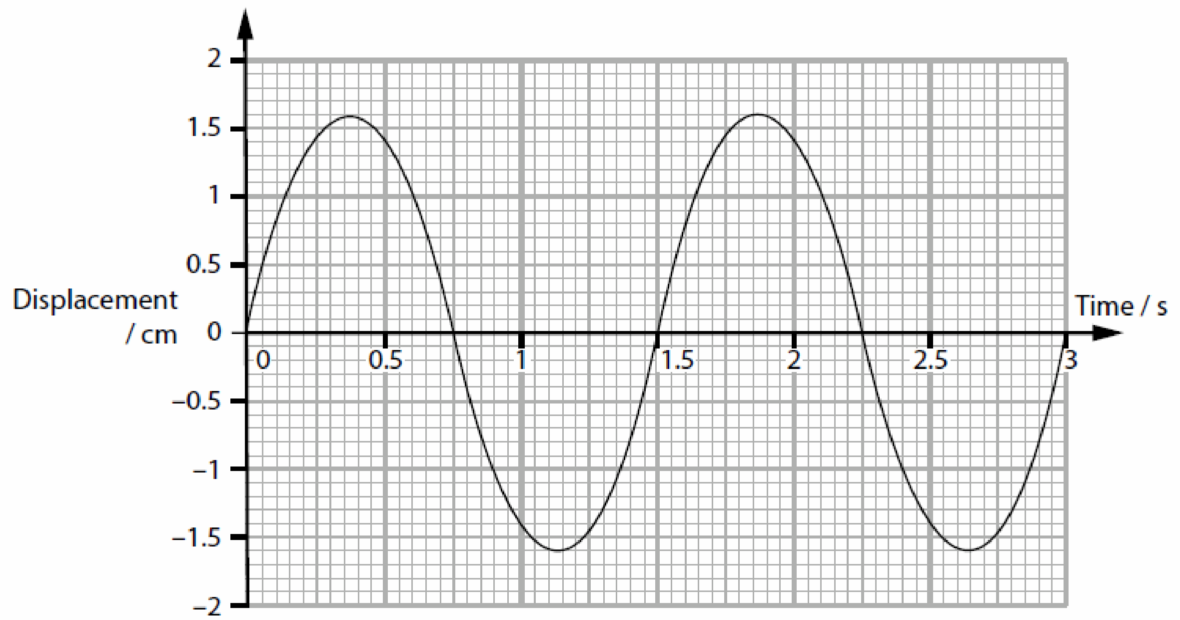


Figure 3

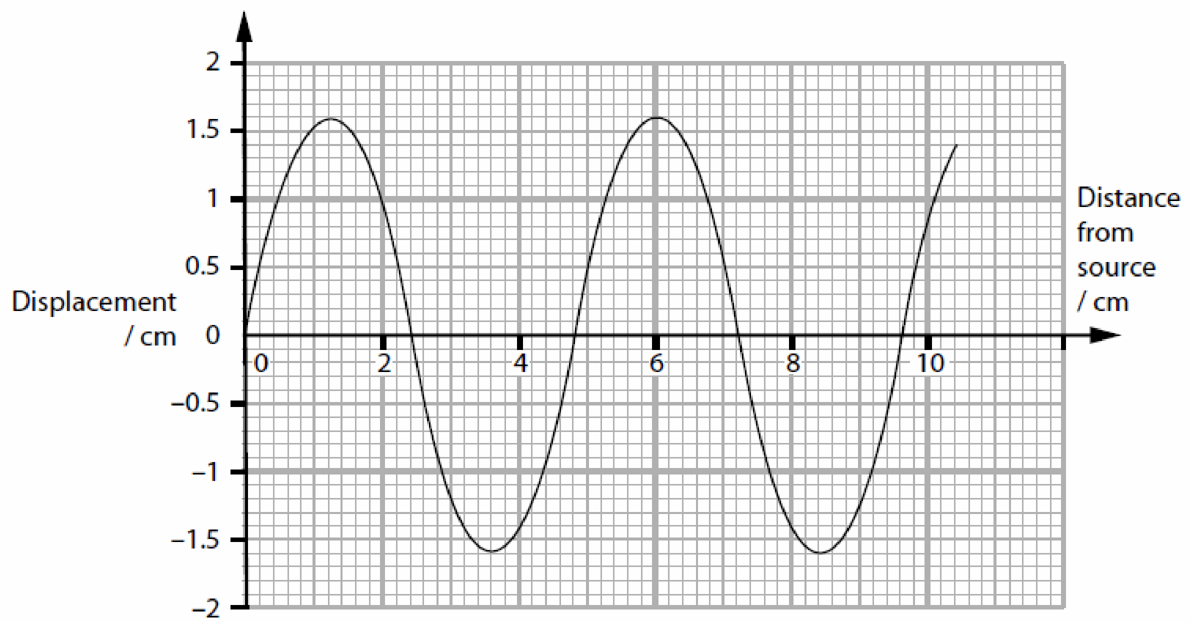


Figure 4

Use the graphs to:
1.1 Give the amplitude of the wave.

[1 mark]

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Amplitude = ... cm

1.2 Give the wavelength of the wave.

[1 mark]

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Wavelength = ... cm

1.3 Calculate the frequency of the wave.

[3 marks]

Show your working.

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Frequency = ... Hz

Reference: BTEC Applied Science Specimen Materials 2

2. Sonar is a technique in which pulses of sound reflect off an unseen object to generate an image of the object.
Sound is a longitudinal wave.
A research ship is using sonar to carry out a survey of the sea floor.
2.1 Describe what is meant by the term longitudinal wave.

[1 mark]

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2.2 The frequency of the sound wave is 12.3 kHz. The speed of sound is 330 ms^{-1}.
Calculate the wavelength of the wave.

[3 marks]

Show your working.

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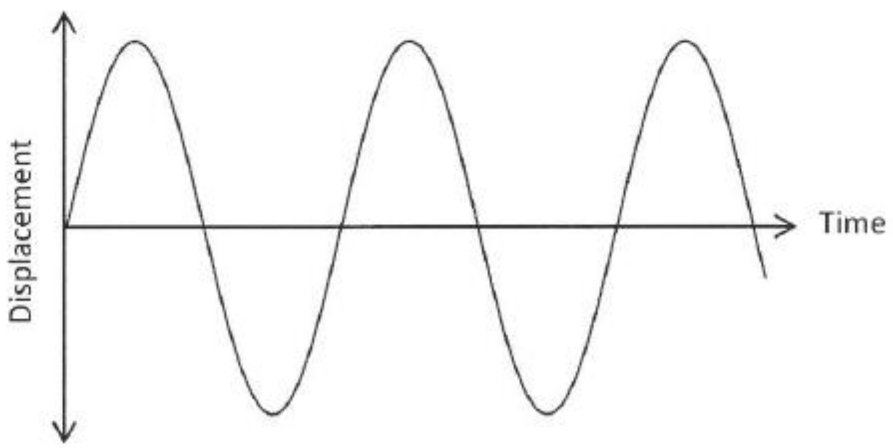
2.3 Label 'amplitude' and 'wavelength' on the CRO trace below.

[2 Marks]



2.4 The period of the wave is 91 μs.
40.5 μs after the first wave is transmitted, another wave is transmitted.
What is the phase difference between the waves.

[3 marks]

Show your working.

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Reference: Zig Zag Educational Resources

TOPIC 2: WAVE SPEED
SPEC CHECK

This the key specification points of the Applied Science course for this part of the topic.

Specification	Learning Outcomes	Completed?
Be able to use the wave equation: $v = f\lambda$	Know that v is the velocity (or speed) of the wave in ms^{-1} Know that f is the frequency of the wave in Hz (s^{-1}) Know that λ is the wavelength of the wave in m Be able to substitute values for any two of velocity, v or frequency, f or wavelength, λ into this equation and calculate a value for the other term Be able to re-arrange/transform the equation, i.e. change the subject of the equation.	

KEY INFORMATION

Read the information found in the key information to understand the concepts of this topic.

Wave Speed, c

Wave Speed is measured in metres per second, m s^{-1}

The speed at which a wave transfers energy from one place to another place varies according to the medium which it propagates (travels) through.

The speed of a wave can be calculated using the following equation:

$$c = f\lambda$$

Here *c* represents the speed of the wave, *f* the frequency and *λ* the wavelength.

For an electromagnetic wave, the speed of the wave is constant for all electromagnetic waves.
In free space (vacuum) light and other electromagnetic waves always travel at 3.0×10^8 m/s – this is represented with the symbol, c, as it is a constant value.
Nothing has ever been observed to travel faster than the speed of an electromagnetic wave in a vacuum.
In solids or liquid media, light travels at a slower speed than in a vacuum.

For mechanical waves, the speed of the wave varies depending on the mechanical wave.
The speed of sound in air is fixed for any given temperature and pressure, so you can only tune brass or woodwind instruments by altering the length of the pipe being used.
You can tune musical instruments with strings to a note without changing the length by making changes to the medium (the string) and so altering the speed of the waves.
Thicker strings with more mass per unit length, give a slower speed and a lower note.
Tighter strings with more tension give a faster speed and hence a higher note.

It is a common examination question to calculate a property with the above wave speed equation.
However, many examination questions do not give you the value of the wavelength – only a measurement along the wave.
You must work out wavelength first and then calculate either speed or frequency.

REVISION SHEET

Highlight or underline the key information on the revision sheet to consolidate your understanding.

Progressive waves

Progressive waves are waves that transfer energy and appear to move from one location to another. Sound, light and water waves are all types of progressive wave.

The speed that a progressive wave transfers energy is related to the frequency and wavelength of the wave.

$$v = f\lambda$$

FS

This means that for a given speed, a higher frequency means a lower wavelength.

v = wave speed, in m s^{-1}
f = frequency, in Hz
λ = wavelength, in m

Example

A sound wave has a wavelength of 1.40 cm.

The speed of sound in air is 340 m s^{-1}.

Calculate the frequency of the sound wave.

Find the frequency of the wave using
$v = f\lambda$

This needs rearranging for f by dividing both sides by λ

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

$$f = \frac{340}{1.40 \times 10^{-2}} = 24300 \text{ Hz} = \mathbf{24.3\ kHz}$$

Example

Convert the following units:

a) 3.2 kHz to Hz
b) 1,600,000 Hz to MHz

a) To convert kHz to Hz, multiply by 10^3, or 1,000.
$3.2 \text{ kHz} = 3.2 \times 10^3 = 3200 \text{ Hz}$

b) To convert Hz to MHz, divide by 10^6, or 1,000,000.
$1\ 600\ 000 \text{ Hz} = \frac{1\ 600\ 000}{1\ 000\ 000} = 1.6 \text{ MHz}$

Exam tip

You might be given frequencies in units such as kHz or THz, so keep an eye out for these.

1 kHz = 10^3 Hz
1 MHz = 10^6 Hz
1 GHz = 10^9 Hz
1 THz = 10^{12} Hz

Credit: Zig Zag Resources Revision Guide Editions

VIDEO

To watch a video looking at this concept, please scan one of the following codes with your smartphone.

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SELF ASSESSMENT

To practice your understanding, answer the following questions.

DO NOT WORRY IF YOU STRUGGLE AT FIRST.

The answers are found after the questions.

A1. A sound wave travels at 300 ms^{-1} and has a frequency of 15 kHz.
Calculate the wavelength of the sound wave.

[3 Marks]

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2. A sound wave travels at 300 ms^{-1} and has a frequency of 12.3 kHz.
Calculate the wavelength of the sound wave.

[3 Marks]

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ANSWERS

A1.

$v = f\lambda$

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

$\lambda = \frac{300}{15 \times 10^3}$

$\lambda = 0.02$ m

A2.

$v = f\lambda$

$\lambda = \frac{v}{f}$ [1]

$\lambda = \frac{330}{12.3 \times 10^3}$ [1]

$\lambda = 0.027$ m [1]

ASSESSMENT QUESTION

Please answer this assessment question on this topic in Applied Science.

This work will be formally assessed with feedback given.

This work will be submitted at the start of the KS5 course in Year 12.

If we require any help or you wish to receive immediate feedback, please e-mail Mr. Turnbull.

1. Various parts of the electromagnetic spectrum are used for communication.
An electromagnetic wave has a frequency of 4.5×10^9 Hz.
The speed of light is 3×10^8 m/s.
1.1 Show that the wavelength of the electromagnetic wave is approximately 7.0 cm.
Show your working.

[3 Marks]

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Wavelength = ... cm

Reference: BTEC Applied Science Specimen Materials 3

2. The red line in the hydrogen emission spectrum has a wavelength of 656 nm.
The speed of light is 3×10^8 m/s.
2.1 Calculate the frequency of the red line in the hydrogen emission spectrum.
Use the equation: $v = f\lambda$

[4 Marks]

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Frequency of the Red Line =... Hz

Reference: BTEC Applied Science January 2020 Examination

TOPIC 3: SUPERPOSITION
SPEC CHECK

This the key specification points of the Applied Science course for this part of the topic.

Specification	Learning Outcomes	Completed?
Understand concepts of displacement, coherence, path difference, phase difference, superposition as applied to diffraction gratings	Understand the principle of superposition of waves, i.e. the net displacement of the medium at any point in space or time, is simply the sum of the individual wave displacements Understand that phase difference is the amount by which one wave leads or lags (falls behind) another wave Phase difference can also be measured in degrees i.e. $1/4\lambda = \frac{1}{4} \times 360^0 = 90^0$ Understand constructive and destructive superposition (interference) Understand that constructive interference occurs when waves are in phase (e.g. a peak meets a peak and they add to give a peak with twice the amplitude) and waves destructively interfere (i.e. cancel each other out) when they are 180° out of phase. (e.g. a peak meeting a trough with the same amplitude gives zero wave displacement) Know that displacement is a vector quantity which refers to the distance moved by a wave or particle or medium from its original position Know that sources of waves are coherent if they have the same frequency and are in phase or have a constant phase difference Know that a path difference of one wavelength gives constructive interference (as a peak will always coincide with another peak and a trough will always coincide with another trough, i.e. the waves arrive in phase with each other) and a path difference of half a wavelength gives destructive interference (as a peak will always coincide with a trough, i.e. the waves have a phase difference of $\frac{1}{2}\lambda$ or 180^0)	

KEY INFORMATION

Read the information found in the key information to understand the concepts of this topic.

Phase Difference

Phase Difference is measured in radians, rad

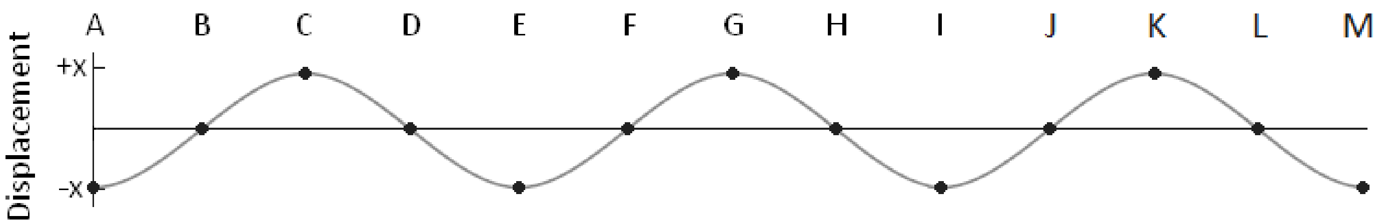
If we look at two particles a wavelength apart (such as C and G) we would see that they are oscillating in time with each other. We say that they are **completely in phase.**
A full wavelength is 360^o of phase.

`In phase' occurs at whole multiples of the wavelength ($n\lambda$).
If two points **are completely in phase**, the two points are moving at the same velocity, meaning speed and direction
Technically two waves are in phase if the waves are vibrating in the same direction, however you to be completely in phase, the wave must be vibrating in the same direction and the same speed.

Two points half a wavelength apart (such as I and K) we would see that they are always moving in opposite directions. We say that they are **completely out of phase or in anti-phase.**
`In anti-phase' occurs at whole plus half multiples ($n + ½\lambda$) of a wavelength. If two points are in anti-phase, the two points are moving with the same speed but travel in opposite directions.
If two points are out of phase, they are simply moving in opposite directions.

Phase relates the relative motion of one part of a wave compared to the relative motion of one part of another wave.

The phase difference between two points depends on what fraction of a wavelength lies between them.



	B	C	D	E	F	G	H	I	J	K	L	M
Phase Difference from A (degrees)	90	180	270	360	450	540	630	720	810	900	990	1080

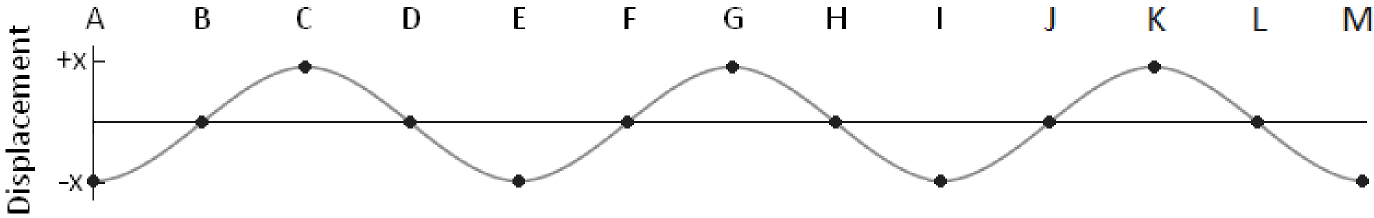
Phase difference occurs as wave energy takes time to travel. Phase difference is measured as an angle representing a fraction of a cycle.
An example of this could be a cyclist's legs as they are exactly half a cycle out of phase with one another, they have a phase difference.

Path Difference

Path Difference is measured in wavelengths, λ

If two light waves leave a bulb and hit a screen the difference in how far the waves have travelled is called the path difference. Path difference is measured in terms of wavelengths.

Path difference is the difference in metres between the lengths of two paths (the distance along the wave).

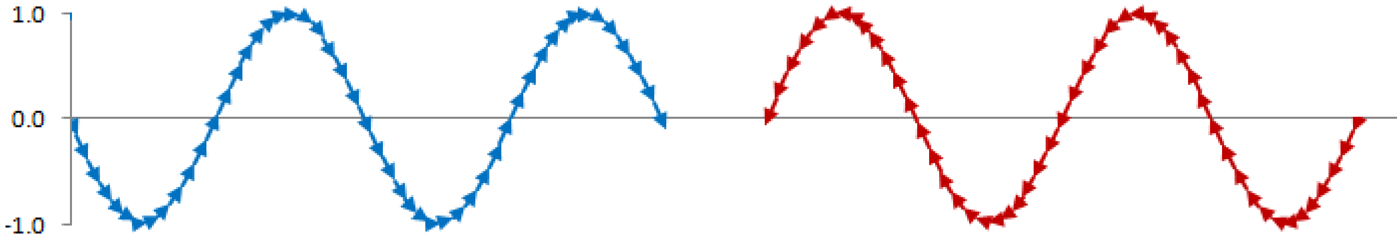


	B	C	D	E	F	G	H	I	J	K	L	M
Path Difference from A	¼λ	½λ	¾λ	1λ	1¼λ	1½λ	1¾λ	2λ	2¼λ	2½λ	2¾λ	3λ

Two waves leaving A with one making it to F and the other to J will have a path difference of 1 wavelength (1λ).

Superposition

Here are two waves that have amplitudes of 1.0 travelling in opposite directions:



Superposition is the process by which two waves combine into a single wave form when they overlap. This is called the principle of superposition.

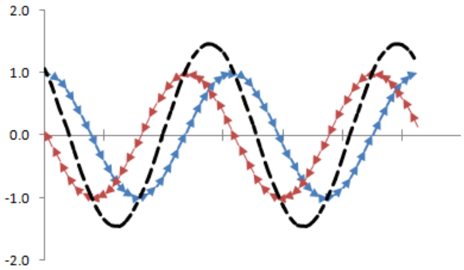
The principle of superposition states that when two waves overlap, their displacements add. **NOT THE DISTANCES BEING ADDED.**

This only happens when two waves of the same type overlap.
This only happens when it is coherent waves overlapping.
Coherent waves are waves which have the same frequency as each other and a fixed phase relastionship.

If we add these waves together the resultant depends on where the peaks of the waves are compared to each other.

If the waves undergoing superposition are vibrating in the same direction, they are said to be **IN PHASE.** If the two waves have the exact same wave pattern, they are totally in phase.
WAVES COMPLETELY IN PHASE LEAD TO CONSTRUCTIVE INTERFERENCE.

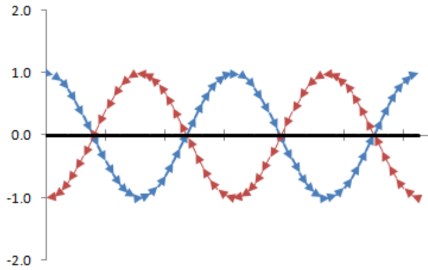
If the waves undergoing superposition are vibrating in opposite direction, they are said to be **OUT OF PHASE OR IN ANTI-PHASE.**
WAVES COMPLETELY IN ANTI-PHASE LEADS TO DESTRUCTIVE INTERFERENCE
Here are three examples of what the resultant could be: a wave with amplitude of 1.5, no resultant wave at all and a wave with amplitude of 2.0



These two waves are in phase with each other.

They superimpose to give larger peaks and larger troughs.

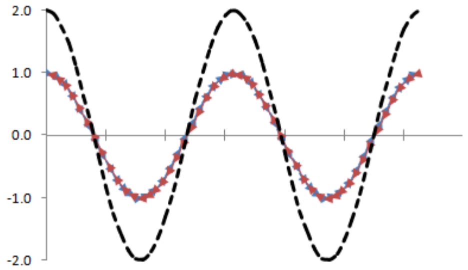
This called interference.



These two waves are completely out of phase with each other.

They superimpose to give no resultant wave at all.

This is destructive interference and a minimum.



These two waves are completely in phase with each other.

They superimpose to give the largest peaks and largest troughs possible.

This is positive interference and a maximum.

An interference pattern of superposition can be produced with two pr

Interference is a detectable pattern of different strengths (amplitudes) of wave oscillation.
This can be observed in large and small water ripples, light and dark fringes for visible light, loud and soft sounds, and good and poor receptions for mobile phones and radios.

Initially the path difference is zero/the two waves are in phase when they meet/the (resultant) displacement is a maximum.

As the waves move against relative to each other, the path difference increases and the two waves are no longer in phase, so the displacement and interference pattern decrease.

When the path difference is one half wavelength, the two are in anti-phase and the patter is at a minimum.

As the path difference continues to increase, the two waves become more in phase and the resultant interference pattern gets stronger again.

A trough and a crest will not cancel each other out completely unless they have the same magnitude and are exactly out of phase.
If two points are exactly out of phase, they are an odd integer of half cycles apart (e.g. 1 or 3) – this means they are multiples of 180 (half a cycle) not 360 (a full cycle) apart.

There are two types of interference.

Constructive Interference
This produces a wave with a higher amplitude than the original waves.

This happens when the waves are completely in phase.

This happens when the two waves have a phase difference which has a multiple of 360 (a full cycle).

Destructive Interference
This produces a wave with no amplitude.

This happens when the waves are completely out of phase (anti-phase).

This happens when the two waves have a phase difference which has a multiple of 180 (a halfl cycle).

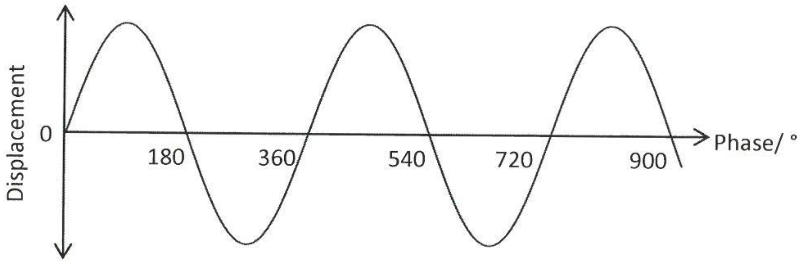
REVISION SHEET

Highlight or underline the key information on the revision sheet to consolidate your understanding.

Phase and coherence

	Definitions
Phase	how far along a single wavelength a point is on a wave
Phase difference	the difference in phase between two waves at a point
Coherent	waves with the same frequency and a constant phase difference
Superposition	the adding of two or more waves into a single resultant wave

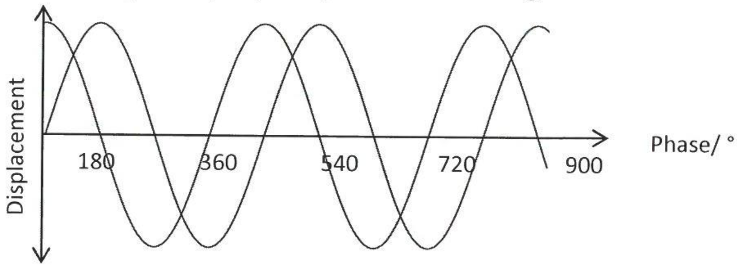
A wave can be talked about in terms of **phase**. The phase of a wave is the position of a point in time on a waveform cycle.



A single wavelength corresponds to a phase of 360°, so half a wavelength corresponds to 180°, and two wavelengths is a phase of 720°.

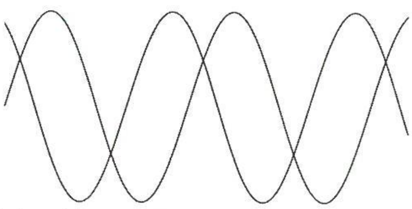
Two waves can be described in terms of **phase difference**, which describes how far apart the waves are in terms of their wavelength.

The two waves below are out of phase by 90°, or a quarter of a wavelength.

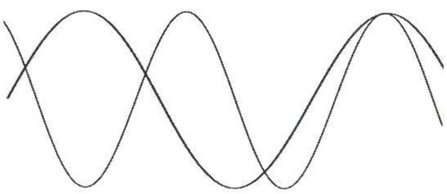


These waves are also **coherent**, which means that they have the **same frequency** and a **constant phase difference**.

The two waves below would be coherent if they travelled at the same speed giving them the same frequency.



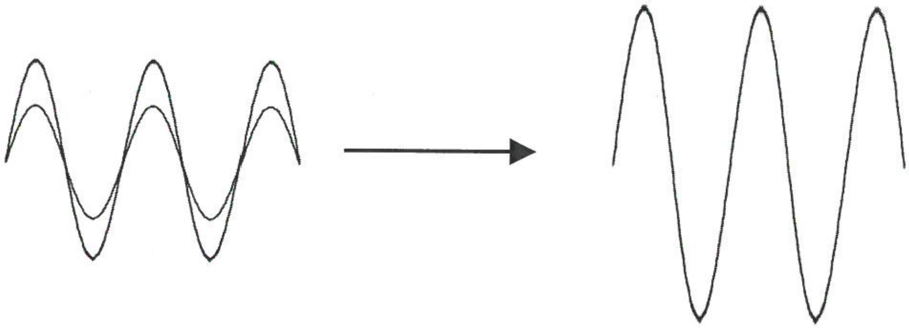
Even if the two waves below travelled at the same speed or had the same frequency, they would not be coherent as they do not have a constant phase difference.



Interference

When two waves meet, they can interfere with each other. This means that they add together into a single wave. How the two coherent waves interact depends on their phase difference. This process is called **superposition**.

If the phase difference of the two waves is 360°, or a multiple of 360°, the waves will interfere **constructively**. This means that the amplitudes of the two waves add up to a single wave that is larger than either of the two individual waves.



If the phase difference between the two waves is 180°, or a multiple of 180°, the waves will interfere **destructively**. This means that the amplitudes of the two waves add up to a zero amplitude – the wave has disappeared.

Credit: Zig Zag Resources Revision Guide Editions

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SELF ASSESSMENT

To practice your understanding, answer the following questions.

DO NOT WORRY IF YOU STRUGGLE AT FIRST.

The answers are found after the questions.

A1. Draw two waves that are out of phase by 120°.

[1 Mark]

A2. Describe how superposition occurs.

[1 Mark]

....

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A3. Two coherent waves have a phase difference of 1260°. Describe the interference of the two waves.

[1 Mark]

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A4. The period of the wave is 81μs. 40.5μs after the first wave is transmitted, another wave is transmitted. What is the phase difference between the waves?

[3 Marks]

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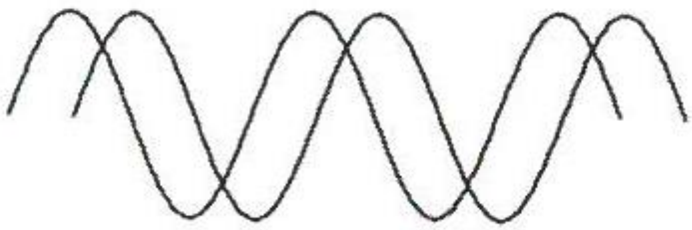
ANSWERS

A1. 120° **i**s a third of a wavelength.



A2. Two waves occupy the same point. The amplitudes of both waves are added.
For constructive superposition, the resultant amplitude increases, for destructive superposition, it decreases.

A3. 1260/180 = 7
7 is an odd number.
When the value is an odd number (it is a multiple of 180 and not 360), the waves interfere destructively.

A4.

Divide the time difference by the period of the wave to find the fraction of the period the difference accounts for

$\frac{40.5}{81} = \frac{1}{2}$ **[1]**

Multiply this by 360 for the phase difference

$phase\ difference = \frac{1}{2} \times 360$ **[1]**

$phase\ difference = 180°$ **[1]**

KEYWORDS

To assess your understanding on this topic, complete this table with the keywords of this topic.

A property used to describe two waves with the same phase difference	
The difference in distances travelled by two waves to the same point	
The difference between two particles on a wave or on different waves	
Two waves meeting at the same point and adding to create a new resultant wave	
Two waves adding to make a larger wave	
Two waves adding to make a smaller wave	
The process that causes waves to spread through a gap or around a boundary	
A device comprised of equally spaced slits to create a spectrum pattern by diffracting and interfering light sources	
Range of wavelengths of light given off by changing energy levels in an atom	
Range of wavelengths with energy levels in an atom missing	
Specific distances that electrons can exist around an atom	
A wave that has no resultant energy transfer and remains in the same position	
A wave that transfers energy and appears to move	
A point on a stationary wave where the amplitude is zero	
A point on a stationary wave with maximum possible displacement	
The enlargement of amplitude of an oscillation when the driving frequency is equal to the natural frequency	
Rate of vibration which causes resonance	
Periodic push which causes resonance	
Pulling force in a taut string	

ANSWERS

Coherence	A property used to describe two waves with the same phase difference
Path difference	The difference in distances travelled by two waves to the same point
Phase difference	The difference between two particles on a wave or on different waves
Superposition	Two waves meeting at the same point and adding to create a new resultant wave
Constructive	Two waves adding to make a larger wave
Destructive	Two waves adding to make a smaller wave
Diffraction	The process that causes waves to spread through a gap or around a boundary
Diffraction grating	A device comprised of equally spaced slits to create a spectrum pattern by diffracting and interfering light sources
Emission spectrum	Range of wavelengths of light given off by changing energy levels in an atom
Absorption spectrum	Range of wavelengths with energy levels in an atom missing
Energy level	Specific distances that electrons can exist around an atom
Stationary wave	A wave that has no resultant energy transfer and remains in the same position
Progressive wave	A wave that transfers energy and appears to move
Node	A point on a stationary wave where the amplitude is zero
Antinode	A point on a stationary wave with maximum possible displacement
Resonance	The enlargement of amplitude of an oscillation when the driving frequency is equal to the natural frequency
Natural frequency	Rate of vibration which causes resonance
Driving force	Periodic push which causes resonance
Tension	Pulling force in a taut string

ASSESSMENT QUESTION

Please answer this assessment question on this topic in Applied Science.

This work will be formally assessed with feedback given.

This work will be submitted at the start of the KS5 course in Year 12.

If we require any help or you wish to receive immediate feedback, please e-mail Mr. Turnbull.

1. When two coherent waves meet, they can interfere.
1.1 What is meant by the term coherent?

[2 Marks]

....

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....

1.2 Describe what happens during constructive and destructive interference?

[2 Marks]

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1.3 Select the option that describes the phase difference required for destructive interference.

[1 Mark]

A	Multiple of 45°
B	Multiple of 90°
C	Multiple of 180°
D	Multiple of 360°

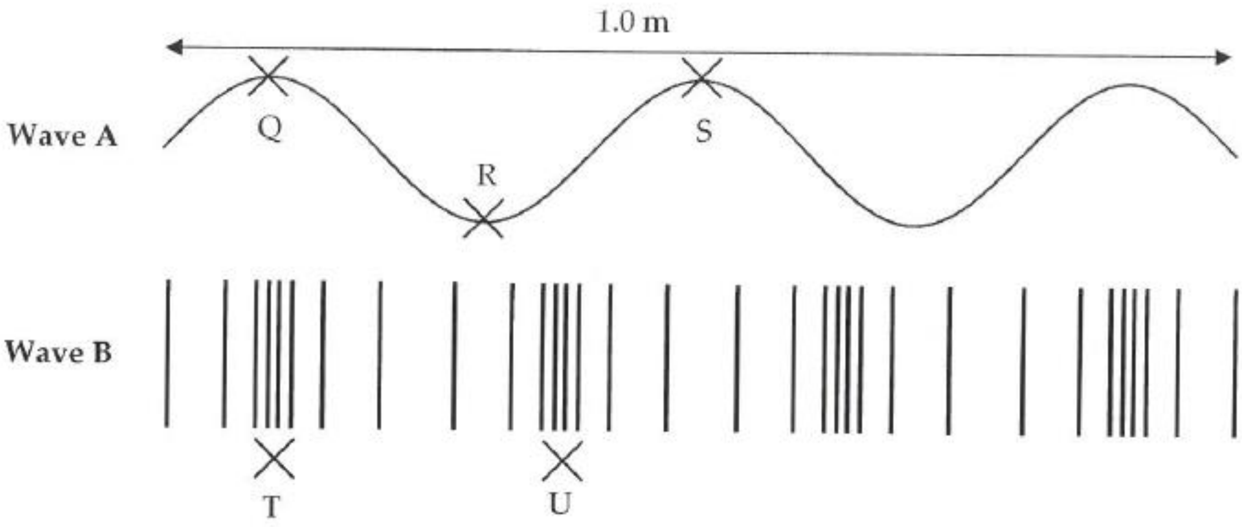
1.4 Select the option that describes the path difference required for constructive interference.

[1 Mark]

A	$n\lambda$
B	$\frac{n}{2}\lambda$
C	$\frac{n+1}{2}\lambda$
D	$(n+1)\lambda$

Reference: Zig Zag Educational Resources

2. The diagrams below show two waves, **A** and **B,** with several points marked.



1.1 Which of the waves is a transverse wave and which is a longitudinal wave?
Explain your answer.

[3 Marks]

....

....

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1.2 Give **one** example of a transverse wave and one example of a longitudinal wave.

[3 Marks]

....

....

....

1.3 State the phase difference between the points

[3 Marks]

Q and **R**

....

....

Q and **S**

....

....

T and **U**

………

………

Reference: Zig Zag Educational Resources

EXTENSION

To further extend your understanding in the Applied Science course to prepare yourself for Year 12 course, read over information on the following topics:

Diffraction Gratings

Emission Spectra of Elements

Standing Waves on Strings

Resonance

Total Internal Reflection

Fibre Optic Communication

Bluetooth Communication

Acknowledgements

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This document has been produced for the Applied Science Extended Certificate Specification.

Student Voice

If you when using this document, you believe there is an improvement to made, please state this in the space below….

Only constructive and reasoned feedback will be considered.