Waves Revision Booklet

Content will be tested on Physics Paper 2

4.6.1 Waves in air, fluids and solids

AQA Physics (8463) from 2016 Topics P4.6. Waves			
Student Checklist	**R**	**A**	**G**
Describe waves as either transverse or longitudinal, defining these waves in terms of the direction of their oscillation and energy transfer and giving examples of each			
Define waves as transfers of energy from one place to another, carrying information			
Define amplitude, wavelength, frequency, period and wave speed and Identify them where appropriate on diagrams			
State examples of methods of measuring wave speeds in different media and Identify the suitability of apparatus of measuring frequency and wavelength			
Calculate wave speed, frequency or wavelength by applying, but not recalling, the equation: ***[$v = f\lambda$] and*** calculate wave period by recalling and applying the equation: ***[$T = 1/f$]***			
Identify amplitude and wavelength from given diagrams			
Describe a method to measure the speed of sound waves in air			
Describe a method to measure the speed of ripples on a water surface			
Required practical 8: *make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid*			

4.6.2 Electromagnetic waves

Describe what electromagnetic waves are and explain how they are grouped			
List the groups of electromagnetic waves in order of wavelength			
Explain that because our eyes only detect a limited range of electromagnetic waves, they can only detect visible light			
HT ONLY: Explain how different wavelengths of electromagnetic radiation are reflected, refracted, absorbed or transmitted differently by different substances and types of surface			
Illustrate the refraction of a wave at the boundary between two different media by constructing ray diagrams			
HT ONLY: Describe what refraction is due to and illustrate this using wave front diagrams			
Required practical activity 10: *investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.*			
HT ONLY: Explain how radio waves can be produced by oscillations in electrical circuits, or absorbed by electrical circuits			
Explain that changes in atoms and the nuclei of atoms can result in electromagnetic waves being generated or absorbed over a wide frequency range			
State examples of the dangers of each group of electromagnetic radiation and discuss the effects of radiation as depending on the type of radiation and the size of the dose			
State examples of the uses of each group of electromagnetic radiation, explaining why each type of electromagnetic wave is suitable for its applications			

4.6.1 Waves in air, fluids and solids

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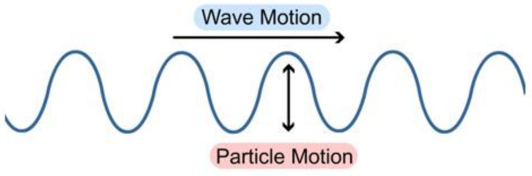
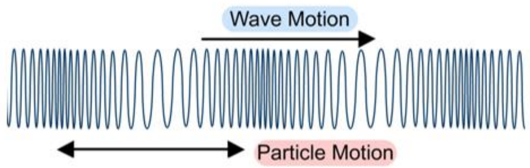
Transverse and Longitudinal Waves

Transverse Wave



Longitudinal Wave



Remember, the particles in a wave move up and down or backwards and forwards only.
It is energy, NOT the particles, that move from one place to another!

In a **transverse wave** the particles within the wave move perpendicular (at 90°) to the direction the wave is travelling.
This is the wave produced in a rope when it is flicked **up and down**.
Examples of transverse waves are:
Water waves, electromagnetic (light) waves and guitar strings.

Longitudinal waves are compression (squash) waves where the particles are vibrating in the same direction as the wave movement.
This is the wave produced when a spring is **squashed** and released.
Examples of longitudinal waves are:
Sound waves and a type of seismic (P) wave.

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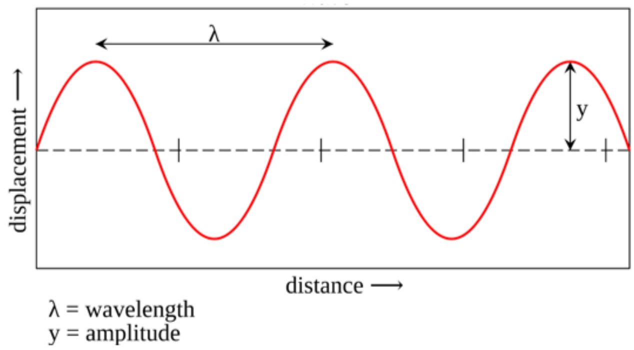
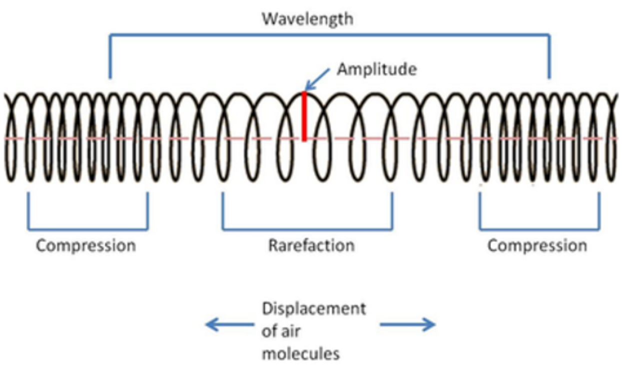
Transverse and Longitudinal Waves





Wavelength (m) – the distance from one point on a wave to the same point on the next wave.
Amplitude (m) – the waves maximum displacement of a point on a wave from its undisturbed position.
Frequency (Hz) – the number of waves passing a point per second.
Period (s) - the time taken to produce one complete wave.

The displacement of a transverse wave is described as **peaks and troughs**. In a longitudinal wave these are described as **compressions and rarefactions**.

Wave speed and wave period calculations

Wave speed is the speed at which energy is transferred by the wave (or how quickly the wave moves) through the medium it is travelling in.

Wave speed (m/s) = Frequency (Hz) x Wavelength (m) $v = f\lambda$

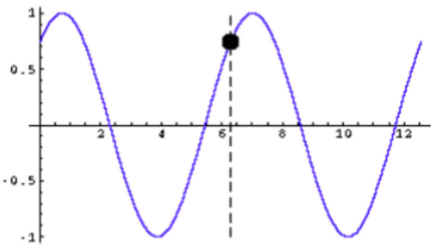
Wave period (T) is the time it takes one complete wave to pass a point (in seconds).

Period (s) = 1 / Frequency (Hz) $T = 1/f$

The wave opposite has a frequency of 0.5Hz and a wavelength of 6cm (0.06m). Calculate the wave period and the wave speed.

Wave period = **1/f** **T = 1/0.5 = 2s**

Wave speed = **f x λ** **v = 0.5 x 0.06 = 0.03m/s**



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Properties of waves

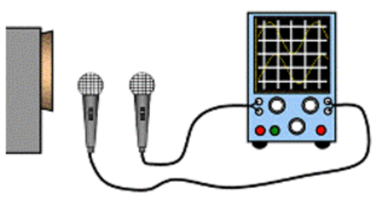
Method for measuring the speed of sound waves in air

100m

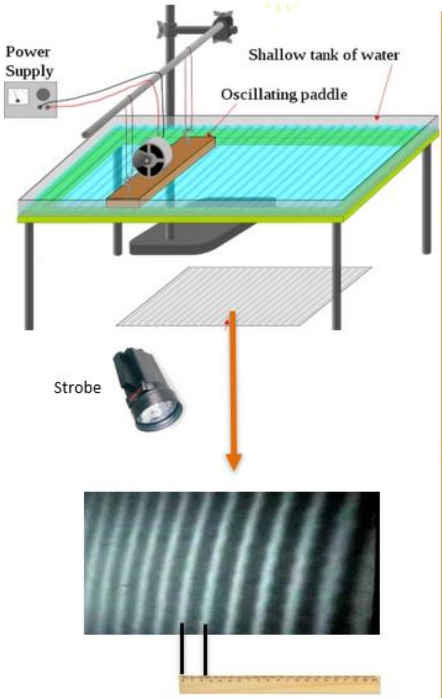
The cannon fires and the stopwatch is started (you can see a flash of light which takes almost zero time to travel 100m). When the sound reaches the observer the stopwatch is stopped. The time was **0.3s**
This will give the time for sound to travel **100m**.

Speed (m/s) = Distance (m) / Time (s)
Speed of sound = 100 / 0.3 = 333.3m/s

In the laboratory, a sound from a loudspeaker passes two microphones a set distance apart. The time recorded for the sound to travel this distance is measured and speed is calculated using the same formula as above.



Method for measuring the speed of ripples on a water surface



A ripple tank is used to make waves which are seen under the glass tank.
A strobe light has its frequency of flashes adjusted until the wave appears stationary – **this is the frequency of the water wave.**
Then, the **wavelength** of the water wave is measured by using a ruler to measure the distance from one peak to the next peak (white line to white line). This is converted to **metres**.

Wave speed (m/s) = Frequency (Hz) x Wavelength (m)

If the frequency of the water wave is 5Hz and the wavelength is 0.6cm:

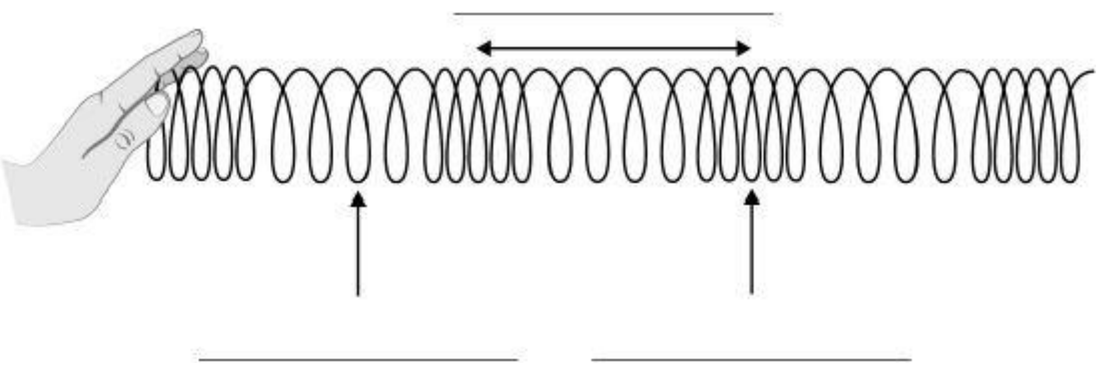
wave speed = 0.5 x 0.006 = 0.03m/s

EXAM QUESTIONS:

Q1.

Figure 1 shows a slinky spring used to model a sound wave.

Figure 1



(a) Label the arrows on **Figure 1**

Choose the answers from the box.

amplitude	**compression**	**frequency**
rarefaction	**wavelength**	

(3)

(b) What type of wave is a sound wave?

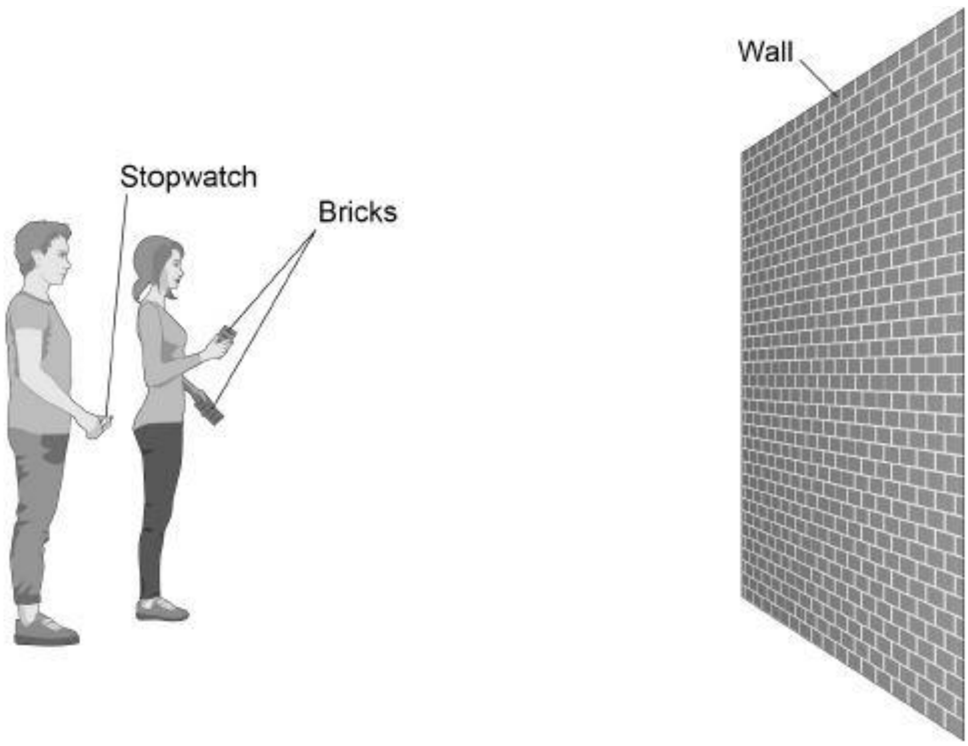
Tick **one** box.

electromagnetic	☐
longitudinal	☐
transverse	☐

(1)

(c) **Figure 2** shows two students measuring the speed of sound in air.

Figure 2



One student bangs two bricks together.

The sound wave produced is reflected from the wall and travels back to the students.

Describe how they can determine the speed of sound.

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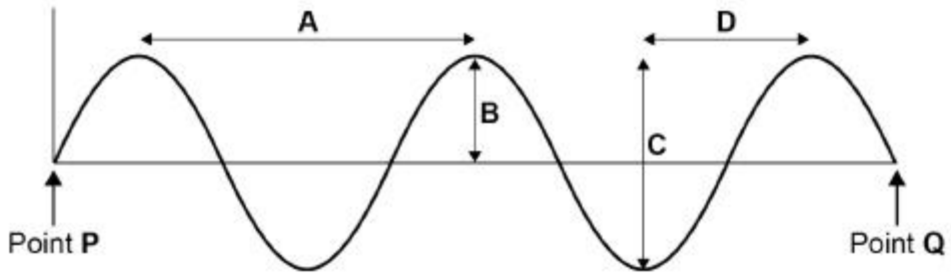
____ **(4)**

Q2.

The diagram shows a wave.



(a) Which arrow shows the amplitude of the wave?

Tick **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)

(b) Which arrow shows the wavelength of the wave?

Tick **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)

(c) It takes 0.5 seconds for a wave in the diagram to travel from point **P** to point **Q**.

Calculate the frequency of the waves shown in the diagram.

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Frequency = ____________________ Hz

(2)

(d) What type of wave is sound?

Tick **one** box.

Electromagnetic	☐
Longitudinal	☐
Transverse	☐

(1)

Two students carried out an experiment to determine the speed of sound.

This is the method used.

1. Student A stands 100 m away from Student B.
2. Student A bangs two blocks of wood together making a loud sound.
3. Student B starts a stopclock when he sees the blocks of wood bang together.
4. Student B stops the stopclock when he hears the sound and records the time.
5. The students repeat steps 2–4 several times.

The students calculated the speed of sound from their results.

(e) Suggest the most likely source of error in the experiment.

____

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(1)

(f) The speed of sound calculated was lower than the true speed of sound in air.

Suggest **one** improvement to the students' method that would give a more accurate value for the speed of sound.

____

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(1)

(g) A student compares the properties of visible light waves and radio waves.

Which **two** properties are the same for both visible light waves **and** radio waves?

Tick **two** boxes.

Both are transverse waves ☐

Both can travel through a vacuum ☐

Both have the same amplitude ☐

Both have the same frequency ☐

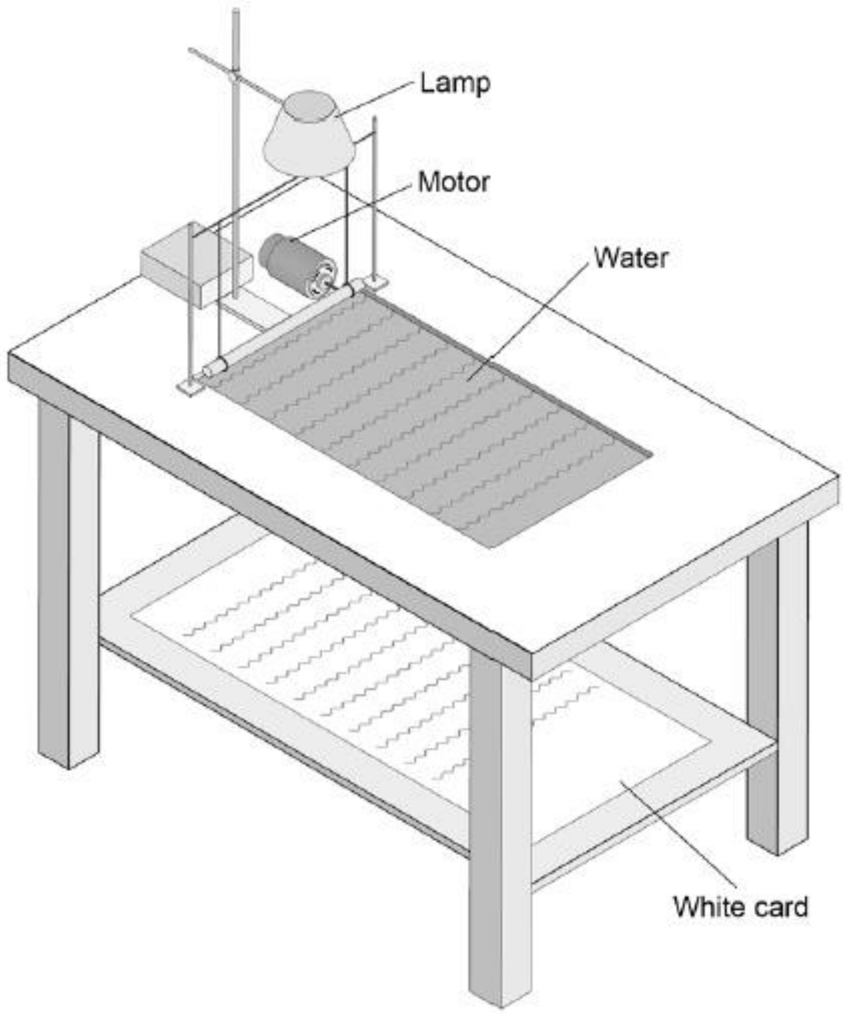
Both have the same wavelength ☐

(2)

(Total 9 marks)

Q3.

The diagram shows a ripple tank.



(a) The motor makes a noise when it is turned on.

Describe the differences between the properties of the sound waves produced by the motor and the water waves in the ripple tank.

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(4)

(b) The period of the sound waves produced by the motor is 8.3 milliseconds.

Calculate the frequency of the sound waves.

Use the Physics Equations Sheet.

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Frequency = ____________________ Hz

(3)

(c) Explain how a student could make appropriate measurements and use them to determine the wavelength of the waves in the ripple tank.

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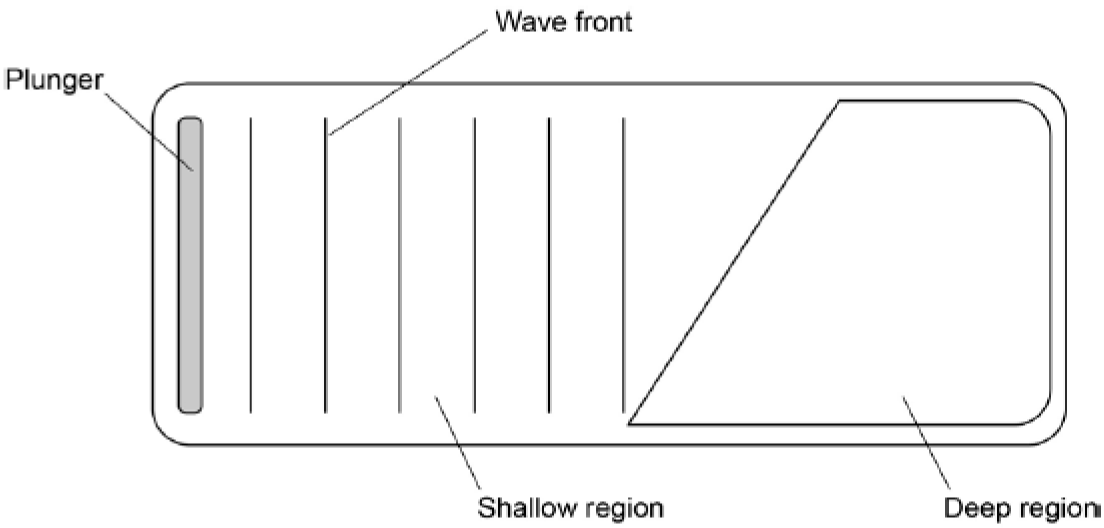
(6)

(Total 13 marks)

Q4.

Some students did an investigation to study the behaviour of waves.

The figure below shows a ripple tank that they used to model the behaviour of waves.



(a) Complete the wave fronts on the figure above.

Show how the wave is refracted as it passes from the shallow region into the deep region.

(1)

(b) Explain what happens to the waves as they pass into the deep region.

(2)

(c) The waves generated on the surface of the water are transverse waves.

Describe the differences between longitudinal waves and transverse waves.

You may include labelled diagrams to help your answer.

(3)

(d) Some students investigate the properties of the waves generated in the figure above.

Student **A** says 'the waves move water from one end of the tank to the other'.

Student **B** says 'that's wrong. Only the waves move, not the water'.

Suggest what the students could do to decide which of them is correct.

(2)

(e) Another student uses a ripple tank where all the water is the same depth.

She measures the wavelength of each wave as 0.34 m.

The period of each wave is 0.42 s.

Calculate the speed of the wave.

Use the correct equation from the Physics Equation Sheet.

Give the unit.

Give your answer to three significant figures.

Speed = _______________

Unit = ______________ **(5)**

Q5.

Waves may be longitudinal or transverse.

(a) Describe the differences between longitudinal waves and transverse waves.

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(3)

(b) Radio waves are electromagnetic waves.

Describe how radio waves are different from sound waves.

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____ **(4)**

4.6.2 Electromagnetic Waves:

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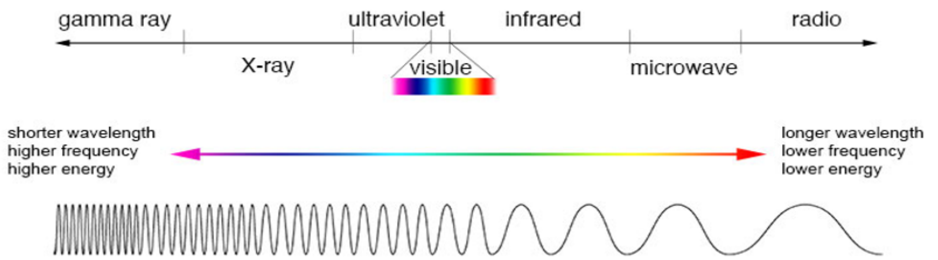
Types of electromagnetic waves

Electromagnetic waves are transverse waves that transfer energy from the wave source to an absorber.

Electromagnetic waves form a **continuous spectrum** from the shortest gamma waves (< 10^{-11}m wavelength) to radio waves (> 100km wavelength).
Shorter wavelengths have a **higher frequency** and **higher energy**.

All electromagnetic waves travel at the same velocity in a vacuum: 300 000 000m/s.



Our eyes are only able to detect a small range of these waves shown as the visible range above. Some animals can see in ultra violet and some can detect infra red.

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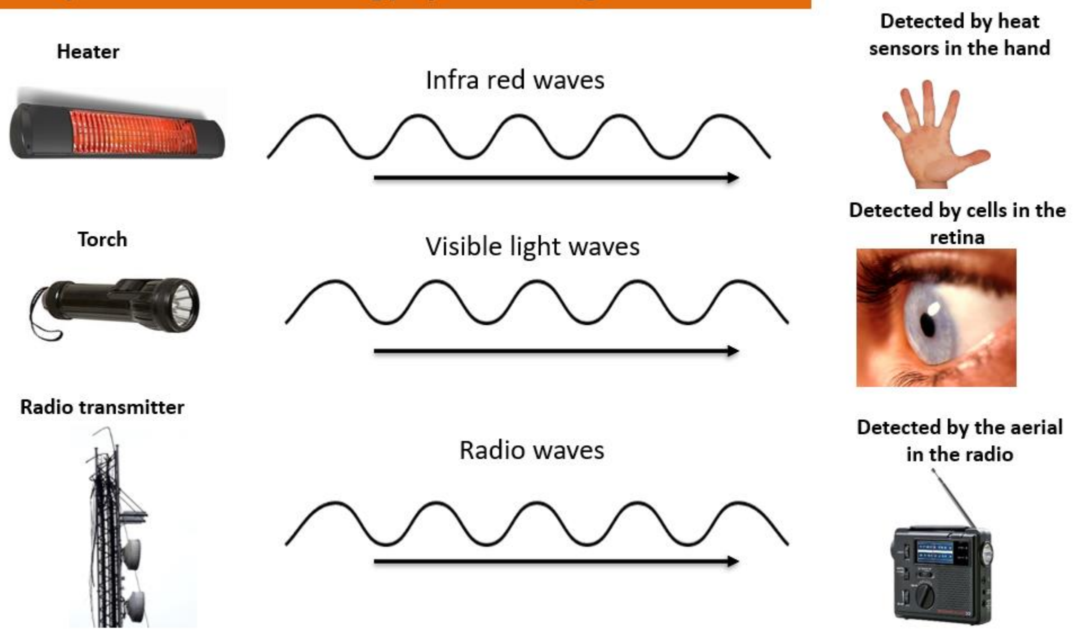
Types of electromagnetic waves

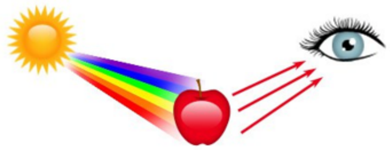
Examples of transfer of energy by electromagnetic waves



Absorption, transmission and reflection of different wavelengths of light

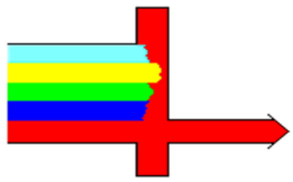
Most materials absorb some of the light falling on it. A white or shiny surface reflects most of the incident light whereas a black surface absorbs most wavelengths of light.

Absorbed light is changed into a **heat** energy store so is not re-radiated as light.



White light/sunlight is made from all the wavelengths of light in the spectrum.
A red object appears red in white light because it only **reflects** the red wavelengths of light, all other colours are absorbed.

If light **transmits** through a coloured object, the colour passing through is the colour we see. As with reflected light, all other wavelengths of light are absorbed by the transparent or translucent material.



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Properties of electromagnetic waves 1 (HT)

Refraction of different wavelengths of light in different materials

Refraction of electromagnetic waves occurs because the **wave changes speed** when it enters a substance of different **optical density**.
The light wave will only refract if one side of the wave strikes the new material before the other side.
The amount of refraction is different for materials of different optical density as seen in Figure 1 opposite.

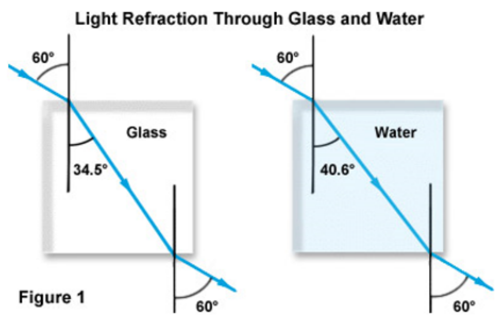
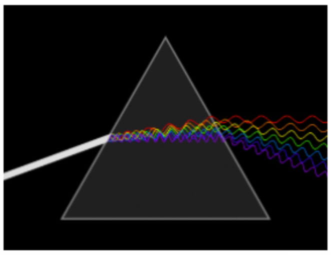


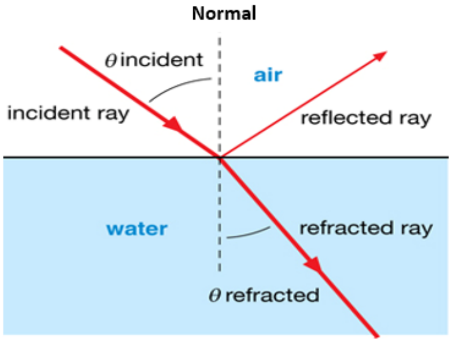
Figure 1



Different wavelengths of light are **diffracted by different amounts**, resulting in a spectrum of colour being produced when white light is refracted (dispersed) by a prism.

Properties of electromagnetic waves 1

Refraction of waves at a boundary– ray diagrams



When light strikes a transparent material, some of the light may be reflected but some will also be **refracted**.

When light enters a substance of greater density, it will be bent (refracted) **towards the normal line.**

Angle of incidence > angle of refraction

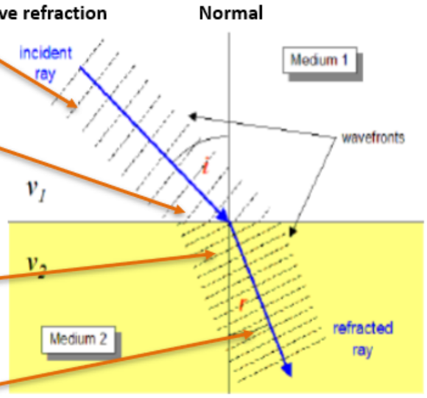
When light enters a substance of lower density, it will be bent (refracted) **away from the normal line.**

Angle of incidence < angle of refraction

Properties of electromagnetic waves 1 (HT)

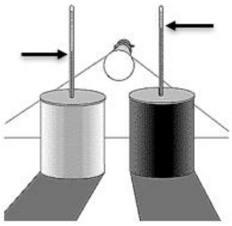
Explaining refraction using wave front diagrams

- The incident ray is shown as wave fronts where all the waves are in phase with each other. This is drawn as a wave line at right angles to the direction in which the wave is travelling.
- The incident ray strikes the denser medium 2 at an angle.
- When the wave front hits a denser material it slows down. One side of the wave front hits before the other side, so slows down first.
- This causes the wave front to bend towards the normal line. Wave fronts will be closer together as the velocity is decreased. Frequency is unchanged.



Properties of electromagnetic waves 1 (HT)

Absorption and radiation of infra red waves (required practical)



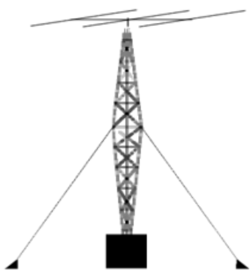
Black surfaces absorb infrared waves better than white or shiny surfaces.

Black surfaces also emit infrared radiation quicker than light coloured surfaces

This is the reason black cars and black curtains get hot in sunshine.
Petrol storage tankers are painted white or polished to reflect the suns IR heat waves.
A black kettle would radiate IR heat quicker than a shiny silver kettle and so would cool down faster. Car radiators are painted black to help them emit IR heat quickly.

Properties of electromagnetic waves 2 (HT)

Radio waves



A radio wave is transmitted at the same frequency as the a.c. current which produced it.

Radio signals are produced when an **alternating current** is passed through a wire in a radio transmitter. The **oscillating (vibrating) particles** in the wire produce a **radio wave** which is modulated and boosted so it can carry the signal over a great distance.

When this radio signal reaches another antenna (e.g. aerial on a radio) the **radio waves cause oscillations in the wire**. This produces an alternating current of the **same frequency as the radio signal.**

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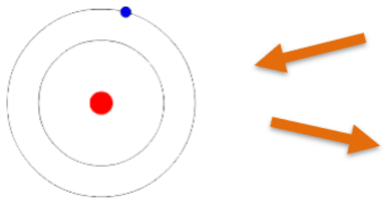
Properties of electromagnetic waves 2

Atoms and electromagnetic waves



Input energy could be:
light, heat, electricity, X rays etc

Energy out will be a type of electromagnetic radiation i.e.
X ray, ultra violet, visible,
infra red, microwave or radio waves.

Changes within the nucleus of an atom can result in the emission of gamma waves. This occurs during the radioactive decay of some unstable atoms.

Atoms can receive energy from external sources.
This energy can cause electrons to "jump" to a **higher energy level**.
When the electron falls back to its original energy level it will release the stored energy in the form of a **photon of electromagnetic radiation.**

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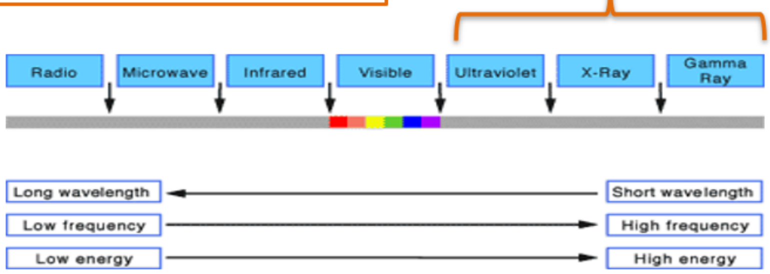
Properties of electromagnetic waves 2

Health risks of high energy electromagnetic radiations

High frequency radiations have **high energy**. They can have a **hazardous** effect on **human tissue**.

UV, X ray and gamma waves are high energy radiations.



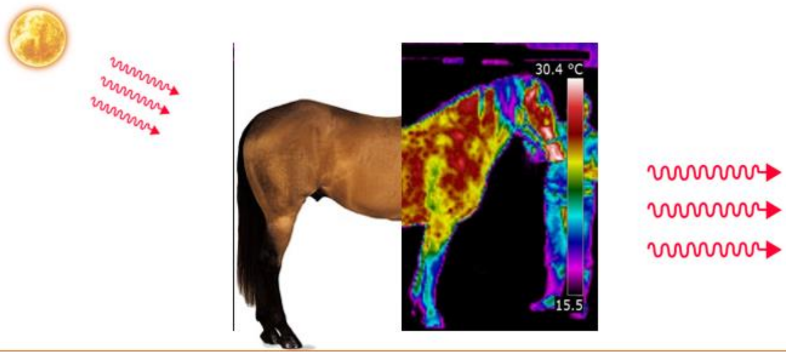
The hazard from high energy radiations also depends on the **dose**.
Radiation dose is a measure of the risk when exposed to these radiations.
Radiation dose is **measured in Sieverts**.
Ultra violet waves can cause sunburn, ageing of the skin and skin cancer.
X rays and gamma rays are ionising radiations that can cause mutations of genes which could result in cancer.

Uses and applications of electromagnetic waves 2

	Type	Application	Suitability (HT)
Low frequency low wavelength ↑	Radio	Television and radio	Travel through atmosphere for long distances
	Microwave	Satellite communications. Cooking food	Travel through atmosphere; agitates water molecules causing them to heat food
	Infrared	Electrical heaters, cooking food, infrared cameras	Heat energy transfer; detection of heat waves
	Visible	Fibre optic communications	Retina can detect light waves; light can travel through optic fibres and carry information
	Ultraviolet	Energy efficient lamps, sun tanning	Some materials can absorb UV and re-emit as visible, energy efficient, skin reacts to UV light causing tanning
	X-rays	Medical imaging and treatment	Pass through soft tissue, penetrate materials to different extents so can produce image
↓ High frequency short wavelength	Gamma rays	Medical imaging and treatment	Kill tissue ; tracers can produce images of internal organs.

Black body radiation (physics only)

All objects (bodies) absorb and reflect infrared radiation. The hotter the object is, the more infrared radiation it emits.



An infrared detecting camera is needed to "see" the heat radiated by the horse

Q1.

The diagram below shows types of waves within the electromagnetic spectrum.

Some of the types of waves are represented by letters.

P	**microwaves**	**Q**	**visible light**	**R**	**S**	**gamma rays**

(a) Which letter shows the position of ultraviolet (UV) radiation within the electromagnetic spectrum?

Tick **one** box.

P ☐ **Q** ☐ **R** ☐ **S** ☐

(1)

(b) A special lamp can produce UV radiation.

Which **two** statements describe the electromagnetic waves emitted by a UV lamp?

Tick **two** boxes.

They have a higher frequency than X-rays.	☐
They have the same wave speed as visible light.	☐
They have a longer wavelength than microwaves.	☐
They have a lower frequency than gamma rays.	☐
They have a greater wave speed than radio waves.	☐

(2)

(c) UV radiation is used to treat a vitamin D deficiency.

People should **not** use a UV lamp for long periods of time.

State **two** risks of exposure to high levels of UV radiation.

1. ____

____

2. ____

(2)

(d) Ionising radiation is used for some medical imaging.

Name **two** types of electromagnetic waves that are used.

1. ______________________________

2. ______________________________

(2)

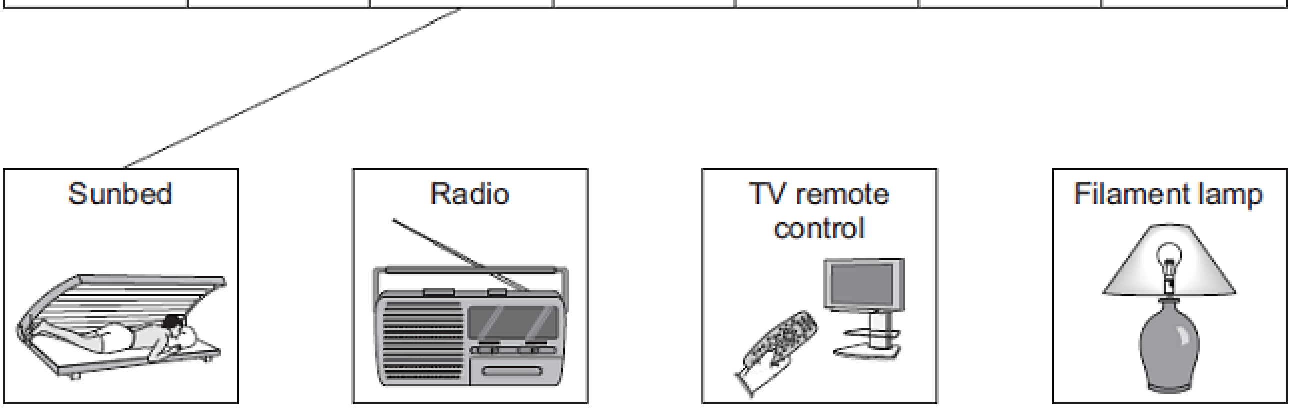
(Total 7 marks)

Q2.

(a) The diagram shows the electromagnetic spectrum.
The pictures show four devices that use electromagnetic waves. Each device uses a different type of electromagnetic wave.

Draw a line from each device to the type of electromagnetic wave that it uses. One has been done for you.

Gamma rays	X-rays	Ultraviolet rays	Visible light	Infra red rays	Microwaves	Radio waves



(3)

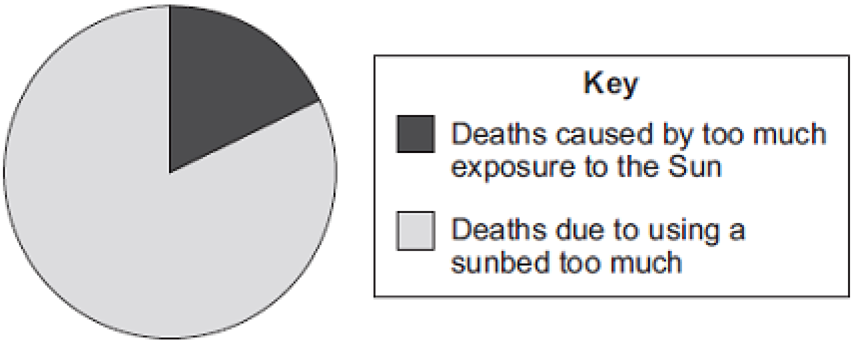
(b) A headline from a recent newspaper article is shown below.

(i) What serious health problem may be caused by using a sunbed too much?

____

(1)

(ii) The pie chart compares the number of deaths in Britain each year which may have been caused by using sunbeds too much, with those which may have been caused by too much exposure to the Sun.



It is difficult for a doctor to be certain that a person has died because of using a sunbed too much.

Suggest why.

____

____

(1)

(iii) A spokesperson for a leading cancer charity said:

> 'We want people, especially young people, to know the possible dangers of using a sunbed.'

Why is it important that you know the possible dangers of using a sunbed?

____

____

(1)
(Total 6 marks)

Q3.

(a) Complete the sentences.

Choose the answers from the box.

ionising	**light**	**sound**	**transmitted**	**waves**

X-rays travel at the speed of ____________________ .

X-rays can cause cancer because they are ____________________ .

(2)

(b) How do X-rays compare with gamma rays?

Tick **one** box.

X-rays have a longer wavelength and a higher frequency ☐

X-rays have a longer wavelength and a lower frequency ☐

X-rays have a shorter wavelength and a higher frequency ☐

X-rays have a shorter wavelength and a lower frequency ☐

(1)

A scientist measured the radiation dose that a person received at different distances from an X-ray machine.

The table shows the results.

Distance from machine in m	**Dose in millisieverts/**			**Mean dose in millisieverts**
	Test 1	**Test 2**	**Test 3**	
0.5	0.152	0.146	0.155	0.151
1.0	0.039	0.035	0.040	**X**
1.5	0.017	0.018	0.017	0.017
2.0	0.012	0.007	0.007	0.009
2.5	0.007	0.006	0.005	0.006

(c) Calculate value **X** in the table.

___

___

___

Mean dose = ____________________ millisieverts

(2)

(d) What conclusion can be made from the results in the table?

Tick **one** box.

The dose decreases if you stand further from the machine. ☐

The dose is directly proportional to the distance. ☐

The dose is the same at all distances from the machine. ☐

There is a linear relationship between dose and distance. ☐

(1)

(e) An X-ray gives a radiation dose of 0.180 millisieverts.

Natural sources give a dose of 0.012 millisieverts per day.

Calculate the time it would take for natural sources to give a dose of 0.180 millisieverts.

___

___

___

Time = ____________________ days

(2)

(f) Suggest why doctors use X-rays even though this increases the risk of cancer to the patient.

___

___

(1)

(g) X-rays can also be used to treat cancer.

A patient receives a dose of 20 millisieverts from an X-ray.

Proton beam therapy delivers 40% of this dose.

Calculate the dose delivered by proton beam therapy.

___

___

___

Dose = ____________________ millisieverts

(2)

(Total 11 marks)

Q4.

Infrared and microwaves are two types of electromagnetic radiation.

(a) State **one** example of the use of each type of radiation for communication.

Infrared: ______________________

Microwaves: ___________________

(2)

(b) Some of the properties of infrared and microwaves are the same.

State **two** of these properties.

1. ___

___

2. ____

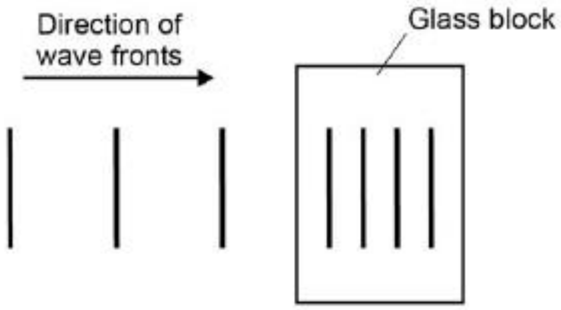
____

(2)
(Total 4 marks)

Q5.

Figure 1 is a wave front diagram showing light travelling through the air and into a glass block.

Figure 1

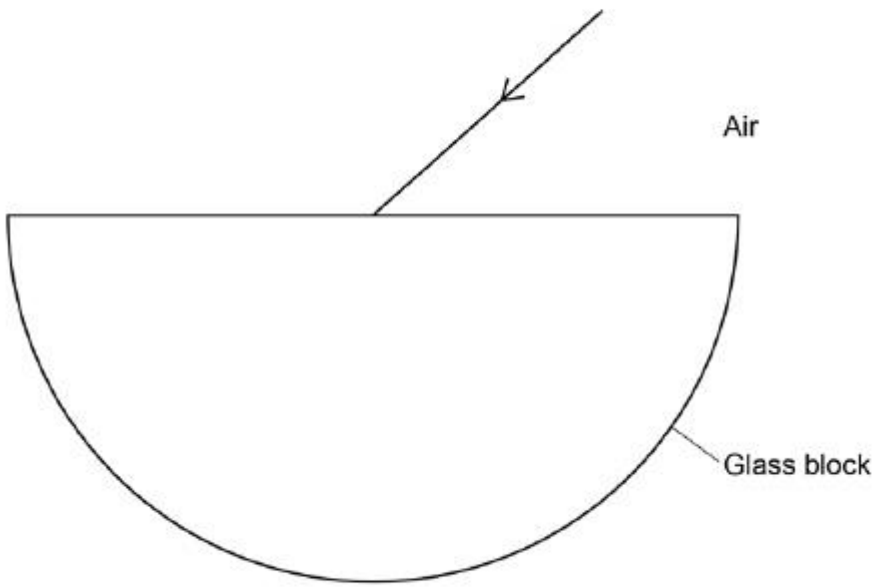


(a) Complete **Figure 1** by drawing wave fronts after they have left the glass block.

(1)

(b) **Figure 2** shows a ray of light incident on a semi-circular glass block.

Figure 2



Complete the ray diagram in **Figure 2**.

- Draw the ray of light passing through and leaving the glass block.
- Label the angle of refraction.

(4)

(c) Explain why the light is refracted.

(2)

(d) A student investigated how different coloured light was refracted by glass.

The student aimed rays of different coloured light at a glass block.

She measured the angle of refraction for each colour.

Give **two** variables that the student should control.

1. ______________________________

2. ______________________________

(2)

The table shows the student's results.

Colour of light	**Angle of refraction in degrees**
Red	27.94
Orange	27.90
Yellow	27.82
Green	27.78
Blue	27.70

(e) Explain why these results could **not** have been obtained with a normal protractor.

(2)

(f) What conclusion can be made about the relationship between the wavelength of light and the angle of refraction?

(1)

(g) Glass does **not** transmit ultraviolet radiation.

Suggest what happens to ultraviolet radiation when it is incident on glass.

____

____

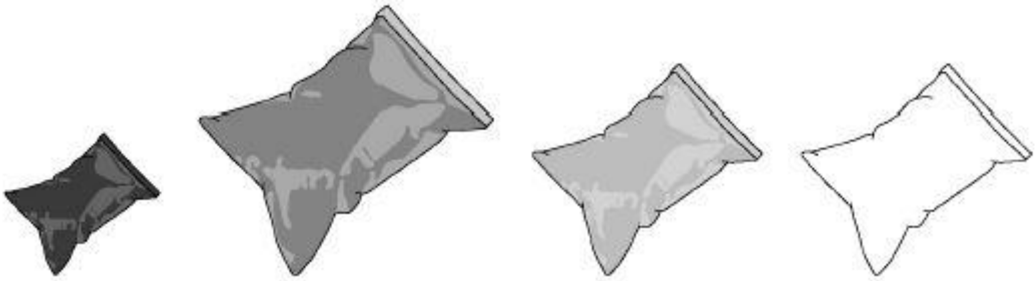
(1)
(Total 13 marks)

Q6.

A solar water bag can be used to heat water for an outdoor swimming pool.

A student wanted to find out if the colour of the solar water bag affects the temperature increase of the water inside the bag.

The diagram below shows some of the equipment used.



This is the method used.

1. Fill each bag with water.
2. Place the four bags on the ground outside.
3. After three hours, measure the temperature of the water inside each bag.
4. Repeat steps 1−3 on the next two days.

(a) Suggest three changes the student should make to this method to get valid results.

1. ____

____

2. ____

____

3. ____

____

(3)

The student repeated the investigation using an improved method.

The results obtained were valid.

The table below shows the results.

Colour of	**Temperature increase in °C**

bag	Day 1	Day 2	Day 3	Mean
Black	44.0	31.4	43.4	39.6
Pale blue	38.5	23.6	38.1	33.4
Pale green	37.9	23.7	37.7	33.1
White	25.3	23.4	24.2	**X**

(b) The student used a thermometer to measure the temperature of the water inside each bag.

What was the resolution of the thermometer?

Resolution = ____________ °C

(1)

(c) Suggest **one** reason why the temperatures increased less on Day 2 than on Day 1 and Day 3.

___

___

(1)

(d) Calculate the mean temperature increase for the white bag.

___

___

Mean temperature increase = ____________ °C

(1)

(e) Which colour of bag would be best to use to heat water?

Give a reason for your answer.

Colour ___

Reason ___

___

___

___

(2)

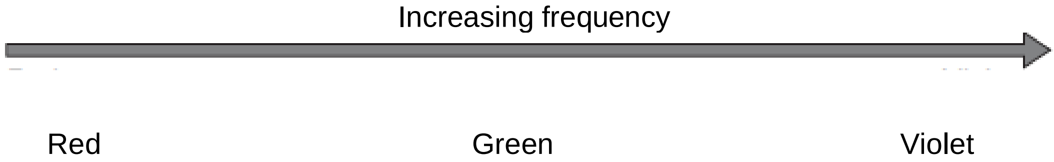
(Total 8 marks)

Q7.

(a) The visible light spectrum has a range of frequencies.

Figure 1 shows that the frequency increases from red light to violet light.

Figure 1



Use the correct answers from the box to complete the sentence.

decreases	**stays the same**	**increases**

As the frequency of the light waves increases, the wavelength

of the light waves ______________________________ and

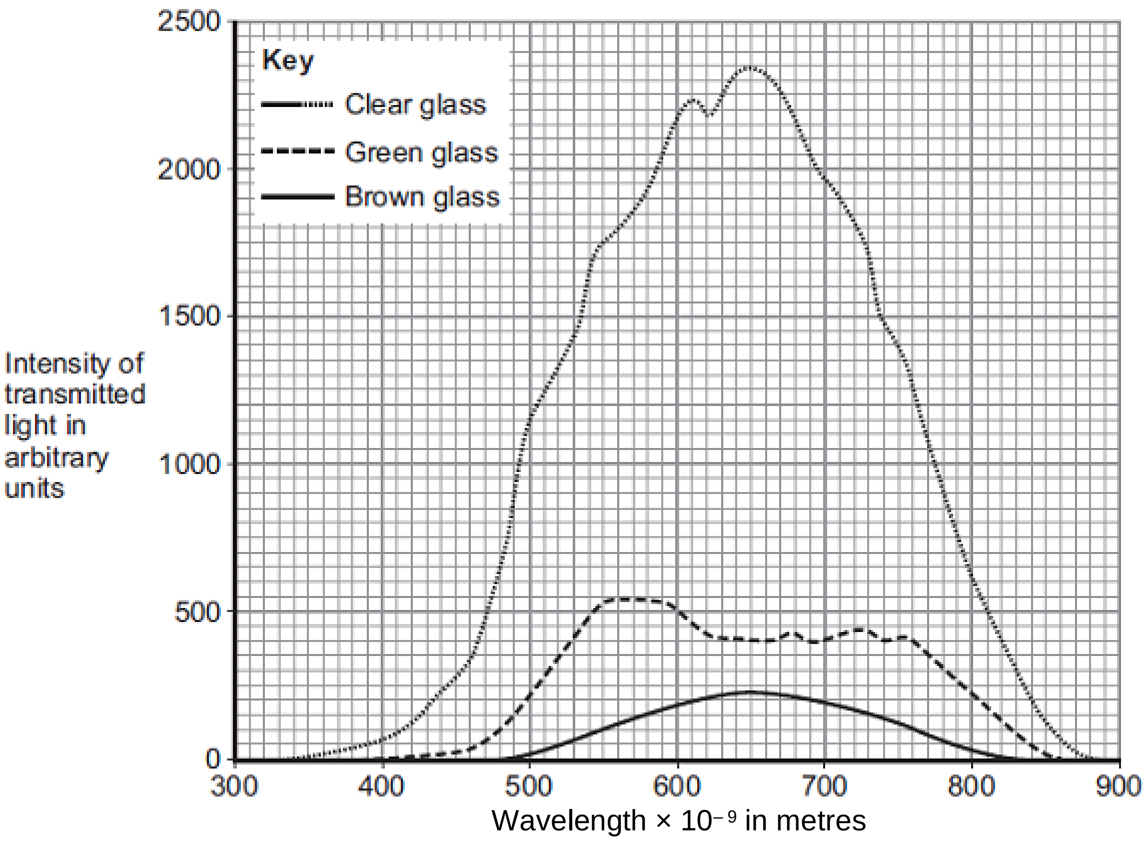
the energy of the light waves ______________________________ .

(2)

(b) Bottled beer will spoil if the intensity of the light passing through the glass bottle into the beer is too high.

Figure 3 shows the intensity of the light that is transmitted through three different pieces of glass.

Figure 3



(i) The pieces of glass all had the same thickness.

Suggest why.

(1)

(ii) Bottles made of brown glass are suitable for storing beer.

Suggest why.

(1)
(Total 4 marks)