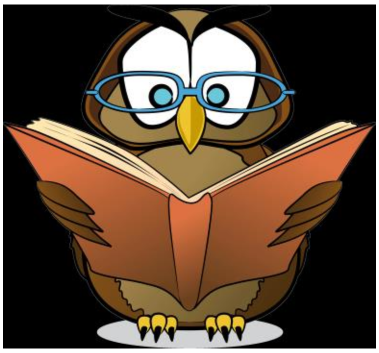


KNOWLEDGE

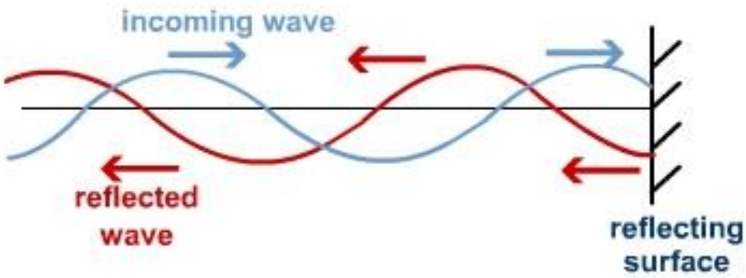
ST MARY’S SCIENCE DEPARTMENT: PHYSICS

A LEVEL PHYSICS
BRIDGING COURSE
WAVES

WEEK 2

VERSION 1.1

NAME	
PHYSICS CLASS	



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

A-LEVEL PHYSICS

TOPIC 3

BRIDGING WORK

Contents

Overview

This bridging course will provide you with a mixture of information about A-level Physics, and what to expect from the course, as well as key work to complete. Students who are expecting to study Physics at A-level, 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 Physics at A-level, 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 Physics, 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.

Course Overview

To successfully achieve a qualification in A-Level Physics students must carry out two years of studies (Year 12 and Year 13) and carry out 3 assessments at the end of the course based on the specification below.

In addition, students must carry out a list of 12 required practical activities that they must carry out. Exam questions will be based on these practicals. 6 practicals will be carried out in Year 12 and 6 practicals will be carried out in Year 13.

If successful, students will receive a practical endorsement along with their A-Level Physics qualification.

First year of A-level

1. Measurements and their errors, including use of SI units and their prefixes, limitations of physical measurement, estimation of physical quantities

2. Particles and radiation, including constituents of the atom, particle interactions, collisions of electrons with atoms.

3. Waves, including progressive waves, interference, diffraction.

4. Mechanics and energy, including projectile motion, Newton's laws of motion.

5. Electricity, including current/ voltage characteristics, circuits, electromotive force and internal resistance.

Second year of A-level

6. Further mechanics and thermal physics, including periodic motion, thermal energy transfer, and molecular kinetic theory model.

7. Fields, including Newton's law of gravitation, orbits of planets and satellites, magnetic flux density.

8. Nuclear physics, including evidence for the nucleus, radioactive decay, nuclear instability.

Plus one option from:

- Astrophysics, including classification of stars by luminosity, Doppler Effect, detection of exoplanets.
- Medical physics, including physics of vision, ECG machines, x-ray imaging.
- Engineering physics, including rotational dynamics, thermodynamics and engines.
- Turning points in physics, including discovery of the electron, Einstein's theory of special relativity.
- Electronics, including discrete semiconductor devices, data communication systems.

Assessment Schedule

To gain a qualification in A Level Physics – you must sit **three** examinations.

Paper 1	+	Paper 2	+	Paper 3
Content • Topics 1 – 5 • and periodic motion		**Content** • Topics 6 – 8		**Content** • Practical skills • Data analysis • Optional topic
Assessment • Written exam: 2 hours • 85 marks • 34% of A-level		**Assessment** • Written exam: 2 hours • 85 marks • 34% of A-level		**Assessment** • Written exam: 2 hours • 80 marks • 32% of A-level
Questions • 60 marks: a mixture of short and long answer questions • 25 marks: multiple choice questions		**Questions** • 60 marks: a mixture of short and long answer questions • 25 marks: multiple choice questions		**Questions** • 45 marks: questions on practical experiments and data analysis • 35 marks: questions on optional topic

The marks awarded on the papers will be scaled to meet the weighting of the components.

Students' final marks will be calculated by adding together the scaled marks for each component. Grade boundaries will be set using this total scaled mark. The scaling and total scaled marks are shown in the table below.

Component	Maximum raw mark	Scaling factor	Maximum scaled mark
Paper 1	85	x1	85
Paper 2	85	x1	85
Paper 3: Section A	45	x1	45
Paper 3: Section B (Astrophysics – option)	35	x1	35
Paper 3: Section B (Medical physics – option)	35	x1	35
Paper 3: Section B (Engineering physics – option)	35	x1	35
Paper 3: Section B (Turning points in physics – option)	35	x1	35
Paper 3: Section B (Electronics – option)	35	x1	35
		Total scaled mark:	250

Aim

In this bridging course, we will outline the basic principles of the four key topics covered in Year 12 Physics.

In each topic, we will start by reviewing the understanding which you gained in GCSE Physics and apply it to more advanced applications found in A-Level Physics.

This is not a comprehensive overview of the A-Level Physics 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 2: WAVES

RECAP TASK

In the previous week, we looked at key concepts in Particle Physics.

This included looking at the structure of the atom, nuclear decay and the mechanism of virtual particles to produce force interactions.

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

Q1. The element uranium has an isotope $^{237}_{92}U$.

Q1.1 Explain what is meant by an isotope.

[2 Marks]

....

....

....

Q1.2 Determine the charge in coulomb of the $^{237}_{92}U$ nucleus.

[2 Marks]

....

....

....

....

Charge = ... C

Q1.3 A positive ion of $^{237}_{92}U$ has a charge of $+4.80 \times 10^{-19}$ C.

Determine the number of electrons in the ion.

[2 Marks]

....

....

....

Number of Electrons = ...

Q1.4 $^{237}_{92}U$ decays by β^- emission to form an isotope of neptunium (Np).

Complete the equation for this decay.

[3 Marks]

$$^{237}_{92}U \rightarrow \; ^{\cdots\cdots}_{\cdots\cdots}Np + \; ^{\cdots\cdots}_{\cdots\cdots}\beta^- + \cdots\cdots$$

Reference: AQA A-Level Physics Legacy Materials

Q2.
The table below contains five statements that refer to isotopes and some radium isotopes.

	$^{223}_{88}Ra$	$^{224}_{88}Ra$	$^{225}_{88}Ra$	$^{226}_{88}Ra$
Isotope with the smallest mass number	✓			
Isotope with most neutrons in nucleus				
Isotope with nucleus which has the largest specific charge				
Isotope decays by β^- decay to form $^{225}_{89}Ac$				
Isotope decays by alpha decay to form $^{220}_{86}Rn$				

Q2.1 Complete the table by ticking **one** box in each row to identify the appropriate isotope. The first row has been completed for you.

[4 Marks]

Q2.2 An atom of one of the radium isotopes in the table is ionised so that it has a charge of $+3.2 \times 10^{-19}$ C.

State what happens in the process of ionising this radium atom.

[1 Mark]

....

....

....

....

Q2.3 The specific charge of the ion formed is 8.57×10^{5} C kg^{-1}.

Deduce which isotope in the table has been ionised. Assume that both the mass of a proton and the mass of a neutron in the nucleus is 1.66×10^{-27} kg.

[3 Marks]

....

....

....

....

Isotope = ____________________

Reference: AQA A-Level Physics Legacy Materials

Q3.1 The table below contains data for four different nuclei, **P**, **Q**, **R** and **S.**

Nuclei	**Number of Neutrons**	**Nucleon Number**
P	5	11
Q	6	11
R	8	14
S	9	17

Q3.2 Which nucleus contains the fewest protons?

[1 Mark]

Nucleus ____________________

Q3.3 Which **two** nuclei are isotopes of the same element?

[1 Mark]

Nuclei ____________________ and ____________________

Q3.4 State and explain which nucleus has the smallest specific charge.

[2 Marks]

....

....

....

....

Q3.5 Complete the following equation to represent β⁻ decay of nucleus R to form nucleus **X**.

$$^{14}_{6}R \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}X + \,^{\cdots\cdots}_{\cdots\cdots} \;\ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots$$

(3)

Q3.6 The strong nuclear force is responsible for keeping the protons and neutrons bound in a nucleus. Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons, quoting suitable values for separation.

[3 Marks]

....

....

....

....

Q3.7 Another significant interaction acts between the protons in the nucleus of an atom.
Name the interaction and name the exchange particle responsible for the interaction.

[2 Marks]

Interaction

....

Exchange particle

....

....

Reference: AQA A-Level Physics Legacy Materials

ANSWERS

Q1.1 (isotopes have)

same number of protons ✔
allow atomic mass / proton number

different numbers of neutrons ✔
allow mass number / nucleon number
TO where mix up atomic number and mass number

2

Q1.2 $92 \times 1.60 \times 10^{-19}$ ✔
correct power
penalise minus sign on answer line

$(+)1.47 \times 10^{-17}$ (C) ✔
Allow 2 sf answer 1.5×10^{-17} (C)
Pay attention to powers on answer line

2

Q1.3 $(4.8 \times 10^{-19} \div 1.60 \times 10^{-19} =)\ 3$ ✔
or
$1.47 \times 10^{-17} - 4.8 \times 10^{-19}$ (= Q) (ecf)

(92 − 3 =) 89 ✔
95 on answer line 1 mark

$$\left(n = \frac{Q}{e} = \frac{1.47 \times 10^{-17} - 4.8 \times 10^{-19}}{1.6 \times 10^{-19}}\right) = 89 \text{ (ecf)}$$

Integer value for n

2

Q1.4 $^{237}_{92}\text{U} \rightarrow ^{237}_{93}\text{Np} + ^{0}_{-1}\beta + \overline{v_{(e)}}$ ✔ ✔ ✔
one mark for:
- *both numbers correct on Np*
- *both numbers correct on β^-*
- *correct symbol for (electron) antineutrino*

3

[9]

Q2.1

	$^{223}_{88}Ra$	$^{224}_{88}Ra$	$^{225}_{88}Ra$	$^{226}_{88}Ra$
Isotope with smallest mass number	(✓)			
Isotope with most neutrons in nucleus				✓
Isotope with nucleus that has highest specific charge	✓			
Isotope that decays by β^- decay to form $^{225}_{89}Ac$			✓	
Isotope that decays by alpha decay to form $^{220}_{86}Rn$		✓		

one mark for each correct row (ignore first row as already ticked)
allow cross instead of tick and ignore any crossed out ticks
if more than one tick in a row then no mark

4

Q2.2 the atom has lost <u>two electrons</u>✓

1
4

Q2.3 (*use of specific charge = charge ÷ mass*)
mass = $3.2 \times 10^{-19} \div 8.57 \times 10^{5} = 3.734 \times 10^{-25}$ (kg)
mass number = $3.734 \times 10^{-25} \div 1.66 \times 10^{-27}$ ✓(= 225)
hence $^{225}_{(88)}Ra$ OR 225✓✓
OR
calculate specific charge for each isotope✓
hence $^{225}_{(88)}Ra$ OR 225✓✓
ignore any reference to electrons
first mark for deduction
bald correct answer scores 2 marks
don't need radium symbol or 88
wrong answer scores zero

3

[8]

Q3.1 Q / boron / B ✓

1

Q3.2 P and R / R and P ✓

1

Q3.3 R ✓

6 / 14 is smallest fraction / 0.43 smallest ratio / 4.13 × 10^7 C / kg ✓

Cannot get second mark if not awarded first mark

2

Q3.4 $^{14}_{6}R \rightarrow ^{14}_{7}X + ^{0}_{-1}e + \overline{\nu_{(e)}}$ ✓✓✓

One mark for each correct symbol on rhs

Ignore –ve sign on e.

Can have neutrino with 0,0 on answer lines

Ignore any subscript on neutrino

3

Q3.5 repulsive below / at 0.5 fm (accept any value less or equal to 1 fm) ✓

attractive up to / at 3 fm (accept any value between 0.5 and 10 fm) ✓

short range OR becomes zero OR no effect ✓

Can get marks from labelled graph

Don't accept negligible for 3rd mark

3

Q3.6 interaction: electromagnetic / em ✓

(virtual) photon/ γ ✓

2

[12]

Definition List

Definitions you must learn for this module are:

Key Word	Definition
Amplitude	The maximum displacement of a vibrating particle; for a transverse wave, it is the distance from the middle to the peak of the wave.
Antinode	The fixed point in a stationary wave pattern where the amplitude is a maximum.
Coherent	When two sources of waves have a constant phase difference and the same frequency.
Cycle	The interval of a vibrating particle (or a wave) from a certain displacement and velocity to the next time the particle (or the next particle) that has the same displacement and velocity.
First harmonic	The pattern of stationary waves on a string when it vibrates at its lowest possible frequency. Each further harmonic is a multiple of the first harmonic.
Frequency	The number of complete cycles of a wave that pass a point each second.
Interference	The formation of points of cancellation and reinforcement where two coherent waves pass through each other.
Longitudinal waves	Waves with a direction of vibration parallel to the direction of propagation of the waves.
Path difference	The difference in distances from two coherent sources to an interference fringe.
Period	The time for one complete cycle of a wave to pass a point.
Phase difference	The fraction of a cycle between the vibrations of two vibrating particles, measured either in radians or degrees.
Progressive waves	Waves which travel through a substance or through space if electromagnetic. It is a transfer of energy.
Stationary waves	Wave patterns with nodes and antinodes formed when two or more progressive waves of the same frequency and amplitude pass through each other. It is a display of energy.
Superposition	Effect of two waves adding displacements together when they meet.
Transverse waves	Waves with a direction of vibration perpendicular to the direction of propagation of the waves.
Wavefront	Lines of constant phase (e.g. wave crests) on a wave.
Wavelength	The shortest distance between two consecutive points on a wave which are in phase.

IMPORTANT

A video of Mr. Turnbull going through this book can be found here.

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TOPIC: 3.3.1.1 Progressive Waves
SPEC CHECK

Specification	Completed?
Oscillation of the particles of the medium.	
amplitude, frequency, wavelength, speed, phase, phase difference, $c = f\lambda$, $f = 1/T$	
Phase difference may be measured as angles (radians and degrees) or as fractions of a cycle.	
Laboratory experiment to determine the speed of sound in free air using direct timing or standing waves with a graphical analysis.	

Student Checklist
Complete the following before attempting any work on this section.

Have I…….	Yes or No?
Read through the notes of this section?	
Highlighted/underlined the key concepts of this section?	
Made my own notes based on the notes of this section?	

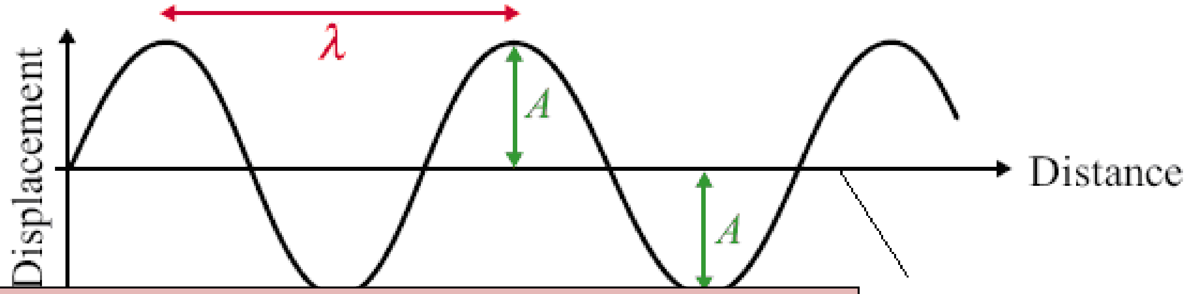
Complete the above checklist with the notes of each section before you attempt to answer any questions on this section of work.

Prior Knowledge Link
This is a topic found in a previous GCSE module - **Waves**

Waves

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.



Study Tip

One oscillation is a section o fa wave from crest to crest, or trough to trough.

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

Exam Tip

It is a common examination question to ask you to define the frequency of a wave.

number of (complete) waves (passing a point) in 1 second (1 mark)

number of waves / time (for the waves to pass a point) (1 mark)

(complete number of) oscillations \ vibrations per second (1 mark)

Wave Speed, c

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

Prior Knowledge Link
This is a topic found in a previous GCSE module - **Waves**

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. For mechanical waves, the speed of the wave varies depending on the mechanical wave.

Exam Tip

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.

Study Tip

This equation is found in the data booklet.

Learn the key terms of each part of the equation.

Learn the SI units of each term in the equation.

Study Tip

Remember that 1Hz = 1 s^{-1}

This will help you remember the frequency equation.

Study Tip

You are not measuring how fast a physical point moves, you are measuring how fast a point on the wave pattern moves.

Study Tip

Displacement is a vector, so it has a direction and magnitude.

If a point has moved below its undisturbed position, it will have a negative displacement.

Study Tip

Amplitude can either be measured at a crest or a trough.

It does not have a direction, only a magnitude.

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° of phase.

> **Exam Tip**
>
> You can convert between radians and degrees for an angular measurement
>
> 360° = 2Π radians 180° = Π radians 90° = Π/2 radians 1° = 0.017 radians

`In phase' occurs at whole multiples of the wavelength (nλ).

If two points **are completely in phase**, the two points are moving at the same velocity, meaning speed and direction

> **Exam Tip**
>
> 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.

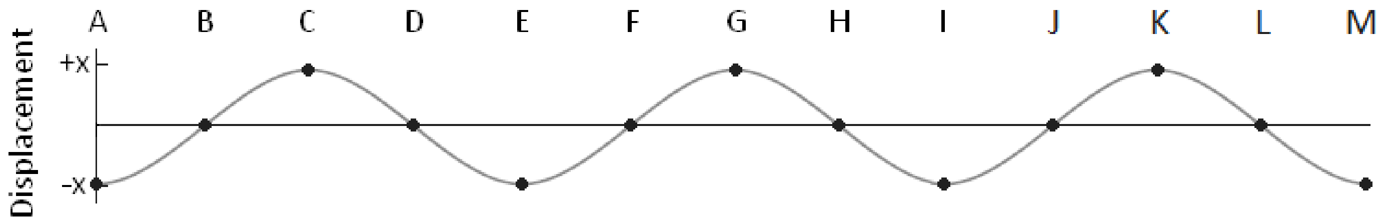
Two points half a wavelength apart (such as I and K) we would see that they are always moving in opposite directions. We say that they are **completely out of phase or in anti-phase.**

`In anti-phase' occurs at whole plus half multiples (n + ½λ) 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, the particles 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** (radians)	½п	1п	1½п	2п	2½п	3п	3½п	4п	4½п	5п	5½п	6п
Phase Difference from **A** (degrees)	90	180	270	360	450	540	630	720	810	900	990	1080

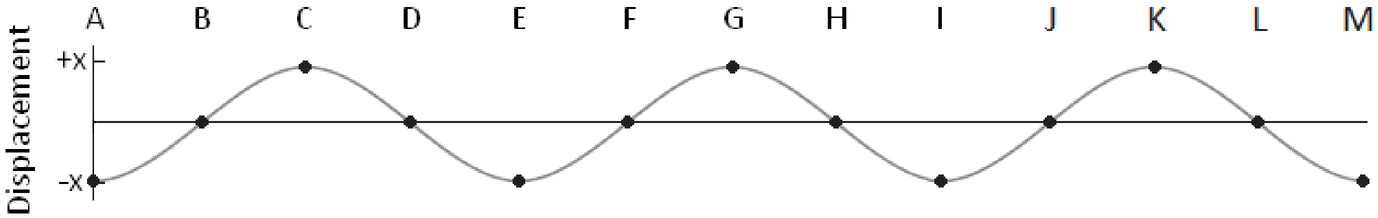
> **Exam Tip**
>
> It is a common question to ask for you to identify the phase difference between two points on a wave.
>
> Remember one whole wavelength = 2Π radians or 360 degrees then work from there.
>
> You can an answer for phase difference in radians or degrees, however, remember that phase difference is always an angular measurement.

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 before hitting the scren 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).

Exam Tip

Do not confuse path difference and phase difference in examination questions.

A path difference should be given in metres or in a multiple of the wavelength.

A phase difference should be given in degrees or radians (in a multiple of Π).

Study Tip

Displacement is a vector, so it has a direction and a magnitude.

If a point has move below its undisturbed position, it will have a negative displacement.

Study Tip

Waves with different frequencies and wavelengths can have quite different properties.

Study Tip

Amplitude can be measured in either at a crest or a trough.

It does not have a direction, only a magnitude.

Study Tip

Phase difference is the difference between two identical points (e.g. the point where the displacement is at a maximum) on two waves.

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REVISION SHEET

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

A ***Wave*** *Transfers* ***Energy*** *Away From Its* ***Source***

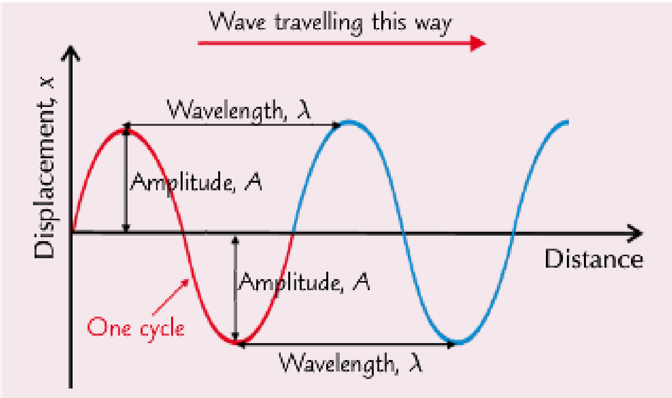
A **progressive** (moving) wave carries **energy** from one place to another **without transferring any material**. The transfer of energy is in the **same direction** as the wave is **travelling**. Here are some ways you can tell waves carry energy:

1) Electromagnetic waves cause things to **heat up**.
2) **X-rays** and **gamma rays** knock electrons out of their orbits, causing **ionisation**.
3) Loud **sounds** cause large oscillations in air particles which can make things **vibrate**.
4) **Wave power** can be used to **generate electricity**.

Since waves carry energy away, the **source** of the wave **loses energy**.

You Need to Know These ***Bits*** *of a* ***Wave***

1) **Displacement**, x, metres — how far a **point** on the wave has **moved** from its **undisturbed position**.
2) **Amplitude**, A, metres — the **maximum magnitude** of the **displacement**.
3) **Wavelength**, λ, metres — the **length** of **one whole wave cycle**, e.g. from **crest** to **crest** or **trough** to **trough**.



4) **Period**, T, seconds — the **time taken** for a **whole cycle** (vibration) to complete.
5) **Frequency**, f, hertz — the **number** of **cycles** (vibrations) **per second** passing a given **point**.
6) **Phase** — a measurement of the **position** of a certain **point** along the wave cycle.
7) **Phase difference** — the amount one wave lags behind another.

Phase and phase difference are measured in angles (in degrees or radians). See p.74.

The ***Frequency*** *is the* ***Inverse*** *of the* ***Period***

$$\text{Frequency} = \frac{1}{\text{Period}} \qquad f = \frac{1}{T}$$

It's that simple.
Get the **units** straight: **1 Hz = 1 s^{-1}**.

The ***Wave Equation*** *Links* ***Wave Speed, Frequency*** *and* ***Wavelength***

1) **Wave speed** can be measured just like the speed of anything else:

$$\text{Wave speed } (v) = \frac{\text{Distance } (d)}{\text{Time } (t)}$$

2) You can use this equation to derive the **wave equation** (but thankfully you don't have to do that, you just need to be able to use it).

$$\text{Speed of wave } (v) = \text{frequency } (f) \times \text{wavelength } (\lambda) \qquad v = f\lambda$$

Remember, you're not measuring how fast a physical point (like one molecule of rope) moves. You're measuring how fast a point on the **wave pattern** moves.

Credit: CGP Revision Guide Editions

REVIEW QUESTIONS

To assess your understanding, answer the following questions on this topic.

A1. How does a wave transfer energy through a medium?

[1 Mark]

....

....

A2. Can displacement or amplitude take a negative value measurement?

[1 Mark]

....

....

A3. What units is displacement measured in?

[1 Mark]

....

....

A4. What units is amplitude measured in?

[1 Mark]

....

....

A5. What units is frequency measured in?

[1 Mark]

....

....

A6. How would you calculate the frequency of a wave given its period?

[1 Mark]

....

....

The answers to the review questions are found on the next page.

REVIEW ANSWERS

A1. By causing the particles in a medium to oscillate.

A2. Displacement can take a negative value.

A3. Metres

A4. Metres

A5. Hertz

A6. Frequency = 1/ Time Period

SELF ASSESSMENT

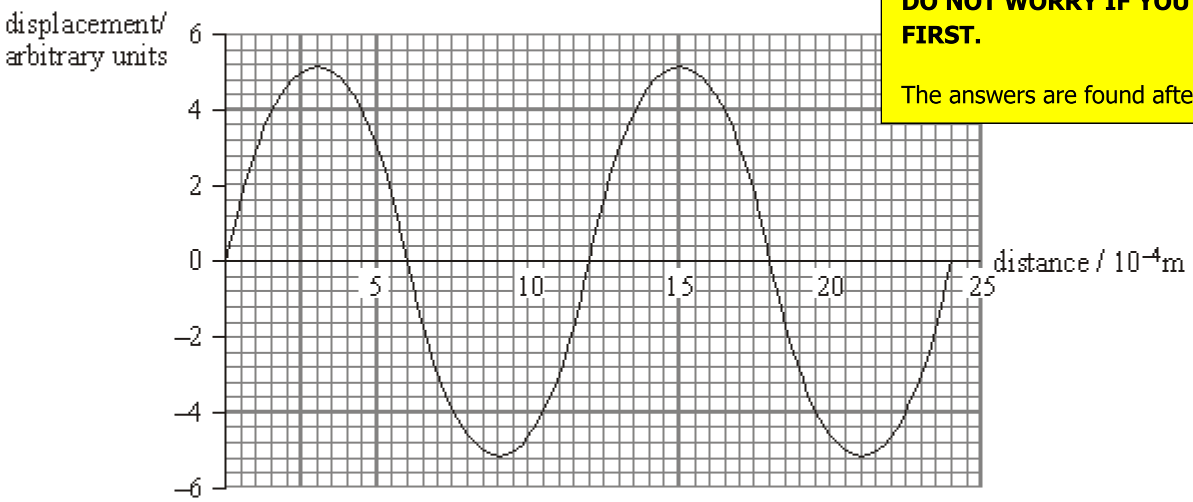
1. Figure 1 shows the displacement of particles in an ultrasound wave at different distances from the source at a particular time. The wave travels at 3200 m s^{-1}.

To practice your understanding, answer the following questions.

DO NOT WORRY IF YOU STRUGGLE AT FIRST.

The answers are found after the questions.

Figure 1



1.1 Use the graph to find the wavelength of the wave in **Figure 1**.

[1 Mark]

....

....

....

....

Wavelength ....

1.2 Calculate the frequency of the ultrasound wave.

[2 Marks]

....

....

....

....

Frequency ....

One industrial use for ultrasound waves is to detect flaws inside a metal block.

Figure 2a shows the arrangement in which the waves are fired downwards in short pulses from a transmitter.

Figure 2b shows the amplitudes of the initial pulse and the reflected signals recorded by the receiver.

You may assume that there is no reflected pulse received from the upper surface of the block.

Figure 2a

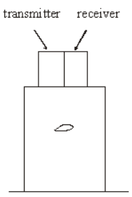
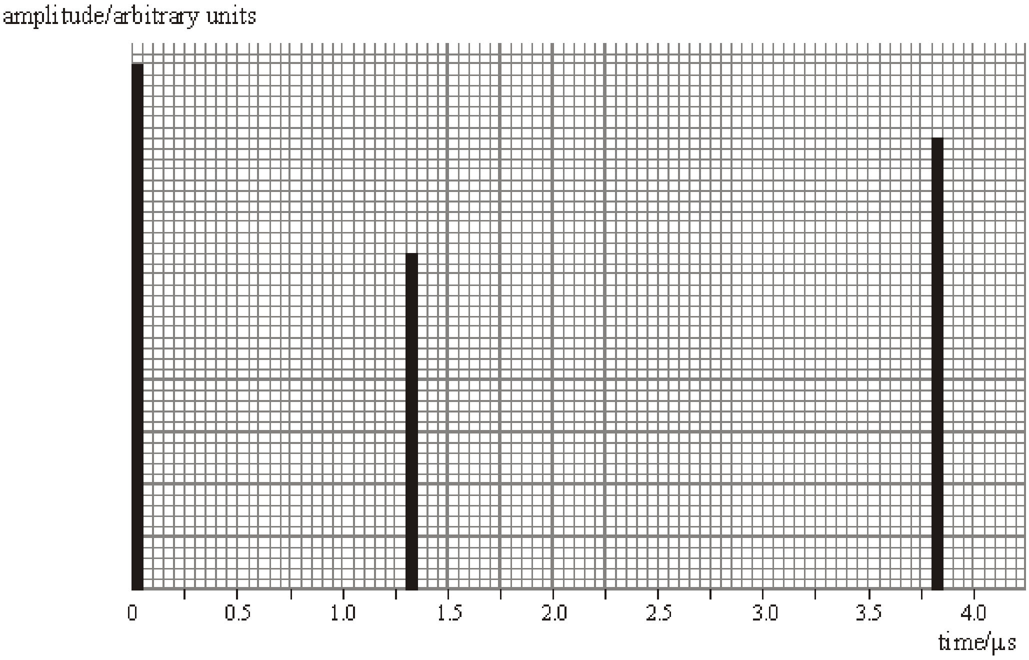


Figure 2b



1.3 The ultrasound wave travels at 3200 m s^{-1}. Use data from **Figure 2b** to calculate the distance of the flaw below the top of the block.

[3 Marks]

....

....

....

....

Distance ....

Reference: AQA Legacy B Examination Material

Q2. Figure 1 shows three particles in a medium that is transmitting a sound wave. Particles **A** and **C** are separated by one wavelength and particle **B** is half way between them when no sound is being transmitted.

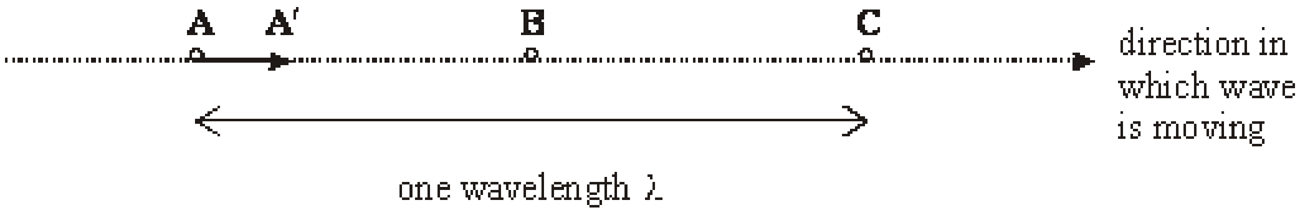


Figure 1

2.1 Name the type of wave that is involved in the transmission of this sound.

[1 Mark]

....

2.2 At one instant particle **A** is displaced to the point **A'** indicated by the tip of the arrow in **Figure 1**. Show on **Figure 1** the displacements of particles **B** and **C** at the same instant. Label the position **B'** and **C'** respectively.

[1 Mark]

2.3 Explain briefly how energy is transmitted in this sound wave.

[2 Marks]

....

....

....

....

Reference: AQA Legacy B Examination Material

ANSWERS

M1.1 wavelength read-off = 1.2 mm

B1

M1.2 $3200/1.2 \times 10^{-3}$ ecf from **M1.1**

C1
3

2.7 MHz

A1

M1.3 read-off correct 1.3 μs

C1

factor of two correct

C1
3

= 2.1×10^{-3} m [2.08] c.a.o.

A1
[6]

M2.1 longitudinal wave

B1
1

M2.2 arrows showing B displaced to the left and C to the right

B1
1

M2.3 particles in the transmitting medium are made to vibrate/given energy

B1

or
mention of a compression/region of increased pressure (or rarefaction) cause nearby particles to vibrate/have energy/move

B1

or
the compression produces a compression further along (the medium)

2
[4]

ASSESSMENT QUESTION

Please answer this assessment question on this topic in Physics.

This work will be formally assessed with feedback given.

This work will be submitted at the start of the A-Level course in Year 12.

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

Q3. Figure 1 shows how the displacement *s* of the particles in a medium carrying a pulse of ultrasound varies with distance *d* along the medium at one instant.

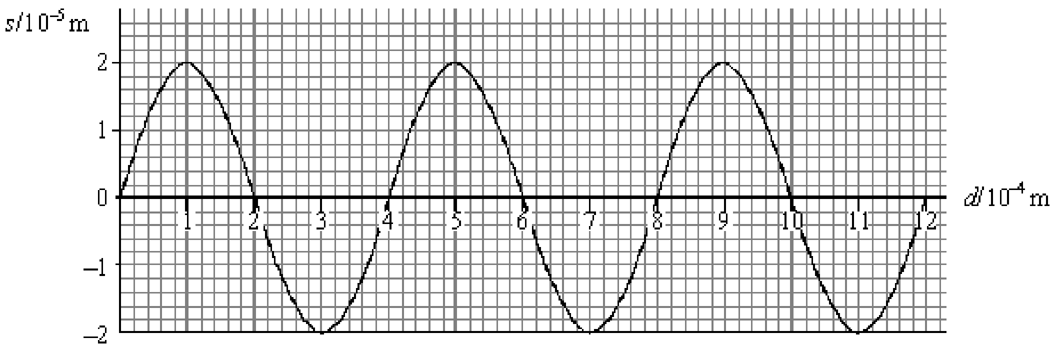


Figure 1

3.1 State the amplitude of the wave.

[1 Mark]

....

3.2 The speed of the wave is 1200 m s^{-1}. Calculate the frequency of oscillation of the particles of the medium when the ultrasound wave is travelling through it.

[3 Marks]

....

....

....

Frequency of Oscillation .... Hz

An ultrasound transmitter is placed directly on the skin of a patient. **Figure 2** shows the amplitudes of the transmitted pulse and the pulse received after reflection by an organ in the body. amplitude

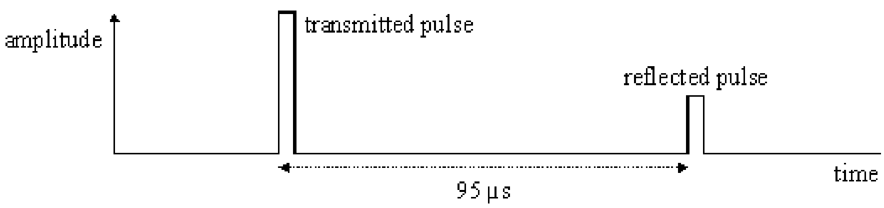


Figure 2

3.3 Give **two** possible reasons why the amplitude of the received pulse is lower than that which is transmitted.

[2 Marks]

Reason 1

....

....

Reason 2

....

....

3.4 The speed of ultrasound in body tissue is 1200 m s^{-1}.

Calculate the depth of the reflecting surface below the skin.

[2 Marks]

....

....

....

....

Depth of Reflecting Surface .... m

Reference: AQA Legacy B Examination Material

TOPIC: 3.3.1.2 Longitudinal and Transverse Waves
SPEC CHECK

Specification	Completed?
Nature of longitudinal and transverse waves.	
Examples to include: sound, electromagnetic waves, and waves on a string.	
Students will be expected to know the direction of displacement of particles/fields relative to the direction of energy propagation and that all electromagnetic waves travel at the same speed in a vacuum.	
Polarisation as evidence for the nature of transverse waves.	
Applications of polarisers to include Polaroid material and the alignment of aerials for transmission and reception.	
Students can investigate the factors that determine the speed of a water wave.	

Student Checklist
Complete the following before attempting any work on this section.

Have I…….	Yes or No?
Read through the notes of this section?	
Highlighted/underlined the key concepts of this section?	
Made my own notes based on the notes of this section?	

Complete the above checklist with the notes of each section before you attempt to answer any questions on this section of work.

Waves

Prior Knowledge Link
This is a topic found in a previous GCSE module **- Waves**

All waves are caused by oscillations and all transfer energy without transferring 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.

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

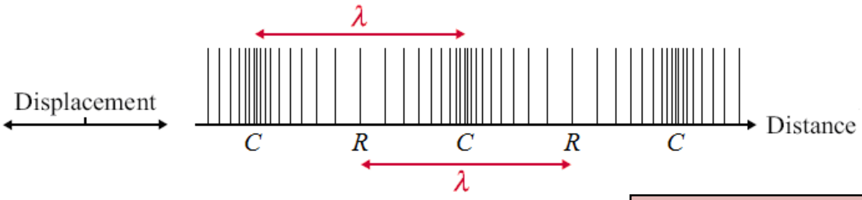
Longitudinal Waves

A longitudinal wave is a wave where the oscillations of the wave are parallel 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 on the wave.

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

Study Tip

Make sure you know at least one example of each type of wave.

Study Tip

For a longitudinal wave, the wavelength is the distance between compressions or rarefactions instead of between crests or troughs in transverse waves.

Examination Tip

It is a common question to explain what type of wave sound is and how the particles move.

longitudinal

(they) oscillate along direction of energy transfer (1 mark)

Study Tip

In displacement-time graphs of waves, the time of one complete wave (e.g. crest to crest) is the period of the wave.

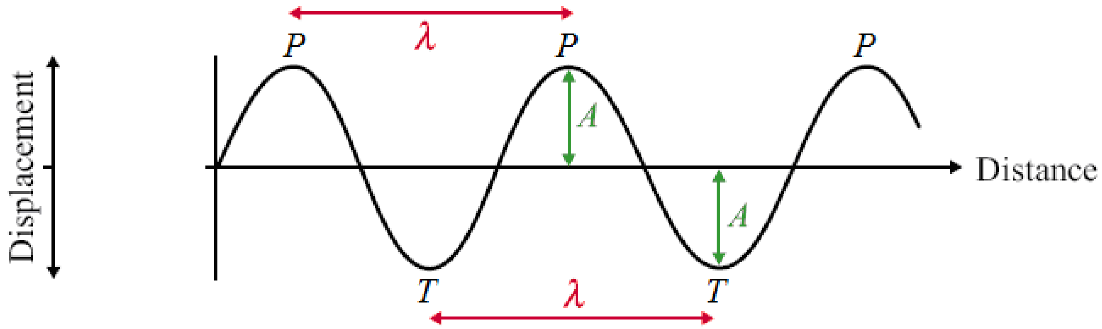
Transverse Waves

In a transverse wave the oscillations of the wave are perpendicular **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.

Exam Tip

It is a common examination question to define longitudinal and transverse waves…

You must refer to the relative direction of oscillations to that of the direction of propagation/transfer of energy (1 mark).

For transverse waves oscillations are at right angles to direction of propagation while in longitudinal waves they are in the same direction (1 mark).

Study Tip

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

VIDEO LINK

To watch a video on the following topic, please scan the following code 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.

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.

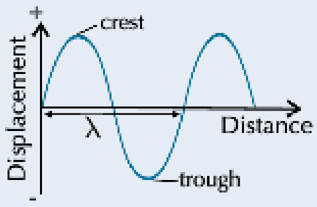
REVISION SHEET

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

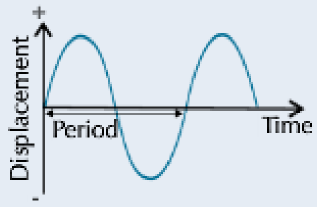
*In **Transverse Waves**, **Vibration** is at Right Angles to the **Direction** of Travel*

1) All **electromagnetic waves** are **transverse**. Other examples of transverse waves are ripples on water or waves on strings.
2) There are **two** main ways of **drawing** transverse waves:

They can be shown as **graphs** of **displacement** against **distance along the path of the wave**.



Or, they can be shown as graphs of **displacement against time** for a point as the wave passes.

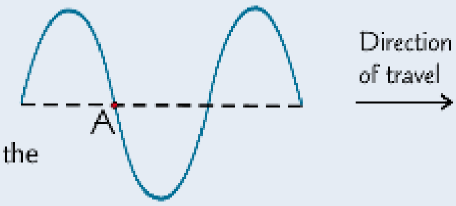


Displacements **upwards** from the centre line are given a **+ sign**. Displacements downwards are given a **– sign**.

3) Both sorts of graph often give the **same shape** (a **sine wave**), so make sure you check out the label on the **x-axis**.
4) You can work out what **direction** a point on a wave is moving in when given a snapshot of the wave.

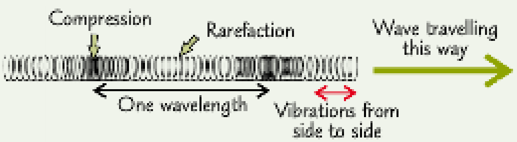
Example: Look at the snapshot of the wave on the right. Which direction is point A on the wave moving in?

1) Look at which **direction** the wave is **travelling** in — here the wave is moving from **left** to **right**.
2) The displacement of the wave **just to the left** of point A is **greater** than point A's. So as the wave travels along, point A will need to move **upwards** to have that displacement. (If the displacement to the left was less than point A's, point A would need to move down.)



*In **Longitudinal Waves** the **Vibrations** are **Along** the Direction of Travel*

The most **common** example of a **longitudinal wave** is **sound**. A sound wave consists of alternate **compressions** and **rarefactions** of the **medium** it's travelling through. (That's why sound can't go through a vacuum.)



Some types of earthquake shock waves are also longitudinal.

The compressions and rarefactions create **pressure variations** in the medium the wave is travelling through — at the points of compression, the **molecules** of the medium are **closer** together, **increasing** the pressure at that point. At the points of rarefaction, the molecules are **further apart**, which means a **lower** pressure at that point.

It's hard to **represent** longitudinal waves **graphically**. You'll usually see them plotted as **displacement** against **time**. These can be **confusing** though, because they look like a **transverse wave**.

Credit: CGP Revision Guide Editions

REVIEW QUESTIONS

To assess your understanding, answer the following questions on this topic.

A1. What is the difference between transverse and longitudinal waves?

[1 Mark]

....

....

....

....

....

....

A2. Give an example of a transverse and a longitudinal wave.

[1 Mark]

....

....

The answers to the review questions are found on the next page.

REVIEW ANSWERS

A1. In transverse waves, the direction of displacement of the particles/fields (the vibration) is at right angles to the direction of energy transfer.

In longitudinal waves, the direction of displacement of the particles/fields (the vibration) is parallel to the direction of energy transfer.

A2. Transverse waves can be electromagnetic waves, water waves, waves on a rope, seismic S-waves.
Longitudinal waves can be sound waves or seismic P-waves.

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.

1.1 State the difference between a longitudinal wave and a transverse wave.

[2 Marks]

....

....

....

....

1.2 State an example of a transverse wave.

[1 Mark]

....

1.3 State an example of a longitudinal wave.

[1 Mark]

....

1.4 Sound with a frequency of 560 Hz travels through steel with a speed of 4800 m s^{-1}. Calculate the wavelength of the sound wave.

[2 Marks]

....

....

....

....

Reference: AQA Legacy B Examination Material

2. Ultrasound waves are used to produce images of a fetus inside a womb.

2.1 Explain what is meant by the frequency of a wave.

[1 Mark]

....

....

....

2.2 Ultrasound is a longitudinal wave. Describe the nature of a longitudinal wave.

[2 Marks]

....

....

....

....

2.3 In order to produce an image with sufficient detail, the wavelength of the ultrasound must be 0.50 mm. The speed of the ultrasound in body tissue is 1540 m s^{-1}. Calculate the frequency of the ultrasound at this wavelength.
Give your answer to an appropriate number of significant figures.

[2 Marks]

....

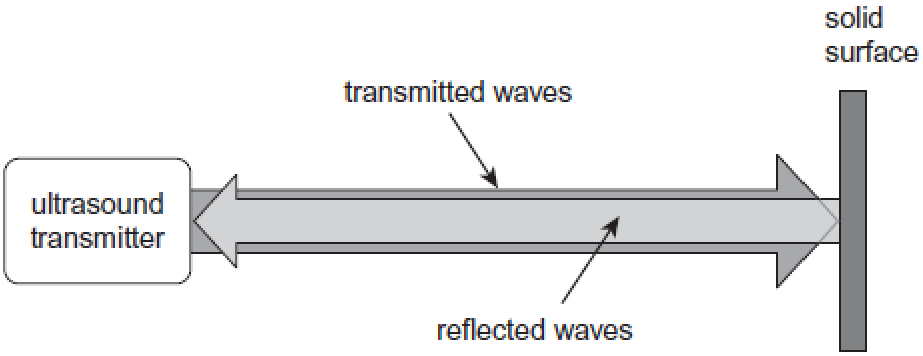
....

....

....

Frequency ______________________ Hz

2.4 A continuous ultrasound wave of constant frequency is reflected from a solid surface and returns in the direction it came from.



Assuming there is no significant loss in amplitude upon reflection, describe and explain the effect the waves have on the particles in the medium between the transmitter and the solid surface.

[3 Marks]

....

....

....

....

....

....

Reference: AQA A-Level Physics Unit 2 June 2014 Examination

ANSWERS

M1.1 loose distinction e.g. one has oscillations parallel to the wave direction and the other has oscillations in the same direction as the wave

C1

transverse -vibrations perpendicular to direction of propagation
longitudinal -vibrations in same direction as direction of propagation

A1
(2)

M1.2 any example of transverse wave

B1
(1)

M1.3 any example of longitudinal wave

B1
(1)

M1.4 $v = f\lambda$

C1

8.6 m

A1
(2)
[6]

M2.1 number of (complete) <u>waves</u> (passing a point) <u>in 1 second</u>
OR
number of waves / time (for the waves to pass a point)
OR
(complete number of) oscillations \ vibrations <u>per second</u>
OR
1 / T with T defined as time for 1 (complete) oscillation ✓

Allow: cycles

Allow: unit time

1

M2.2 <u>For two marks</u>:
oscillation of particles \ medium \ material etc, but not oscillation of wave is parallel to \ in same direction as
the direction wave (travels) ✓ ✓

<u>For one mark</u>:
particles \ material \ medium <u>move(s)</u> \ disturbance \ displacement
parallel to \ in same direction as
the direction wave travels
OR
(oscillations) parallel to direction of wave travel ✓

the one mark answer with:
mention of <u>compression</u>s and <u>rarefaction</u>s

OR
(longitudinal waves) cannot be polarised

gets **two** marks
✓
Allow
Vibration
Allow direction of energy transfer | wave propagation

2

M2.3 ($f = 1540 / 0.50 \times 10^{-3}$)
= 3 100 000 (Hz) ✓ (3 080 000)
2sf ✓

2

M2.4 no more than two points from either list (max 3):
Description
- mention of nodes and antinodes
- particles not moving at a node

- maximum displacement at antinode
- particles either side of node in antiphase / between two nodes in phase
- variation of amplitude between nodes

Explanation
- a stationary wave (forms)

- two waves are of equal frequency or wavelength (and amplitude in the same medium)
- reflected and transmitted waves \ waves travelling in opposite directions, pass through each other

- superpose / interference occurs

- constructive interference at antinodes
- destructive interference at nodes

✓ ✓ ✓
Allow 'standing wave'

3
[8]

ASSESSMENT QUESTION

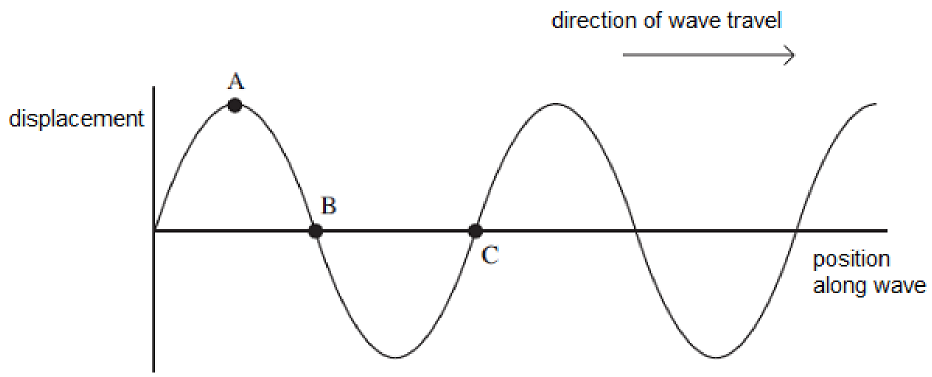
Please answer this assessment question on this topic in Physics.

This work will be formally assessed with feedback given.

This work will be submitted at the start of the A-Level course in Year 12.

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

M3. Earthquakes produce transverse and longitudinal seismic waves that travel through rock. The diagram below shows the displacement of the particles of rock at a given instant, for different positions along a transverse wave.



State the phase difference between

[2 Marks]

M3.1 points **A** and **B** on the wave ________________________________

M3.2 points **A** and **C** on the wave ________________________________

M3.3 Describe the motion of the rock particle at point **B** during the passage of the next complete cycle.

[2 Marks]

....

....

....

....

M3.4 A scientist detects a seismic wave that is polarised. State and explain what the scientist can deduce from this information.

[2 Marks]

....

....

....

....

The **frequency** of the seismic wave is measured to be 6.0 Hz.

M3.5 Define the frequency of a progressive wave.

[1 Mark]

....

....

....

M3.6 Calculate the wavelength of the wave if its speed is 4.5×10^3 m s^{-1}.

[2 Marks]

....

....

....

....

Wavelength ______________________ m

TOPIC: 3.3.1.3 Principle of Superposition of Waves and Formation of Stationary Waves

SPEC CHECK

Specification	Completed?
Stationary waves.	
Nodes and antinodes on strings. $f = 1/2l \times \sqrt{T/\mu}$ for first harmonic.	
The formation of stationary waves by two waves of the same frequency travelling in opposite directions.	
A graphical explanation of formation of stationary waves will be expected.	
Stationary waves formed on a string and those produced with microwaves and sound waves should be considered.	
Stationary waves on strings will be described in terms of harmonics. The terms fundamental (for first harmonic) and overtone will not be used.	
Students can investigate the factors that determine the frequency of stationary wave patterns of a stretched string.	

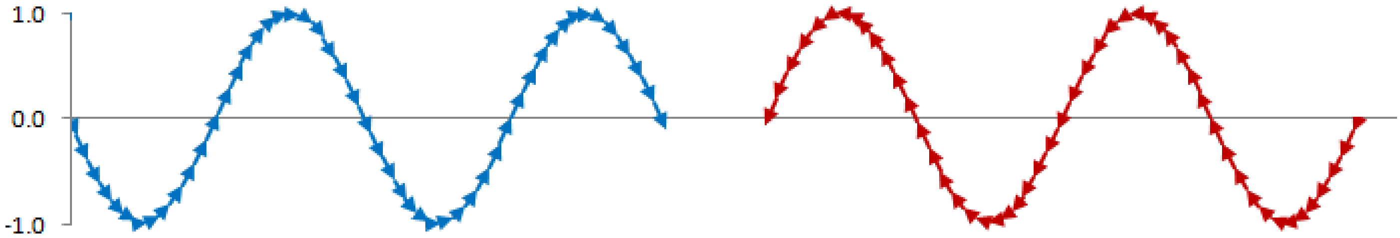
Student Checklist
Complete the following before attempting any work on this section.

Have I…….	Yes or No?
Read through the notes of this section?	
Highlighted/underlined the key concepts of this section?	
Made my own notes based on the notes of this section?	

Complete the above checklist with the notes of each section before you attempt to answer any questions on this section of work.

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.

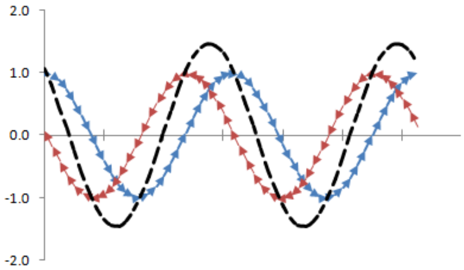
The principle of superposition states that when two waves overlap, their displacements add.
NOT THE DISTANCES BEING ADDED.
To calculate the superposition, you add the vectors of each wave.
This only happens when two waves of the same type overlap.
This only happens when it is coherent waves overlapping.

Study Tip

Remember the vector sum is the sum of the two displacements looking at direction and magnitude.

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

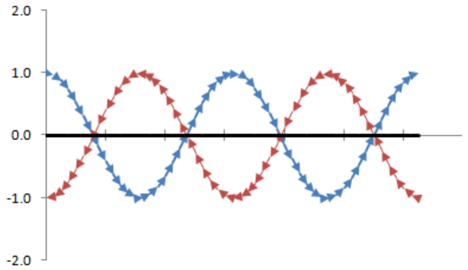
If the waves undergoing superposition are vibrating in the same direction, they are said to be **IN PHASE.** If the two waves have the exact same wave pattern, they are totally in phase.
WAVES COMPLETELY IN PHASE LEAD TO CONSTRUCTIVE INTERFERENCE.
Constructive interference leads to large peaks and troughs.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

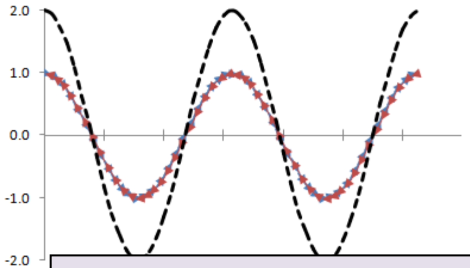
This called **constructive interference.**



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 **constructive interference** and a maximum.

Exam Tip

It is a common examination question to ask how the interference pattern changes throughout the superposition of two waves.

Initially the path difference is zero/the two waves are in phase when they meet/the (resultant) displacement is a maximum (1 move)

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 (1 mark)

When the path difference is one half wavelength, the two are in anti-phase and the patter is at a minimum. (1 mark)

As the path difference continues to increase, the two waves become more in phase and the resultant interference pattern gets stronger again. (1 mark).

Study Tip

A trough and a crest will not cancel each other out completely unless they have the same magnitude.

Study Tip

Waves do not need to have the same amplitude to be in phase, they do need to have the same frequency and wavelength.

Study Tip

If two points are exactly out of phase, they are an odd integer of half cycles apart (e.g. 1 or 3)

Study Tip

Compare the position of two equivalent points on two waves to find the phase difference between them.

Study Tip

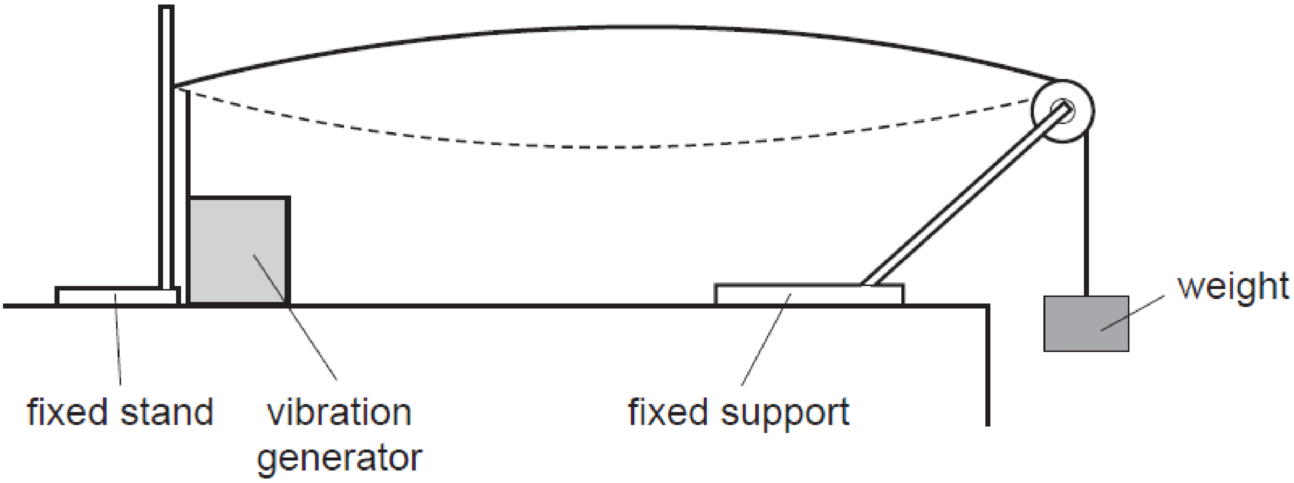
Amplitude only has magnitude, but displacement has a magnitude and a direction.

Stationary/Standing Waves

Prior Knowledge Link
This is a topic found in a previous GCSE module - **Waves**

When two similar waves travel in opposite directions, they can superpose to form a standing (or stationary) wave. This is an application of the superposition discussed.

In this section, there is the experimental set up of how we can form a standing wave on a string.



The vibration generator sends waves down the string at a certain frequency and phase difference; they reach the end of the string and reflect back at the same frequency and phase difference.

On their way back the two waves travelling in opposite direction superpose to form a standing wave made up of nodes and antinodes.

Exam Tip

To form a standing wave, the following must occur.

A progressive wave is reflected off a surface (1 mark).

The progressive wave is coherent with itself – as the frequency and phase difference are unchanged

(1 mark)

The progressive wave does not reduce in amplitude (1 mark).

The progressive wave interferes with itself and produces a standing wave (1 mark).

Exam Tip

It is a common examination question to define what a stationary wave is and what a progressive wave is…

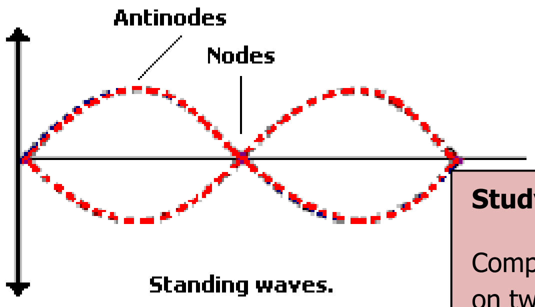
A stationary wave is a wave which contains energy (1 mark)

In a stationary wave all oscillating particles have constant amplitude (1 mark)

A progressive wave is a wave that transfers energy from one point to another (1 mark)

Without transferring material/ (causing permanent displacement of the medium) (1 mark)

Here is an example of a standing wave.



Study Tip

At the n^{th} harmonic, n/2 wavelengths will fit on the string.

Study Tip

Compare the position of two equivalent points on two waves to find the phase difference between them.

There are many examples of standing waves in the real world, the most common of which is the microwave set up in a microwave oven.

Study Tip

If two points are exactly out of phase, they are an odd integer of a half cycle (180°) apart.

There are two points of major interest on a standing wave.

Nodes: Positions on a standing wave which do not vibrate.
The waves superimpose/combine to give zero displacement.
This happens when the waves are **completely out of phase.**

Antinodes: Positions on a standing wave which show maximum vibration.
Positions on a standing wave where there is a maximum displacement.
This happens when the waves are **completely in phase.**

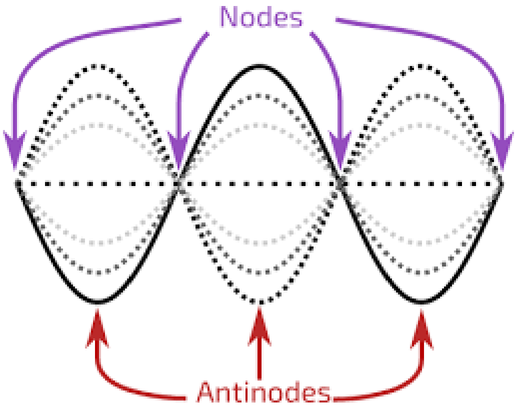
Study Tip

If two points are exactly in phase, they are an even integer of a half cycle (180°) apart.

In reality, a standing wave is a combination of many waves.

Study Tip

If you are asked to sketch a standing wave, make sure you make it clear where the nodes and anti-nodes are.



Study Tip

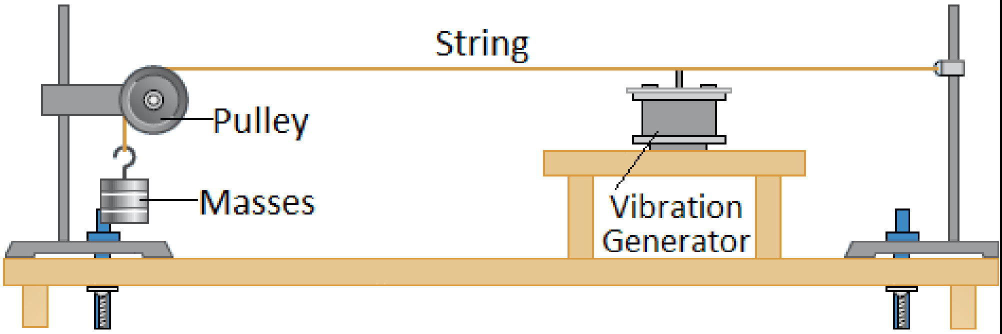
At the n^{th} harmonic, the number of anti-nodes is equal to n, and the number of nodes is equal to n + 1.

Exam Tip

It is a common examination question to ask why you get melting/bright light/loud sound at the anti-node…

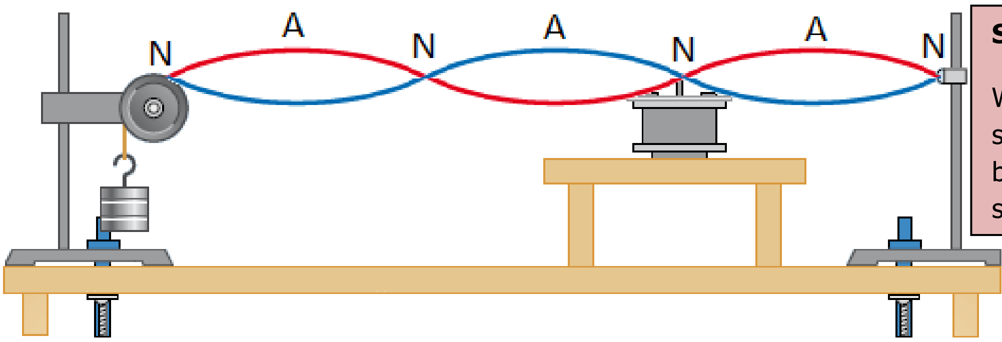
Energy/amplitude is a maximum (1 mark)

The food melts/there is a bright light/there is a loud sound at the antinode (1 mark)



A progressive wave is one where the wave moves from one point to another. It is a transfer of energy.

A stationary wave is one where a wave is trapped between two boundaries and reflects back on itself. It is a display of energy.



Study Tip

Waves do not need to have the same amplitude to be in phase, but they do not need to have the same frequency and wavelength.

Exam Tip

It is a common examination question to ask how this apparatus can form a standing wave on a string and what this means.

A wave and its reflection/waves travelling in opposite directions meet/interact/overlap/cross/pass through etc (1 mark)

Same wavelength (or frequency) (1 mark)

This forms nodes – point of minimum or no disturbance (1 mark)

This forms antinode – is a point of maximum amplitude (1 mark)

The nodes form when two waves (always) cancel/ destructive interference / 180^o phase difference /in antiphase [out of phase is not enough] (of the two waves at the node)[not peak meets trough] (1 mark)

The antinode occurs with – reinforcement / constructive interference occurs / (displacements) in phase (1 mark)

Mention of superposition [not superimpose] of the two waves (1 mark)

In this wave, energy is not transferred (along in a standing wave) (1 mark)

Statistically, this is the most common question on A-Level Physics examinations.

Study Tip

The position on the x-axis tells you at what point in the wave cycle you are.

Here is a comparison between standing waves and progressive wave.

You must be able to compare the properties of each.

Do not confuse the different types of waves in examination questions.

	Standing Waves	Progressive Waves
Amplitude	Maximum at antinode and zero at nodes	The same for all parts of the wave
Frequency	All parts of the wave have the same frequency	All parts of the wave have the same frequency
Wavelength	Twice the distance between adjacent nodes	The distance between two adjacent peaks
Phase	All points between two adjacent nodes in phase	Points one wavelength apart in phase
Energy	No energy translation	Energy translation in the direction of the wave
Waveform	Does not move forward	Moves forwards

Exam Tip

It is a common examination question to ask what the motion of a particle in a progressive wave is over a complete cycle.

The particle oscillates from equilibrium to maximum positive displacement, back to equilibrium, then to max negative displacement and back to equilibrium /starting position /rest position (1 mark)

Harmonics

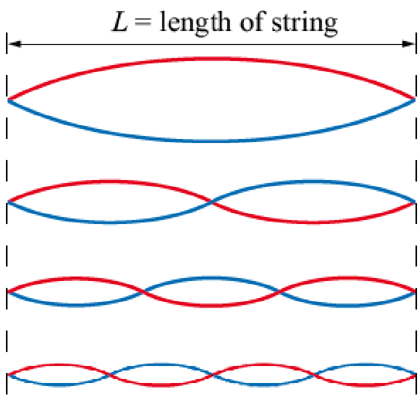
As we increase the frequency of the vibration generator, we will see standing waves being set up. The first will occur when the generator is vibrating at the fundamental frequency (or first harmonic), f_0, of the string.

First Harmonic $f = f_0$ $\lambda = 2L$
2 nodes and 1 antinode

Second Harmonic $f = 2f_0$ $\lambda = L$
3 nodes and 2 antinodes

Third Harmonic $f = 3f_0$ $\lambda = \frac{2}{3}L$
4 nodes and 3 antinodes

Fourth Harmonic $f = 4f_0$ $\lambda = \frac{1}{2}L$
5 nodes and 4 antinodes



As we increase the frequency of the signal generator, the standing wave only forms at the harmonic frequencies.

The frequencies of the harmonics are all multiples of the first harmonic.
If the frequency of the wave is not a first harmonic multiple, a standing wave will not form.

Examination Tip: If asked to calculate a harmonic, calculate the fundamental (or first harmonic) using the equation given in the equation booklet, then multiply this value by the number of the harmonic.

Study Tip

A straight-line graph of distance against number of nodes can be plotted for this experiment.

The gradient of the graph gives $\lambda/2$, which you can use to work out the wave speed.

Study Tip

Remember that $c = f\lambda$

Study Tip

If you are given the first harmonic frequency, you can work out the resonant frequency, f, at the nth harmonic with

f = n x first harmonic frequency

Study Tip

If you are asked to sketch a standing wave, make sure you make it clear where the antinodes and nodes are. You do not need to draw loads of dotted lines, as long as you show what shape the string is vibrating.

VIDEO LINK

To watch a video on the following topic, please scan the following code 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.

REVISION SHEET

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

You get Stationary Waves When a ***Progressive Wave*** *is* ***Reflected*** *at a* ***Boundary***

A stationary wave is the **superposition** of **two progressive waves** with the **same wavelength**, moving in **opposite directions**.

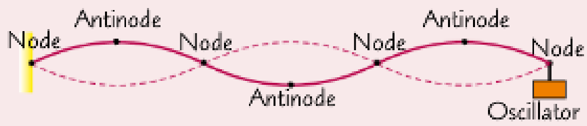
The progressive waves must also have the same speed and frequency.

1) Unlike progressive waves, **no energy** is transmitted by a stationary wave.
2) You can demonstrate stationary waves by attaching a **vibration transducer** at one end of a **stretched string** with the other end fixed. The transducer is given a wave frequency by a **signal generator** and creates that wave by vibrating the string.
3) The wave generated by the vibration transducer is **reflected** back and forth.
4) For most frequencies the resultant **pattern** is a **jumble**. However, if you alter the **signal generator** so the **transducer** produces an **exact number of waves** in the time it takes for a wave to get to the **end** and **back again**, then the **original** and **reflected** waves **reinforce** each other.
5) At these **"resonant frequencies"** you get a **stationary** (or **standing**) **wave** where the **pattern doesn't move** — it just sits there, bobbing up and down. Happy, at peace with the world...

A sitting wave.

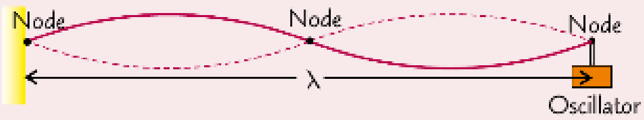
Stationary Waves in ***Strings*** *Form* ***Oscillating "Loops"*** *Separated by* ***Nodes***

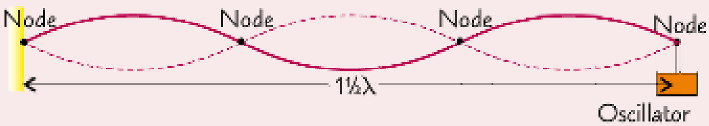
1) Each particle vibrates at **right angles** to the string.
2) **Nodes** are where the **amplitude** of the vibration is **zero**.
3) **Antinodes** are points of **maximum amplitude**.
4) At resonant frequencies, an **exact number** of **half wavelengths** fits onto the string.



The standing wave above is vibrating at the **lowest possible** resonant frequency (the **fundamental mode of vibration** — also called the **first harmonic**). It has **one "loop"** with a **node at each end**.

This is the **second harmonic**. It is **twice** the **fundamental mode of vibration**. There are two "**loops**" with a **node** in the **middle** and **one at each end**.





The **third harmonic** is **three times** the fundamental mode of vibration. **1½ wavelengths** fit on the string.

Credit: CGP Revision Guide Editions

REVIEW QUESTIONS

To assess your understanding, answer the following questions on this topic.

A1. What does the principle of superposition say?

[1 Mark]

....

....

A2. Describe constructive interference.

[1 Mark]

....

....

A3. What is total destructive interference?

[1 Mark]

....

....

A4. What does it mean for two waves to be in phase?

[1 Mark]

....

....

A5. How is a stationary wave formed?

[1 Mark]

....

....

A6. Does a stationary wave transfer energy?

[1 Mark]

....

....

The answers to the review questions are found on the next page.

REVIEW ANSWERS

A1. When two waves meet, the resultant displacement equals the vector sum of the individual displacement.

A2. When two waves pass through each other and their displacements combine to make a displacement with greater magnitude.

A3. When two waves pass through each other and their displacements cancel each other out completely.

A4. When their phase difference is an odd multiple of 180^o (half a cycle).

A5. When two progressive waves are travelling in the opposite direction to each other, with the same frequency and the same amplitude, their superposition creates a stationary wave.

A6. No

SELF ASSESSMENT

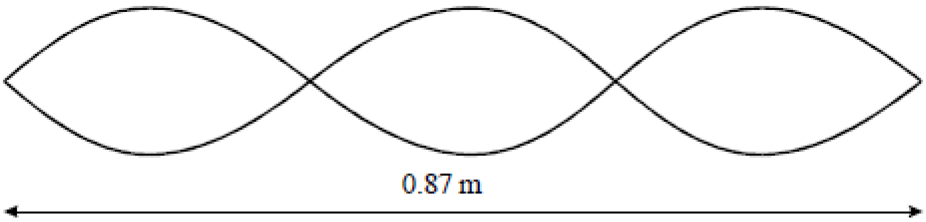
To practice your understanding, answer the following questions.

DO NOT WORRY IF YOU STRUGGLE AT FIRST.

The answers are found after the questions.

Q1. The drawing below shows a standing wave set up on a wire of length 0.87 m.

The wire is vibrated at a frequency of 120 Hz.



1.1 Calculate the speed of transverse waves along the wire.

[3 Marks]

....

....

....

....

1.2 Show that the fundamental frequency of the wire is 40 Hz.

[2 Marks]

....

....

....

Reference: AQA Legacy B Examination Material

Q2. The equation for the speed, v, of a transverse wave along a stretched string is:

$$v = \sqrt{\frac{T}{\mu}}$$

where T is the tension in the string and μ is the mass per unit length of the string.

2.1 State the quantities that would need to be measured in order to calculate a single value for the speed of the wave using the equation. Name a suitable measuring instrument for each quantity.

[4 Marks]

....

....

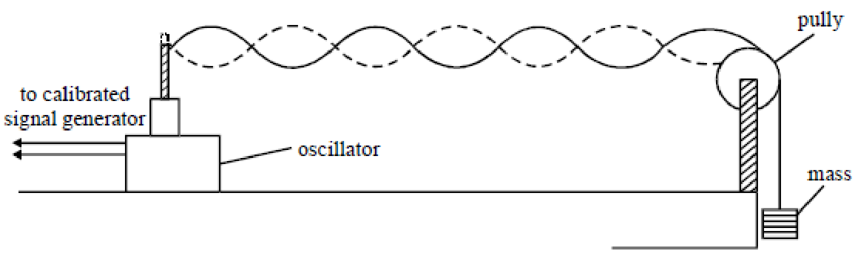
....

....

....

....

2.2 The apparatus shown in the diagram below could be used to measure a value for v.



Explain how this apparatus may be used to calculate an accurate value of the speed of the transverse wave along the string.

[4 Marks]

....

....

....

....

....

....

....

....

Reference: AQA Legacy B Examination Material

ANSWERS

M1.1 λ = 0.58(m) **or** (2 / 3 × 0.87) **C1**

*$c = f\lambda$ **or** substituted values* **C1**

69.6 (70) m s^{-1} **A1**
(3)

M1.2 λ = 0.87 × 2 **or** λ = 1.74 **or** in formula **M1**

69.6 / 1.74 or 70 / 1.74 = 40.2 **A1**
(2)

or
The drawing shows third harmonic (second overtone) **M1**

so, 120 = 3 × f_0 so f_0 = 40 Hz
do **not** allow just 120 / 3 **A1**
[5]

M2.1 tension – newtonmeter **B2**

or tension – from mass on balance **B1**

and – multiply by g **B1**

mass – balance / scales **B1**

length – rule / tape / ruler **B1**
(4)

M2.2 frequency read from signal generator when standing wave produced / use of strobe etc. **B1**

measure λ using several loops or full length of string **B1**

node → node / each loop = λ / 2 **B1**

use of $c = f\lambda$ **B1**
(4)

ASSESSMENT QUESTION

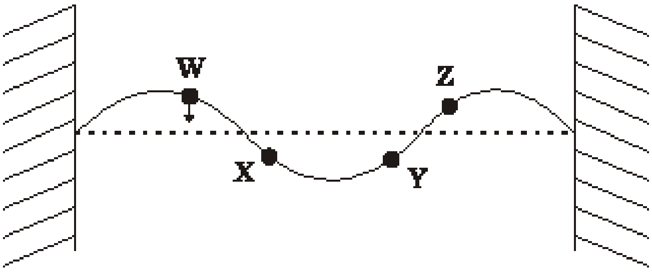
Please answer this assessment question on this topic in Physics.

This work will be formally assessed with feedback given.

This work will be submitted at the start of the A-Level course in Year 12.

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

Q3. The figure below shows the appearance of a stationary wave on a stretched string at one instant in time. In the position shown each part of the string has its maximum displacement. The arrow at **W** shows the direction in which the point **W** is about to move.



3.1 Mark clearly on the diagram the directions in which points **X**, **Y** and **Z** are about to move.

[2 Marks]

3.2 State the conditions necessary for a stationary wave to be produced on the string.

[2 Marks]

....

....

3.3 In the figure above, the frequency of vibration is 120 Hz. Calculate the frequency of the fundamental vibration for this string.

[2 Marks]

....

....

....

....

Frequency of the Fundamental Vibration.. Hz

Reference: AQA Legacy B Examination Material

REVISION CHECKLIST

Specification reference	Checklist questions	
3.3.1.1	Can you explain oscillation of particles in terms of amplitude, frequency, wavelength, speed, phase, and phase difference?	☐
3.3.1.1	Can you explain that phase difference may be measured as angles (radians and degrees) or as fractions of a cycle?	☐
3.3.1.2	Can you explain the nature of longitudinal and transverse waves, including sound, electromagnetic waves, and waves on a string?	☐
3.3.1.2	Can you describe the direction of displacement of particles/fields relative to the direction of energy propagation?	☐
3.3.1.2	Can you recall that all electromagnetic waves travel at the same speed in a vacuum?	☐
3.3.1.3	Can you define stationary waves?	☐
3.3.1.3	Can you describe nodes and antinodes on strings?	☐
3.3.1.3	Can you describe the formation of stationary waves by two waves of the same frequency travelling in opposite directions?	☐
3.3.1.3	Can you draw a diagram to explain the formation of stationary waves?	☐
3.3.1.3	Can you describe stationary waves formed on a string and those produced with microwaves and sound waves?	☐
3.3.1.3	Can you describe stationary waves on strings in terms of harmonics?	☐

FURTHER READING

You may wish to read around the following topics to further extend your understanding ahead of the start of the course in Year 12.

Interference from a Diffraction Grating

SCAN ME

SCAN ME

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

Refraction, Total Internal Reflection and Fibre Optics

SCAN ME

SCAN ME

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

DATASHEET

DATA – FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\,s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\,m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\,m^{-1}}$
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	$\mathrm{J\,s}$
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\,m^2\,kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\,K^{-1}\,mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\,K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\,m^{-2}\,K^{-4}}$
the Wien constant	α	2.90×10^{-3}	$\mathrm{m\,K}$
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	$\mathrm{C\,kg^{-1}}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^{7}	$\mathrm{C\,kg^{-1}}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$\mathrm{N\,kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\,s^{-2}}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.97×10^{24}	6.37×10^{6}

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
curved surface area of cylinder	$= 2\pi rh$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^{\pm}$	0.510999
	muon	$\mu^{\pm}$	105.659
mesons	π meson	$\pi^{\pm}$	139.576
		π^0	134.972
	K meson	$K^{\pm}$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

		Lepton number
Particles:	$e^-, \nu_e; \mu^-, \nu_\mu$	$+1$
Antiparticles:	$e^+, \overline{\nu_e}, \mu^+, \overline{\nu_\mu}$	-1

Photons and energy levels

photon energy $E = hf = hc/\lambda$

photoelectricity $hf = \phi + E_{k\,(max)}$

energy levels $hf = E_1 - E_2$

de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

Waves

wave speed $c = f\lambda$ *period* $f = \frac{1}{T}$

first harmonic $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

fringe spacing $w = \frac{\lambda D}{s}$ *diffraction grating* $d \sin\theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 *and* n_2,

law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

critical angle $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

moments moment $= Fd$

velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

equations of motion $v = u + at$ $s = \left(\frac{u+v}{2}\right)t$

$v^2 = u^2 + 2as$ $s = ut + \frac{at^2}{2}$

force $F = ma$

force $F = \frac{\Delta(mv)}{\Delta t}$

impulse $F\,\Delta t = \Delta(mv)$

work, energy and power $W = F\,s\cos\theta$

$E_k = \frac{1}{2}m\,v^2$ $\Delta E_p = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

$efficiency = \frac{useful\ output\ power}{input\ power}$

Materials

density $\rho = \frac{m}{V}$ *Hooke's law* $F = k\,\Delta L$

Young modulus $= \frac{\text{tensile stress}}{\text{tensile strain}}$ *tensile stress* $= \frac{F}{A}$ *tensile strain* $= \frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

Acknowledgements

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All relevant information has been credited in the document.

This document has been produced for educational purposes only.

This document has been produced for the AQA A Level Physics 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.