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EDEXCEL INTERNATIONAL GCSE PHYSICS: QUESTIONS BY TOPIC

Waves (3)

IGCSE Physics Topic 3

51 questions · 463 marks · Mark schemes included

Pearson Edexcel International GCSE (9-1) Physics 4PH1, Papers 1P/1PR & 2P/2PR, 2019-2025

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 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

51 questions · 463 marks · 4 sub-topics



SUB-TOPIC 3.1

WAVE PROPERTIES, THE WAVE EQUATION AND THE DOPPLER EFFECT

Sub-topic 3.1 · 12 questions · 86 marks · lowest tariff first



- 5** A toy produces continuous waves when floating on the surface of a pool of water.

The waves spread out as circular wavefronts.

Diagram 1 shows the wavefronts produced when the toy is not moving, as viewed from above.

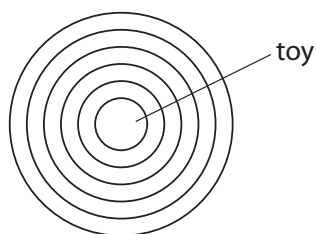


Diagram 1

Diagram 2 shows the wavefronts produced when the toy is moving across the surface of the pool of water.

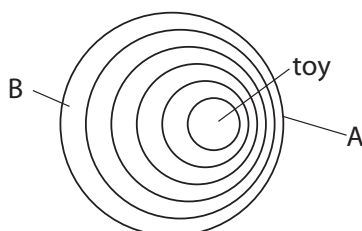


Diagram 2

- (a) Draw an arrow on diagram 2 to show the direction the toy is moving.

(1)



(b) Explain how the frequency of the waves at point A is different to the frequency of the waves at point B.

(4)

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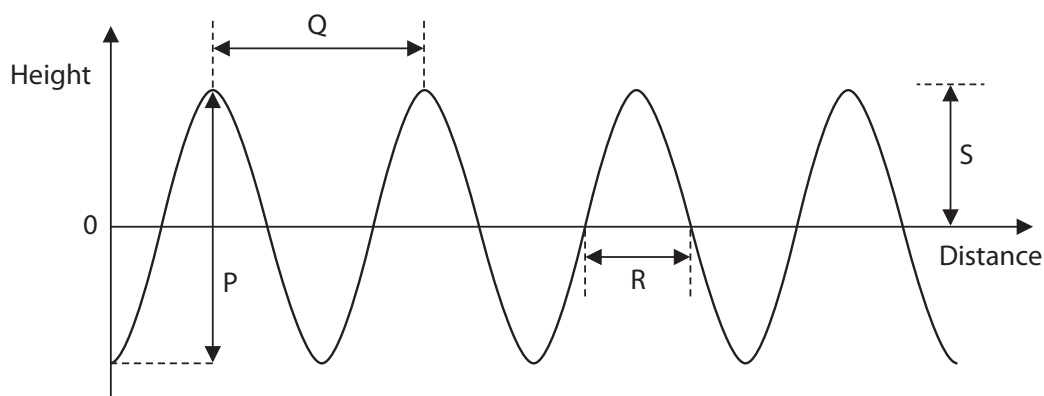
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(Total for Question 5 = 5 marks)



1 The diagram represents a water wave travelling on the surface of some water.



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

(1)

- ☐ A P
- ☐ B Q
- ☐ C R
- ☐ D S

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

(1)

- ☐ A P
- ☐ B Q
- ☐ C R
- ☐ D S

(c) What type of wave is this water wave?

(1)

- ☐ A electromagnetic
- ☐ B gravitational
- ☐ C longitudinal
- ☐ D transverse

(d) The time period of the wave is 2.7 s.

Calculate the frequency of the wave.

(2)

frequency= Hz

(Total for Question 1 = 5 marks)

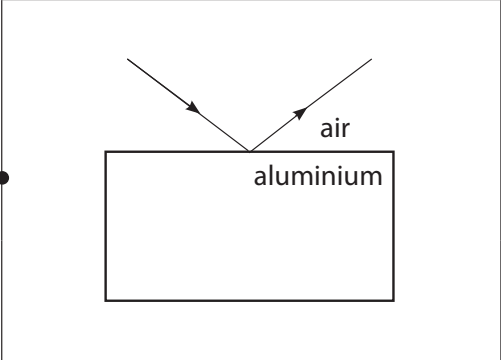
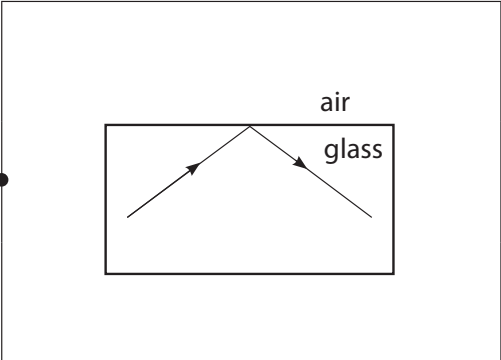
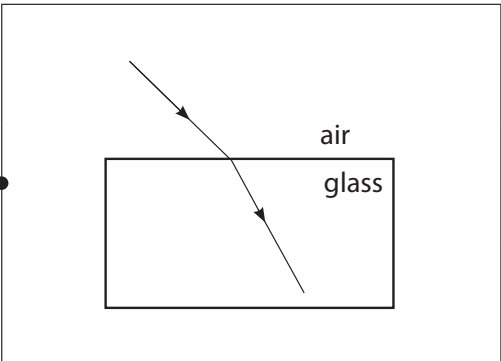


1 This question is about wave behaviour.

- (a) The boxes give three types of wave behaviour and the diagrams give three examples of wave behaviour.

Draw one straight line from each wave behaviour to the example that best shows that behaviour.

(3)

Wave behaviour	Example
total internal reflection	
refraction	
reflection	

(b) State two properties that all waves have in common.

(2)

1

2

(Total for Question 1 = 5 marks)



2 X-rays are electromagnetic waves used to obtain images of bones.

An x-ray machine produces x-ray waves with a frequency of 1.25×10^{18} Hz.

(a) Calculate the time period of these x-rays.

(2)

time period = ... s

(b) X-rays have a speed of 3.00×10^8 m/s in air.

Calculate the wavelength of these x-rays.

(3)

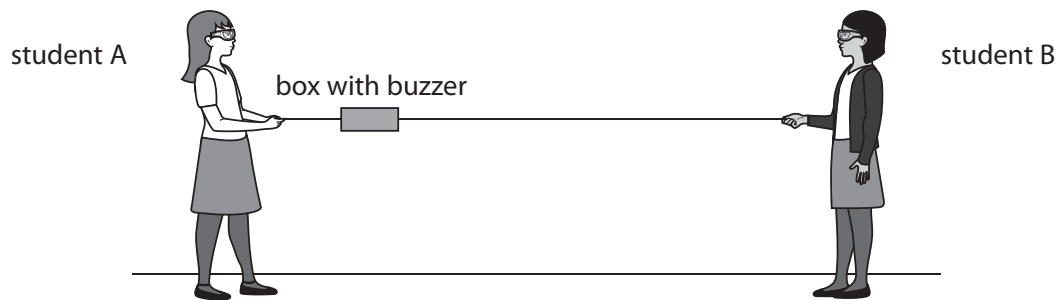
wavelength = ... m

(Total for Question 2 = 5 marks)



9 The diagram shows two students holding a piece of string with a box attached.

The box has a buzzer inside and can move along the string.



The buzzer in the box emits a loud sound of constant frequency.

The box moves **away** from student A at a constant speed.

Explain why the sound heard by student A has a different frequency to the sound emitted by the buzzer.

(5)

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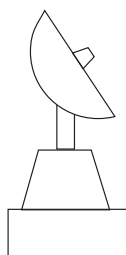
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(Total for Question 9 = 5 marks)

5 This question is about using radio waves to track an aeroplane.



aeroplane



aerial at airport

- (a) Radio waves are emitted from an aerial at an airport, and are then reflected back to the aerial from an aeroplane.

The time taken between emitting the radio waves and receiving the waves back at the aerial is 1.9 milliseconds.

Show that the aeroplane is approximately 300 km away from the aerial.

[speed of radio waves = 3.0×10^5 km/s]

(3)

- (b) As the aeroplane travels away from the airport, it sends a signal to the airport using radio waves with a wavelength of 1.2 m.

When the signal is received at the airport, the wavelength is 1.1×10^{-6} m longer than when it is emitted by the aeroplane.

Calculate the speed of the aeroplane using the formula

$$\frac{\text{change of wavelength}}{\text{wavelength}} = \frac{\text{speed of aeroplane}}{\text{speed of radio wave}}$$

[speed of radio waves = 3.0×10^8 m/s]

(3)

speed of aeroplane = ... m/s

(Total for Question 5 = 6 marks)



8 A car is moving along a road.

(a) The car has an initial velocity of 26 m/s .

The car then accelerates at 1.2 m/s^2 until it reaches a velocity of 35 m/s .

(i) State the formula linking acceleration, change in velocity and time taken.

(1)

(ii) Calculate the time taken for the car to accelerate to 35 m/s .

(3)

time = ... s



(b) A radar speed gun is used to measure the speed of the moving car.



© Petar An/Shutterstock

The radar speed gun emits radio waves towards the moving car.

The moving car reflects the radio waves back to a detector on the gun.

The detected radio waves have a different frequency from the emitted radio waves.

This change in frequency is used to measure the speed of the moving car.

Explain this change in frequency when the car is moving towards the radar speed gun.

(4)

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(Total for Question 8 = 8 marks)

- 4 Ground-penetrating radar (GPR) uses radio waves to detect changes in material underground.

(a) (i) State the formula linking the speed, frequency and wavelength of a wave.

(1)

(ii) GPR radio waves have a frequency of 170 MHz.

The speed of radio waves is $3.0 \times 10^8 \text{ m/s}$.

Calculate the wavelength of the waves.

(3)

wavelength = ... m

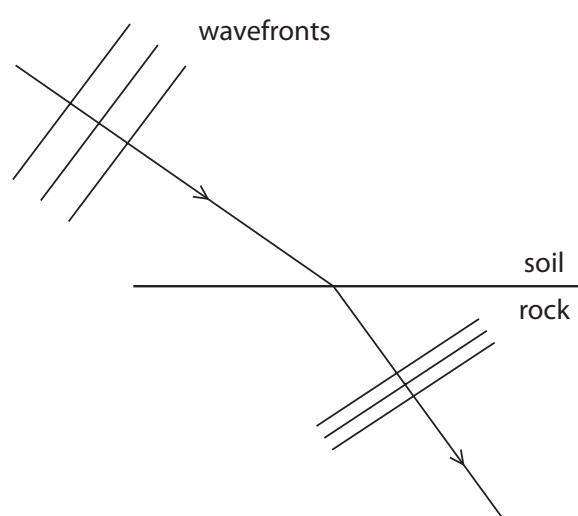
(b) (i) A radio wave passes through the ground and refracts at the boundary between soil and rock.

The diagram shows three wavefronts of the wave before and after refraction.

The wave is also reflected at the boundary between the soil and the rock.

Complete the diagram to show three wavefronts after the wave has been reflected at the boundary.

(3)



- (ii) Explain why the radio waves passing through the rock have a smaller wavelength than the radio waves passing through the soil.

(3)

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(Total for Question 4 = 10 marks)



8 A student uses a ripple tank to investigate water waves.

Diagram 1 shows the ripple tank when viewed from the side.

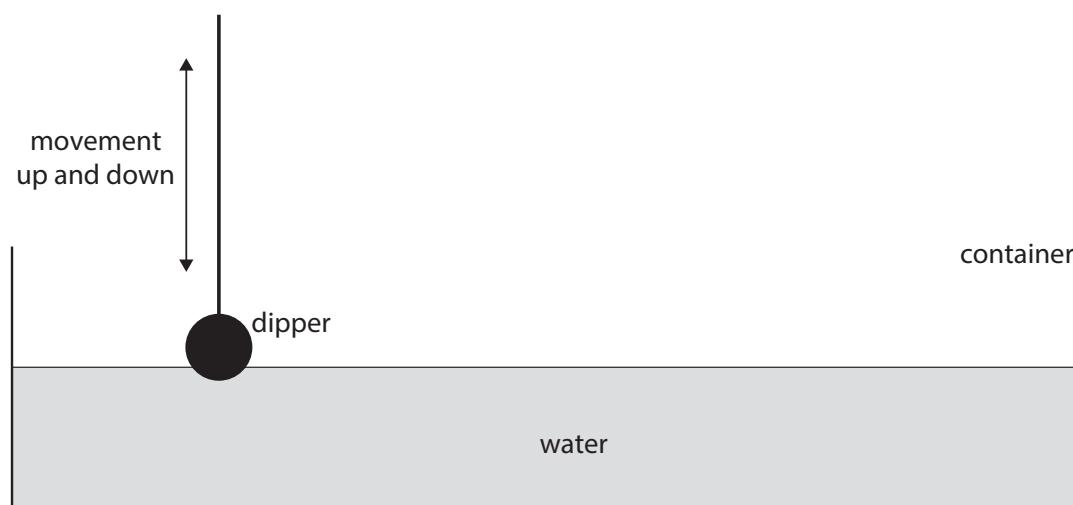


Diagram 1

A dipper moves up and down to produce waves on the surface of the water in the container.

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

State what is meant by a **transverse wave**.

You may draw a diagram to help your answer.

(2)

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- (b) Diagram 2 shows the surface of the ripple tank, at an instant in time, when viewed from above.

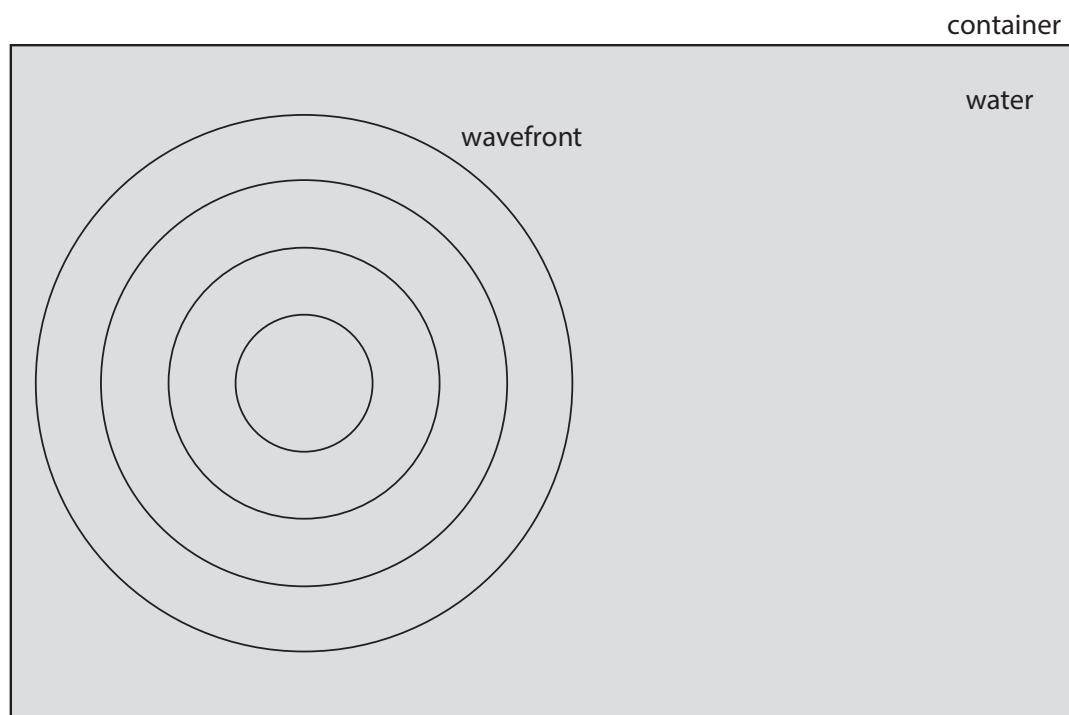


Diagram 2

The dipper produces circular waves on the surface of the water.

- (i) 1 cm in diagram 2 is equal to 2 cm in the laboratory.

Use the diagram to measure the wavelength of the water waves.

(2)

wavelength = ... cm

- (ii) The dipper moves up and down with a frequency of 15 Hz.

Calculate the speed of the waves.

(3)

wave speed = ... m/s



- (c) The student then makes the dipper move horizontally to the right at constant speed.

The dipper continues to move up and down with a frequency of 15 Hz.

Diagram 3 shows the surface of the ripple tank, at an instant in time, when viewed from above.

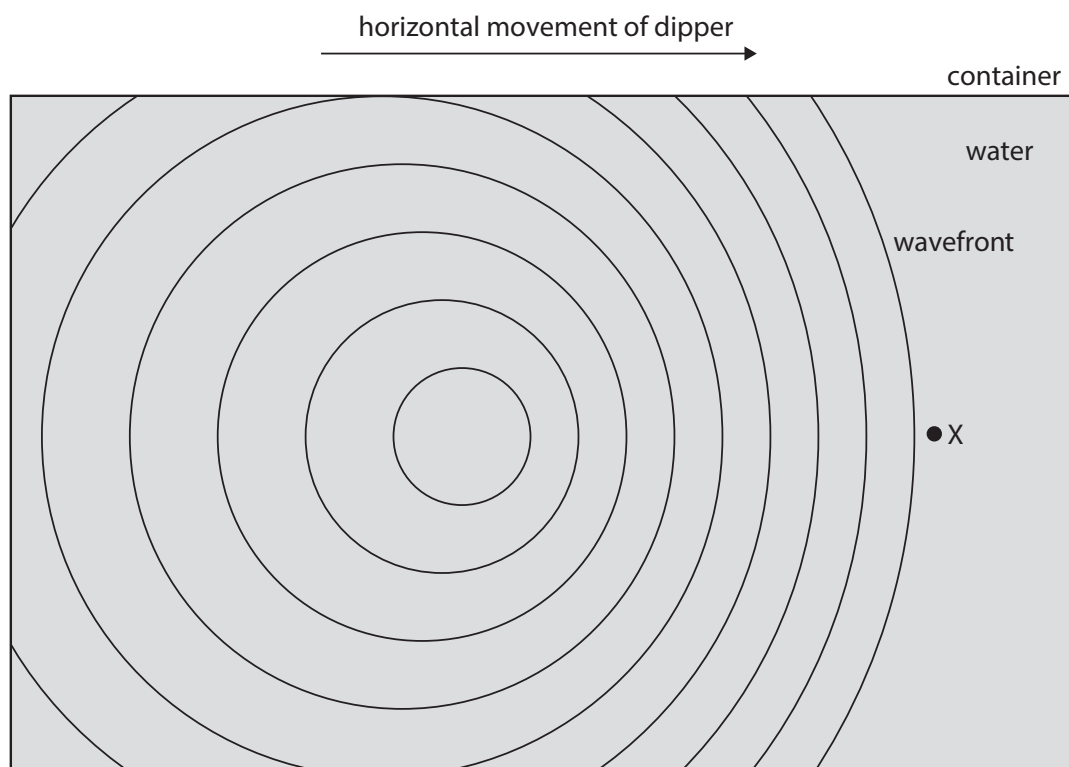


Diagram 3

Explain how the frequency of the waves arriving at point X compares with the frequency at which the dipper moves up and down.

(4)

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(Total for Question 8 = 11 marks)

11 A ball is moving through the air with a speed of 54.8 m/s. The ball has a mass of 159 g.

(a) Calculate the energy in the kinetic store of the ball.

Give your answer to 3 significant figures.

(4)

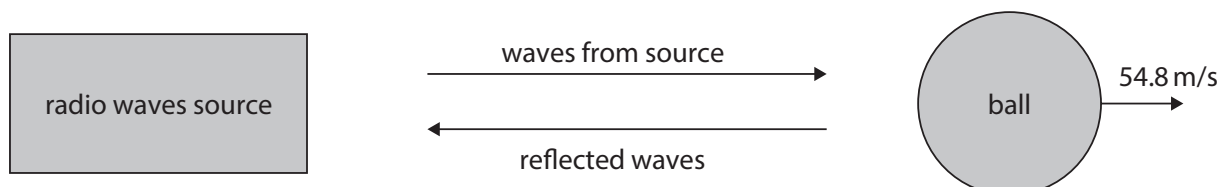
energy in kinetic store = ... J

(b) The speed of the ball is measured using radio waves.

Radio waves of frequency 2.90×10^{10} Hz travel towards the ball from a source.

The radio waves then reflect off the ball.

The reflected radio waves change frequency depending on the speed of the ball. This change in frequency is due to the Doppler effect.



- (i) The change in frequency can be calculated using this formula.

$$\text{speed of ball} = \frac{\text{change of frequency}}{\text{source frequency}} \times \frac{\text{speed of radio waves}}{2}$$

Show that the change in frequency of the radio waves is approximately $1.1 \times 10^4 \text{ Hz}$.

[speed of radio waves = $3.00 \times 10^8 \text{ m/s}$]

(3)

- (ii) The change in frequency of the radio waves happens because the ball acts as a new source of radio waves.

The ball is moving away from the original source of radio waves.

Explain the change in frequency of the radio waves when the radio waves reflect off the ball.

(3)

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(Total for Question 11 = 10 marks)



6 This question is about cosmic microwave background radiation (CMBR) and the Big Bang.

(a) CMBR has a mean frequency of 1.6×10^{11} Hz.

(i) State the formula linking wave speed, frequency and wavelength.

(1)

(ii) Show that the mean wavelength of CMBR is about 2 mm.

[speed of light = 3.0×10^8 m/s]

(3)

(b) CMBR was first released after the Big Bang.

When CMBR was first released it had a wavelength of about 9×10^{-5} mm, but now it has a wavelength of about 2 mm.

Using this information, explain how CMBR supports the Big Bang theory.

(2)

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(c) Explain how the cosmological red-shift of galaxies also supports the Big Bang theory.

(4)

(Total for Question 6 = 10 marks)



SUB-TOPIC 3.2

THE ELECTROMAGNETIC SPECTRUM

Sub-topic 3.2 · 9 questions · 69 marks · lowest tariff first



1 The table shows an incomplete electromagnetic spectrum.

radio waves	microwaves	A	visible light	B	x-rays	gamma rays
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Two parts of the electromagnetic spectrum are missing.

The missing parts are labelled A and B.

(a) (i) Name the part labelled A.

(1)

(ii) Name the part labelled B.

(1)

(b) (i) Give a use of microwaves.

(1)

(ii) Give a use of gamma rays.

(1)

(Total for Question 1 = 4 marks)



1 This question is about waves.

(a) (i) Which of these waves is longitudinal?

(1)

- ☐ A infrared
- ☐ B radio
- ☐ C sound
- ☐ D ultraviolet

(ii) Draw a straight line linking each electromagnetic wave to its correct hazard.

(2)

Electromagnetic wave

Hazard

microwave

skin burns

blindness

infrared

internal heating
of body tissue

cell mutation

(b) (i) Which of these is a use for x-rays?

(1)

- ☐ A checking for broken bones
- ☐ B cooking food
- ☐ C detecting forged banknotes
- ☐ D smoke detectors



(ii) Which of these is a use for infrared waves?

(1)

- ☐ **A** checking for broken bones
- ☐ **B** cooking food
- ☐ **C** detecting forged banknotes
- ☐ **D** sterilising medical instruments

(Total for Question 1 = 5 marks)



1 This question is about electromagnetic (EM) waves.

(a) The boxes show some EM waves and their uses.

Draw one straight line from each EM wave to its correct use.

One has been done for you.

(3)

EM wave		Use
gamma	●	● long range communication
infrared	●	● cooking
radio waves	●	● sterilising food
ultraviolet	●	● observing internal structures
x-rays	●	● fluorescent lamps

(b) Which of these is a hazard of microwave radiation?

(1)

- ☒ A blindness
- ☒ B cell mutation
- ☒ C internal heating of tissue
- ☒ D skin burns

(c) State the name of an electromagnetic wave with a wavelength longer than microwave radiation.

(1)

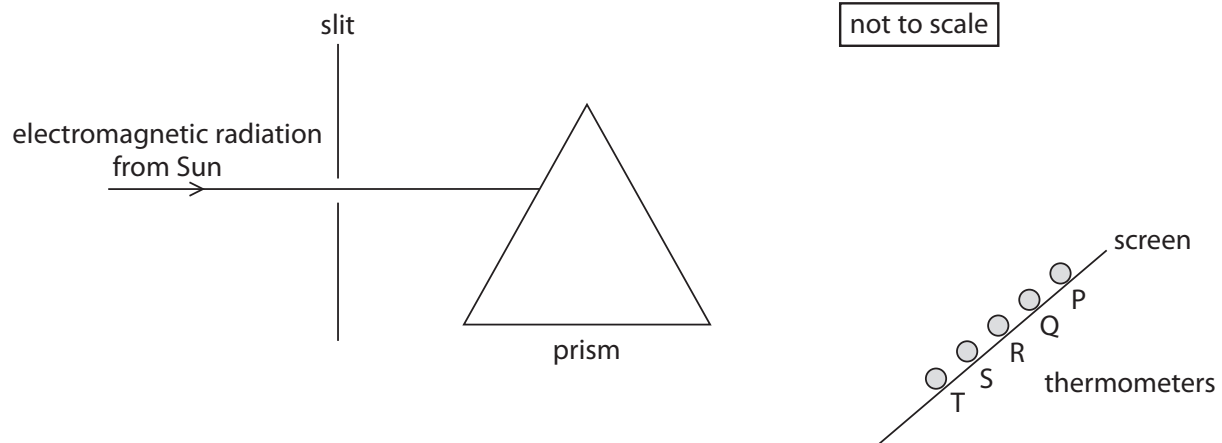
(Total for Question 1 = 5 marks)

- 2 The diagram shows the apparatus used to demonstrate the existence of electromagnetic radiation just beyond the visible spectrum.

Electromagnetic radiation from the Sun passes through a slit and a prism.

The electromagnetic radiation refracts through the prism onto the screen.

Five thermometers are placed in front of the screen.



- (a) Complete the table to show the missing parts of the electromagnetic spectrum.

(3)

Thermometer	Part of electromagnetic spectrum
P	
Q	red light
R	
S	violet light
T	

(b) Suggest why the lower part of each thermometer should be painted black.

(2)

(c) The equipment is left for a short period of time.

The thermometers now show higher temperatures than before.

State the part of the electromagnetic spectrum in this demonstration that would give the largest temperature increase.

(1)

(Total for Question 2 = 6 marks)



1 The photograph shows a security camera.

The camera detects light waves and sound waves.



(a) State two differences between light waves and sound waves.

(2)

1

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2

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(b) The camera detects infrared waves, which allow the camera to record videos in the dark.

(i) Which of these electromagnetic waves has a longer wavelength than infrared waves?

(1)

- ☐ A gamma rays
- ☐ B microwaves
- ☐ C ultraviolet rays
- ☐ D visible light waves

(ii) Which of these is another use for infrared waves?

(1)

- ☐ A fluorescent lamps
- ☐ B heating lamps
- ☐ C satellite transmissions
- ☐ D sterilising medical equipment

(iii) Which of these is a harmful effect of infrared waves?

(1)

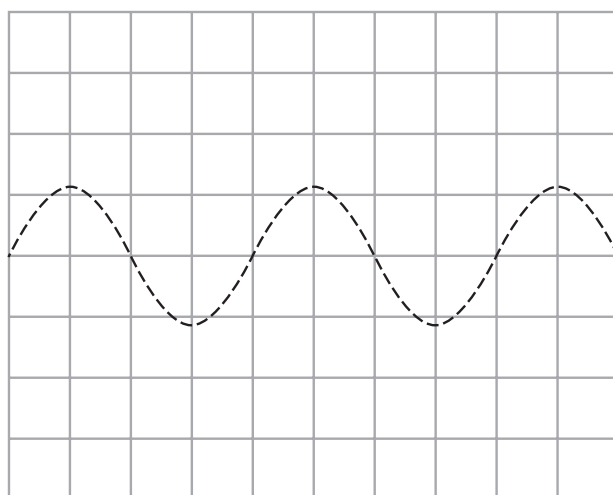
- ☐ A blindness
- ☐ B cancer
- ☐ C internal heating of body tissue
- ☐ D skin burns

(c) The grid shows the oscilloscope trace for a quiet, low-pitch sound wave.

The security camera has an alarm that produces a loud, high-pitch sound.

On the grid, draw a trace to represent the sound wave produced by the alarm.

(2)



(Total for Question 1 = 7 marks)

1 This question is about the electromagnetic spectrum.

(a) The table gives some statements about the electromagnetic spectrum.

Place three ticks (✓) in the table to show which statements are correct.

(3)

Statement	Correct
all electromagnetic waves are longitudinal	
all electromagnetic waves travel at the same speed in free space	
radio waves have the longest wavelength in the electromagnetic spectrum	
x-rays have the highest frequency in the electromagnetic spectrum	
all electromagnetic waves transfer energy	
all electromagnetic waves can cause cancer	



(b) Electromagnetic waves can be useful, but can also be harmful.

(i) Give one use and one harmful effect of microwaves.

(2)

use

harmful effect

(ii) Give one use and one harmful effect of gamma rays.

(2)

use

harmful effect

(Total for Question 1 = 7 marks)



- 3 The photograph shows infrared heating lamps being used to harden fresh paint on a car.



(Source: © Dmitry Kalinovsky / Shutterstock)

- (a) Give a harmful effect of infrared waves.

(1)

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- (b) The heating lamps produce visible light waves in addition to infrared waves.

- (i) Give two similar properties of visible light waves and infrared waves.

(2)

1

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2

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- (ii) Give two differences between the properties of visible light waves and infrared waves.

(2)

1

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2

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- (c) The infrared heating lamps are placed 1.5 m from the car.

Calculate the time taken for infrared waves emitted from a lamp to reach the car.

[for infrared waves, speed = 3.0×10^8 m/s]

(3)

time taken = ... s

- (d) Paint takes less time to harden when it absorbs more energy from infrared radiation.

A technician observes that white paint takes more time to harden than black paint.

Explain this observation.

(2)

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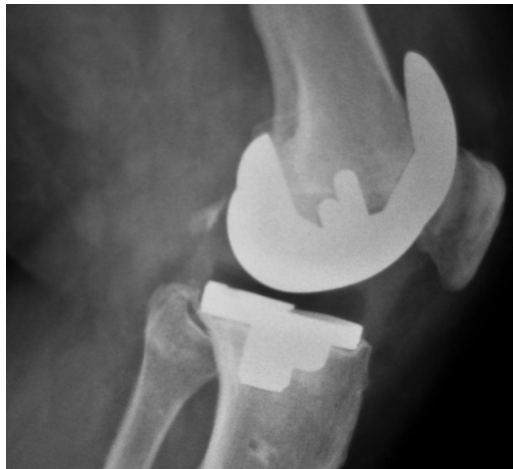
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(Total for Question 3 = 10 marks)



- 6 The photograph shows an x-ray image of a person's knee. The person has had part of their knee replaced.



(Source: © edwardolive/Shutterstock)

- (a) X-rays are part of the electromagnetic spectrum.

All electromagnetic waves are transverse waves and transfer energy.

- (i) State another property that all electromagnetic waves have in common.

(1)

- (ii) State a harmful effect of excessive exposure to x-rays.

(1)

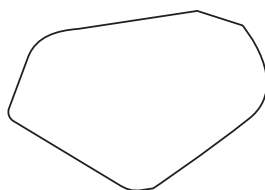
(iii) Describe the difference between transverse waves and longitudinal waves.

You may draw a diagram to help your answer.

(3)



- (b) The diagram shows a part of the knee called the patella. The patella has been removed from a person's knee.



The patella is a small, irregularly shaped bone that is denser than water.

Describe how to find the mass and the volume of the patella bone.

(4)

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(c) A scientist finds the volume and mass of a patella.

The mass of the patella is 17 g.

The volume of the patella is 13 cm^3 .

Calculate the density of the patella.

Give your answer to 2 significant figures.

(4)

density = ... g/cm^3

(Total for Question 6 = 13 marks)



11 Fluorescent tube lamps can be used in schools and office buildings for lighting.

The photograph shows an engineer installing a fluorescent tube lamp.



(Source: © Naparat / Shutterstock)

Diagram 1 shows a simplified view of the components of a fluorescent tube lamp.

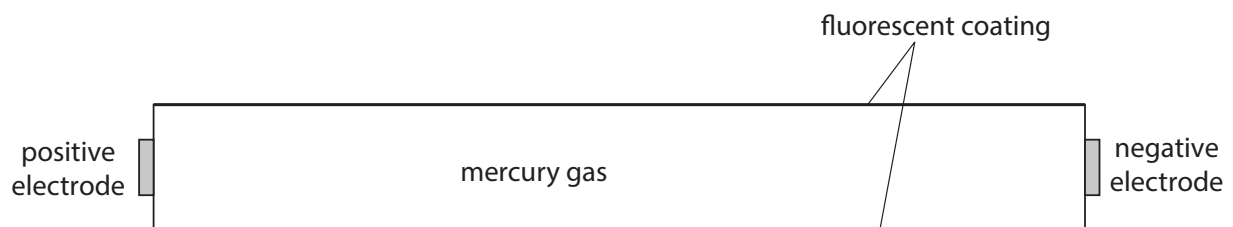


Diagram 1

(a) When the lamp is on, a large voltage is applied between the positive electrode and the negative electrode.

(i) State what is meant by the term **voltage**.

(1)

- (ii) The large voltage causes electrons to accelerate from the negative electrode towards the positive electrode.

An electron gains $1.0 \times 10^{-16} \text{ J}$ of energy when it accelerates between the electrodes.

Show that the voltage between the electrodes is about 600V.

[magnitude of electron charge = $1.6 \times 10^{-19} \text{ C}$]

(3)

- (iii) The electron gains $1.0 \times 10^{-16} \text{ J}$ of energy in its kinetic store when it accelerates from the negative electrode to the positive electrode.

Calculate the speed of an electron when it reaches the positive electrode.

Assume the electron is initially at rest.

[electron mass = $9.1 \times 10^{-31} \text{ kg}$]

(4)

speed = ... m/s



- (b) When the electrons accelerate between the electrodes, they collide with mercury atoms.

Energy is transferred to the mercury atoms during the collisions. This causes the mercury atoms to emit ultraviolet light.

Atoms in the fluorescent coating absorb this ultraviolet light, which is then re-emitted as light from a different part of the electromagnetic spectrum.

Diagram 2 shows this process.

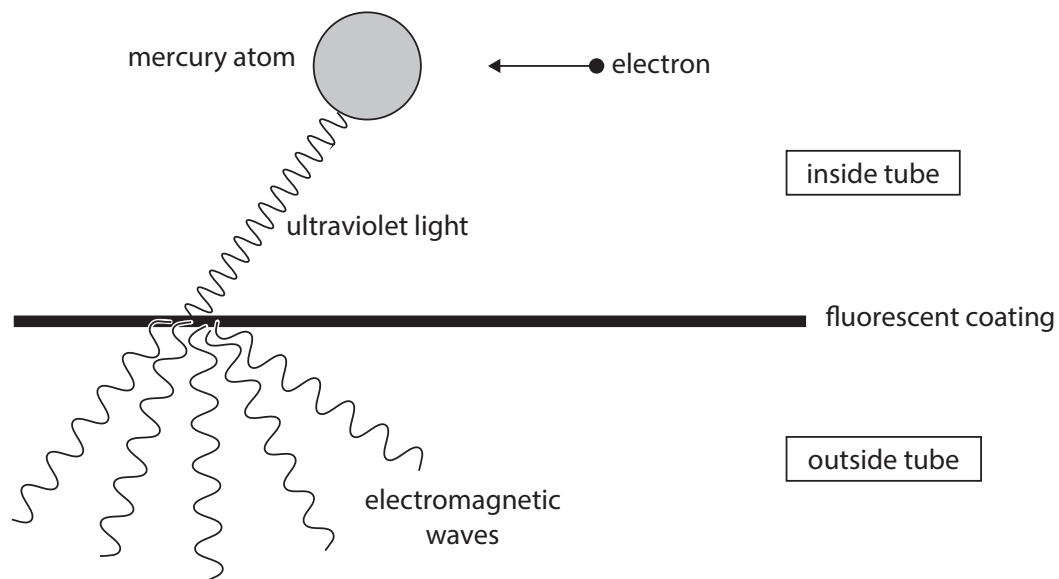


Diagram 2

- (i) Suggest why the tube must have a fluorescent coating for the lamp to operate effectively.

(2)

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- (ii) Explain why the fluorescent tube lamp is dangerous if the fluorescent coating becomes damaged.

(2)

(Total for Question 11 = 12 marks)



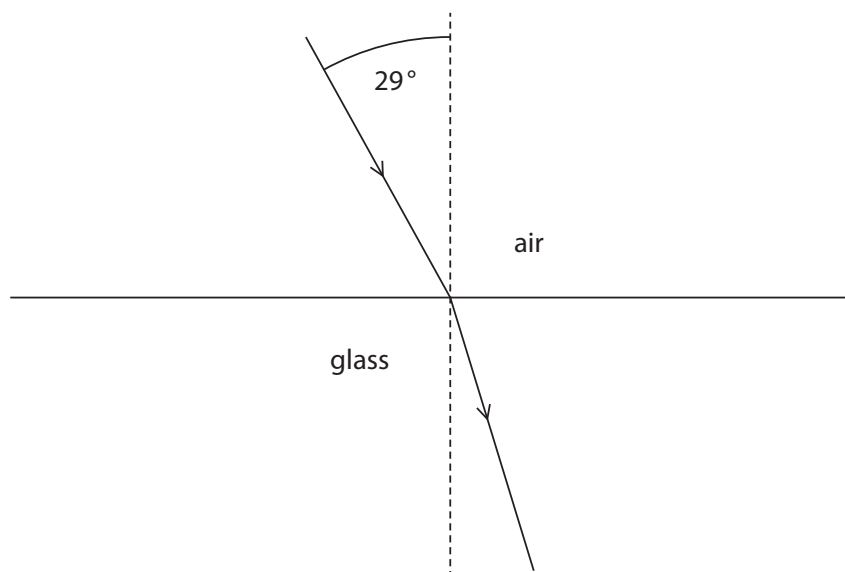
SUB-TOPIC 3.3

REFLECTION, REFRACTION AND TOTAL INTERNAL REFLECTION

Sub-topic 3.3 · 14 questions · 154 marks · lowest tariff first



- 6 The diagram shows a ray of light travelling from air into glass.



- (a) Use a protractor to determine the angle of refraction.

(1)

angle of refraction = ... degrees

- (b) State the formula linking refractive index, angle of incidence and angle of refraction.

(1)

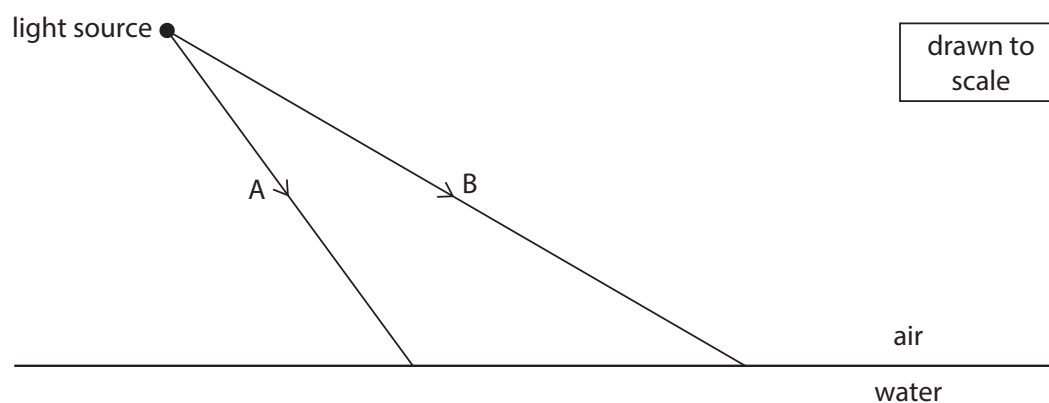
- (c) Calculate the refractive index of this glass.

(3)

refractive index = ...

(Total for Question 6 = 5 marks)

- 8 The diagram shows two rays of light, A and B, incident on the boundary between air and water.



12 This question is about refraction.

- (a) Diagram 1 shows a ray of light incident on the boundary between a liquid called acetone and air.

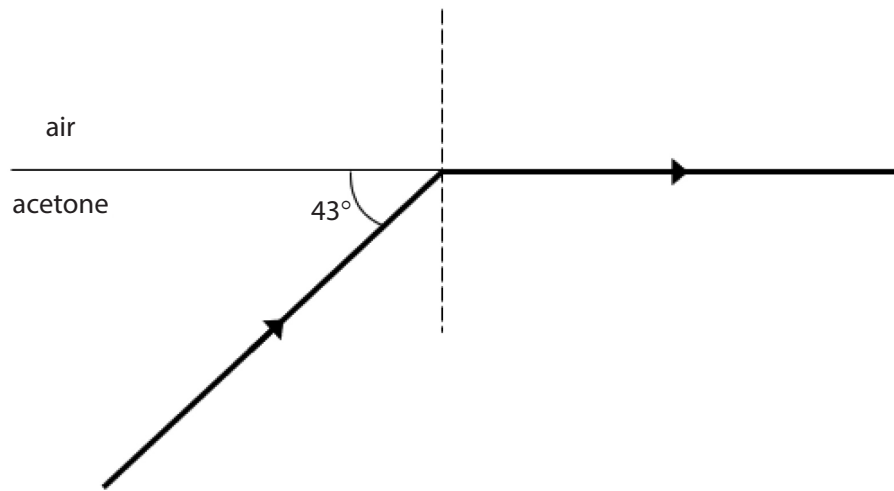


Diagram 1

- (i) Calculate the critical angle for the boundary between acetone, and air.

(1)

critical angle = ... $^\circ$

- (ii) State the formula linking critical angle and refractive index.

(1)

- (iii) Calculate the refractive index of acetone.

(2)

refractive index = ...

(b) Diagram 2 shows a ray of light incident on the boundary between water and air.

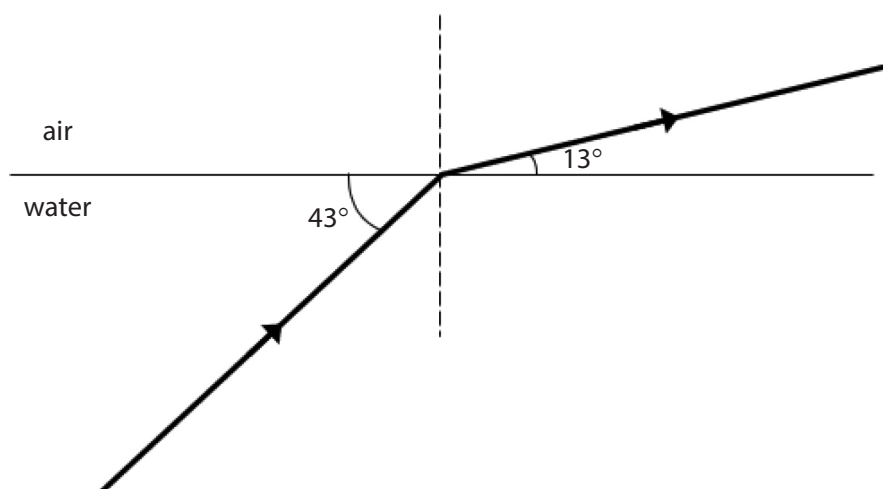


Diagram 2

Explain how the refractive index of water compares to the refractive index of acetone.

(3)

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(Total for Question 12 = 7 marks)

10 This question is about light.

(a) Diagram 1 shows a light ray entering a glass prism.

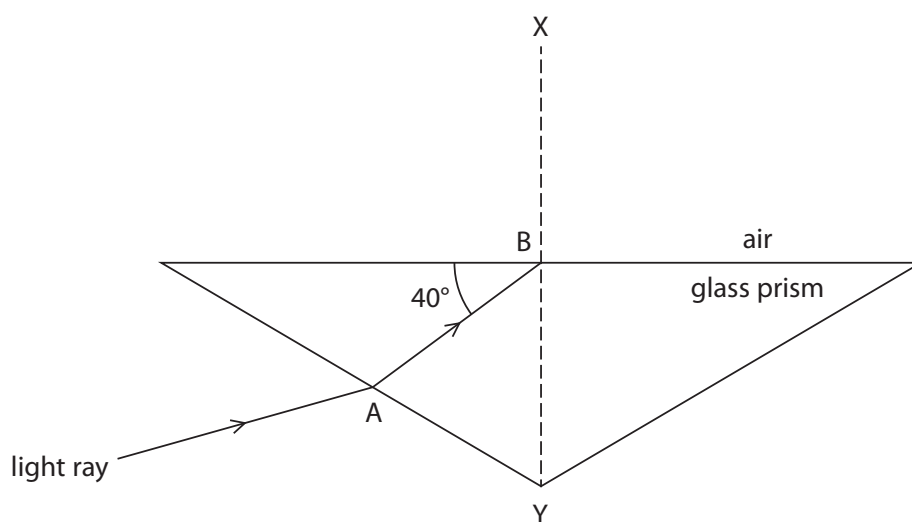


Diagram 1

(i) Describe what happens to the light ray when it enters the prism at point A.

(2)

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.....

.....

(ii) State the name of line XY.

(1)

.....

(iii) State the formula linking critical angle and refractive index.

(1)

(iv) The refractive index for the glass in this prism is 1.6

Calculate the critical angle for the glass in this prism.

(3)

critical angle = ...^o

(v) Complete Diagram 1 by continuing the path of the light ray from point B.

(2)



- (b) Diagram 2 shows a similar prism that is made from a material with a different refractive index.

The critical angle for the material of this prism is 55°

Complete Diagram 2 by continuing the path of the light ray.

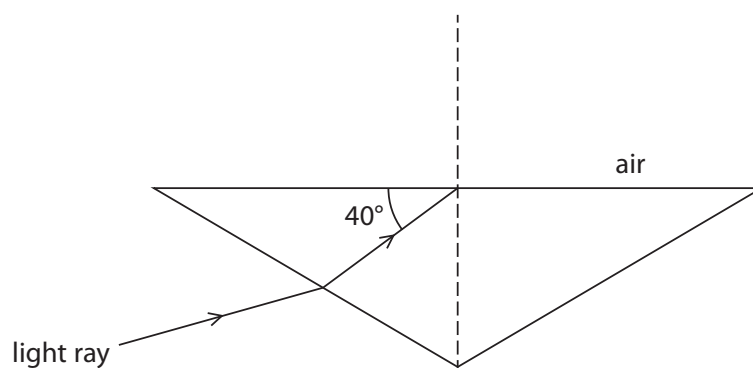


Diagram 2

(2)

(Total for Question 10 = 11 marks)

8 This question is about atmospheric optical illusions.

- (a) A mirage is an optical illusion formed due to total internal reflection of light from the sky at the boundary between cold air and hot air.

Diagram 1 shows how a mirage is formed.

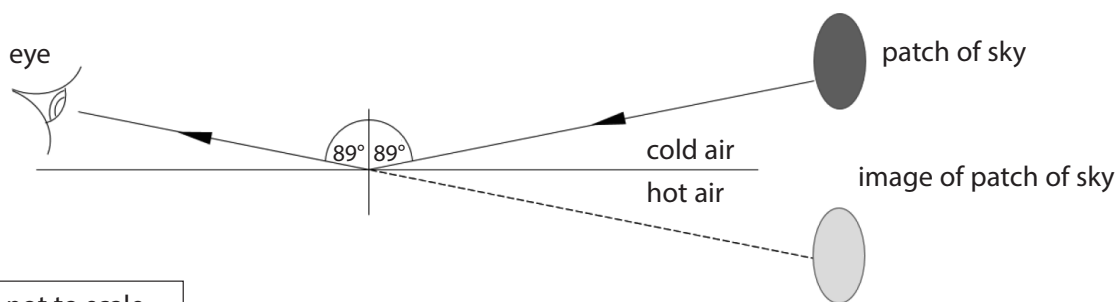


Diagram 1

- (i) State the formula linking critical angle and refractive index.

(1)

- (ii) The critical angle of the cold air at the boundary is 88.500°

Calculate the refractive index of the cold air.

Give your answer to 5 significant figures.

(3)

refractive index = ...

(b) (i) Diagram 2 shows a ray of light from the Sun.

The refractive index of the atmosphere is greater than the refractive index of space.

Complete the diagram by drawing the path of the ray of light through the atmosphere.

(2)

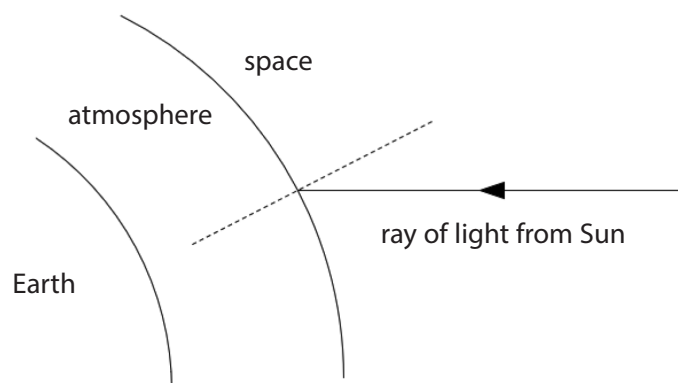


Diagram 2

(ii) Diagram 3 shows a ray of light from the Sun when the Sun is directly overhead.

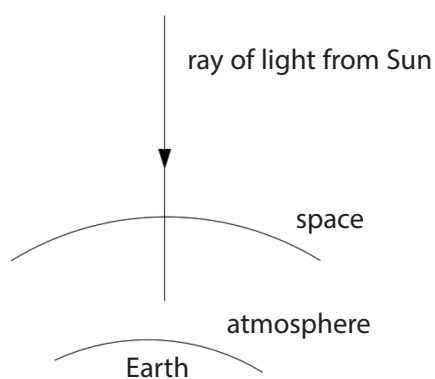


Diagram 3

Explain why the ray of light does not change direction when it enters the atmosphere.

(2)

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(iii) Explain why the wavelength of the light reduces when it enters the atmosphere.

(2)

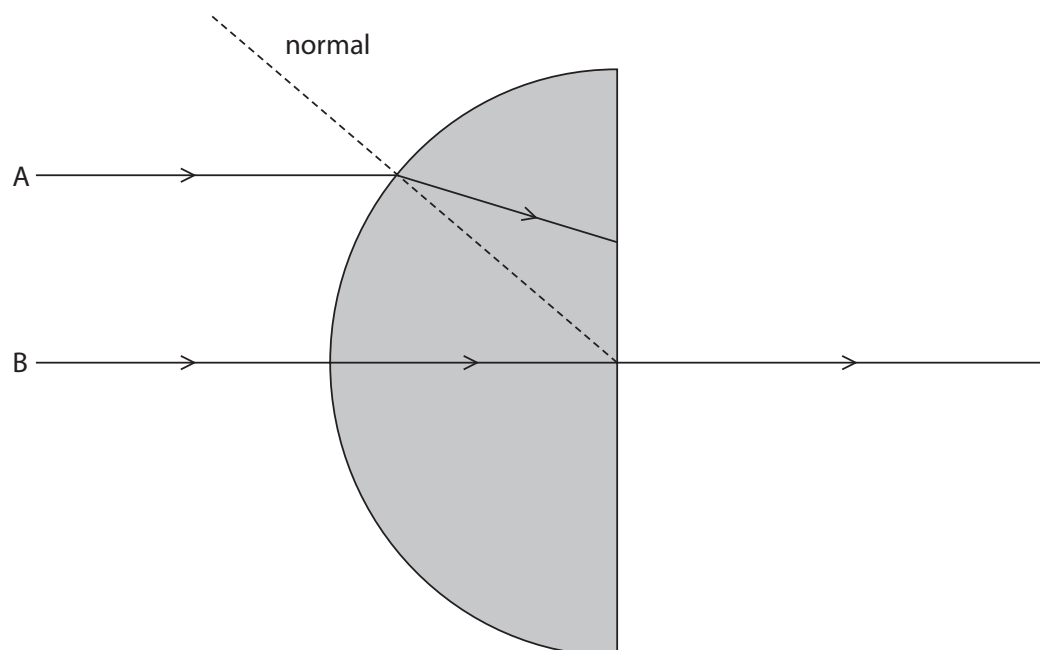
(iv) Suggest why the Sun appears not to be circular when it is close to the horizon at sunset.

(1)

(Total for Question 8 = 11 marks)



6 The diagram shows two rays of green light entering a semicircular glass block.



- (a) (i) Measure the angle of incidence and the angle of refraction for ray A as it enters the glass block.

(2)

angle of incidence = ... degrees

angle of refraction = ... degrees

- (ii) State the formula linking refractive index, angle of incidence and angle of refraction.

(1)

- (iii) Calculate the refractive index of the glass.

(3)

refractive index = ...



- (b) (i) Complete the path of ray A until it crosses ray B.

Label the point where the rays cross with the letter F.

(2)

- (ii) The refractive index of glass for red light is lower than for green light.

Explain what would happen to point F if red light were used instead of green light.

You may draw a diagram to help your answer.

(3)

(Total for Question 6 = 11 marks)



- 9 A student does an investigation to determine the refractive index of a block made from flint glass.

(a) She directs a ray of red light at the block, as shown in diagram 1.

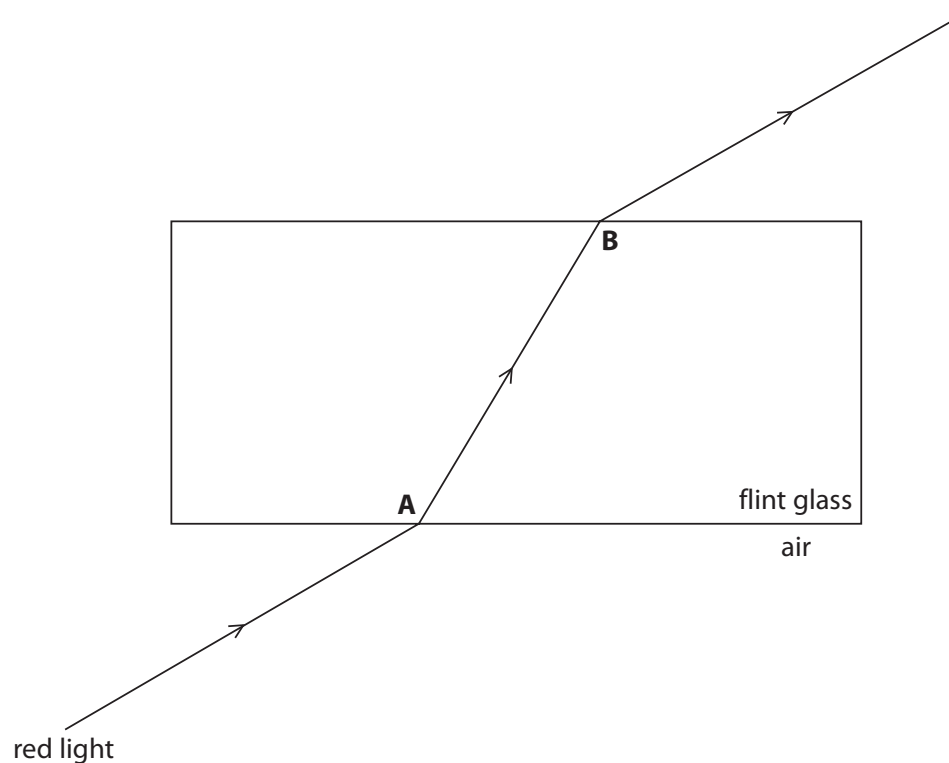


Diagram 1

- (i) Some of the light is reflected from the surface of the block at point A.

On diagram 1, draw this reflected ray of light.

(1)

- (ii) Use a protractor to determine the angle of incidence and the angle of refraction of the red light at point A on diagram 1.

(2)

angle of incidence = ... degrees

angle of refraction = ... degrees

- (iii) State the formula linking refractive index, angle of incidence and angle of refraction.

(1)

- (iv) Calculate the refractive index of the glass for red light.

(2)

refractive index = ...

- (v) Describe how the student could improve her investigation to obtain a more reliable value of the refractive index.

(3)

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(b) The student replaces the red light with a blue light.

Diagram 2 shows a ray of blue light directed at point A, at the same angle of incidence as the previous ray of red light.

The dashed lines on diagram 2 show the previous path of the ray of red light.

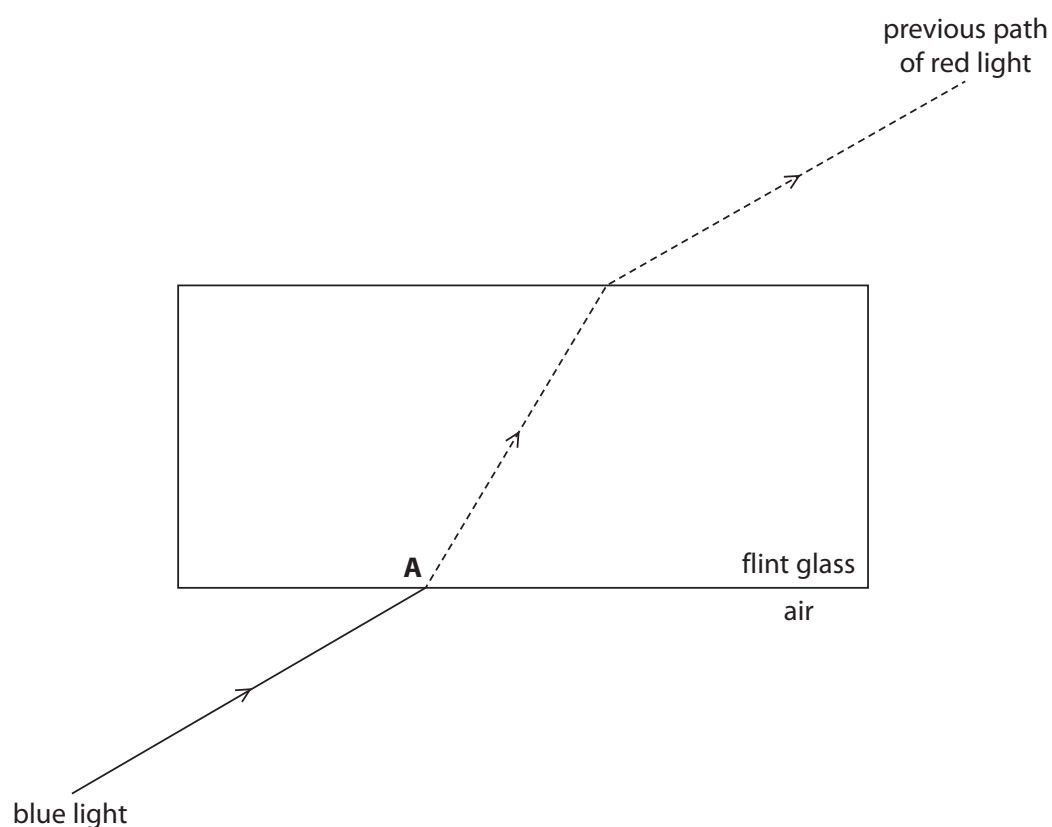


Diagram 2

The refractive index of flint glass for blue light is higher than the refractive index of flint glass for red light.

Complete diagram 2 by drawing the path of blue light from point A until it passes into air.

(3)

(Total for Question 9 = 12 marks)

- 11 Diagram 1 shows what happens when light is incident on a piece of transparent material.

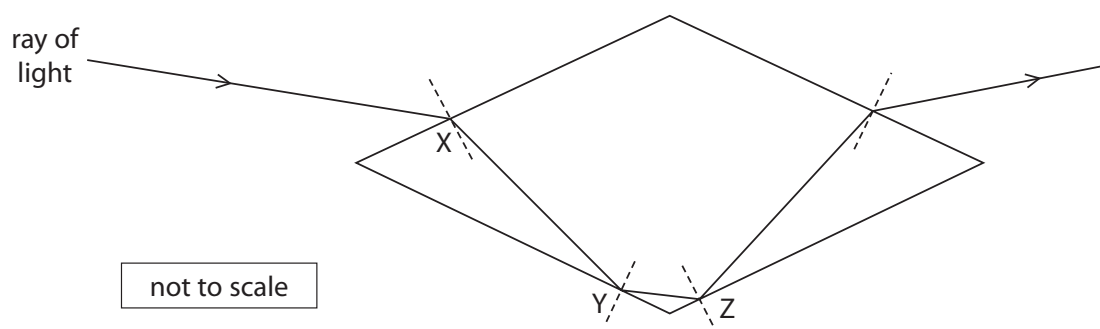


Diagram 1

- (a) When very bright light shines on this transparent material, a small amount of light is reflected at point X.
- (i) On diagram 2, draw the reflected ray from point X.

(2)

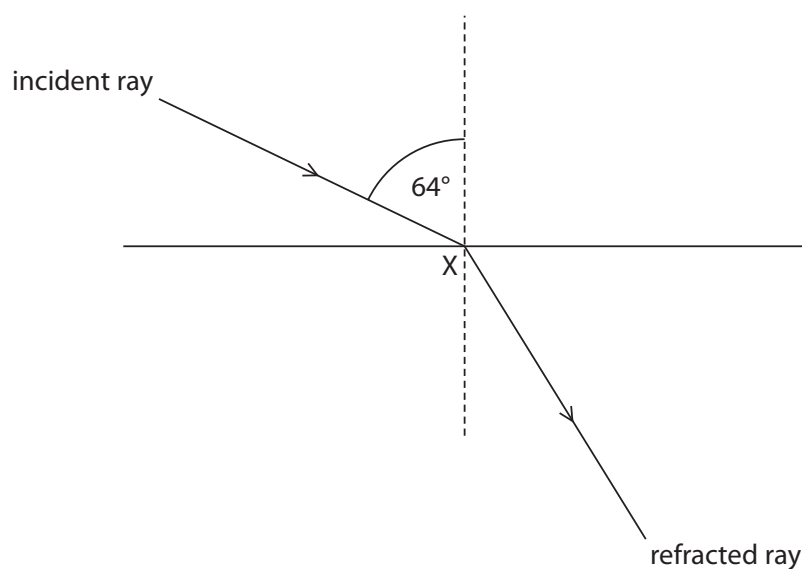


Diagram 2

- (ii) Measure the angle of **refraction** at point X on diagram 2.

(1)

angle = ... degrees

(iii) State the formula linking refractive index, angle of incidence and angle of refraction. (1)

(iv) Show that the refractive index of the transparent material is about 1.7 (2)

(v) State the formula linking refractive index and critical angle. (1)

(vi) Calculate the critical angle for the transparent material. (2)

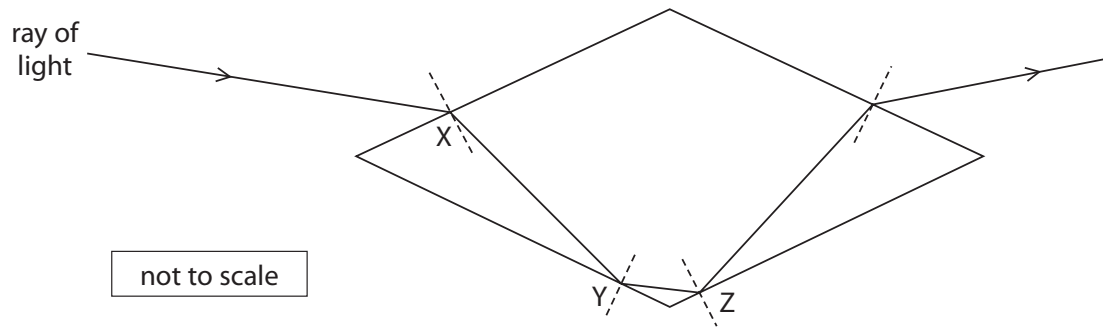
critical angle = ... degrees

QUESTION 11 CONTINUES ON NEXT PAGE



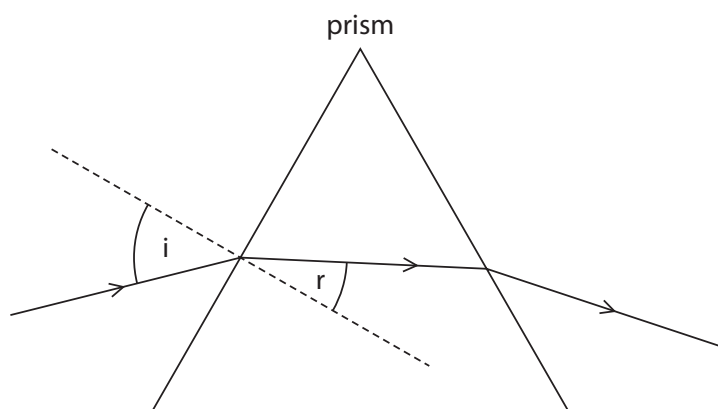
(b) Explain the behaviour of the light at points Y and Z.

(3)



(Total for Question 11 = 12 marks)

- 7 (a) A glass prism can be used to refract light.



- (i) State the name of the piece of equipment used to measure angles.

(1)

- (ii) Measure the angle of incidence and the angle of refraction for the light entering the prism.

(2)

angle of incidence = ... degrees

angle of refraction = ... degrees

- (iii) State the formula linking refractive index, angle of incidence and angle of refraction.

(1)

- (iv) Calculate the refractive index of the glass.

(2)

refractive index = ...



- (b) Two galaxies, A and B, emit red light with a reference wavelength of 630 nm.

An astronomer measures the wavelength of red light from galaxy A when the light arrives at the Earth.

The astronomer's value for the wavelength is 645 nm.

- (i) Calculate the difference between the astronomer's value for the wavelength and the reference wavelength of red light.

(1)

difference in wavelength = ... nm

- (ii) The change in wavelength happens because galaxy A is moving away from the Earth.

Calculate the speed of galaxy A.

[speed of light = 3.0×10^8 m/s]

(3)

speed = ... m/s



(iii) Light from galaxy B has twice the redshift as light from galaxy A.

Galaxy B is twice as far away from Earth as galaxy A.

Explain how these observations support the Big Bang theory of the origin of the Universe.

(2)

(Total for Question 7 = 12 marks)



- 9 (a) A light ray travels from air into water.

Diagram 1 shows the direction of the light ray and the wavefronts in air.

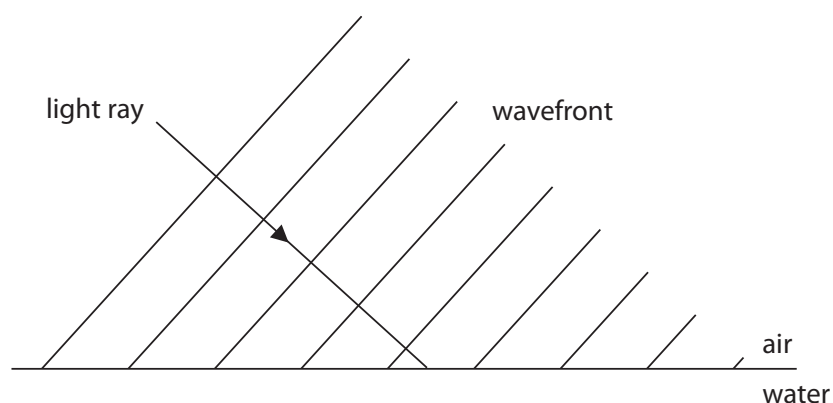


Diagram 1

The refractive index of water is greater than the refractive index of air.

- (i) Complete diagram 1 by showing

- the wavefronts in the water
- the path of the light ray in the water

(3)

- (ii) Explain what happens to the wavelength of light when it passes from air into water.

(2)

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- (b) Diagram 2 shows what can happen when a light ray travelling in glass meets the boundary with air.

The wavefronts are not shown in this diagram.

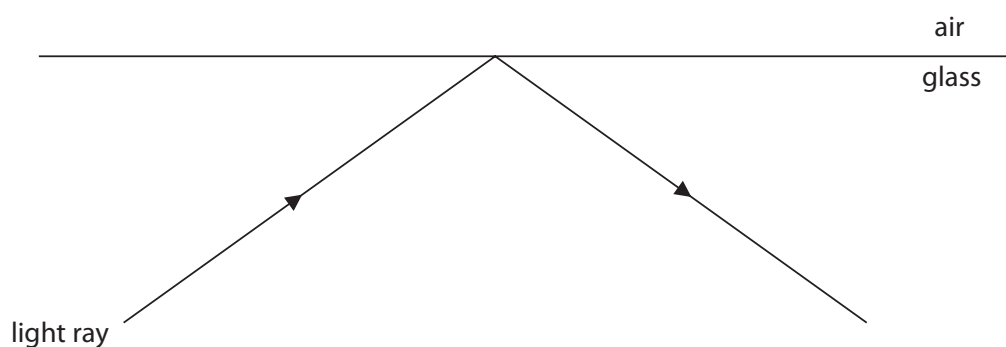


Diagram 2

- (i) Add the normal to diagram 2.

(1)

- (ii) Measure the angle of incidence in diagram 2.

(1)

angle of incidence = ... degrees

- (iii) The glass has a refractive index of 1.6

Calculate the critical angle of the glass-air boundary.

(3)

critical angle = ... degrees



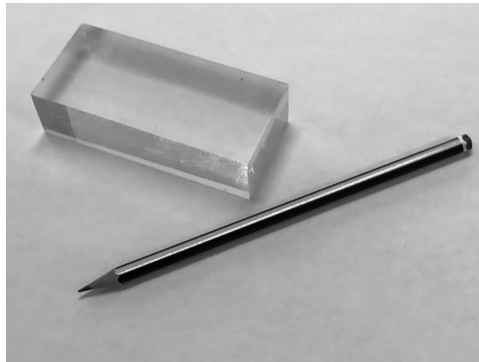
(iv) Explain the path of the light ray shown in diagram 2.

(3)

(Total for Question 9 = 13 marks)



- 6 A student does an experiment to determine the refractive index of a glass block.



- (a) The student places the glass block on a piece of paper and draws round the block with a pencil.

Name two additional pieces of equipment the student will need for his experiment. (2)

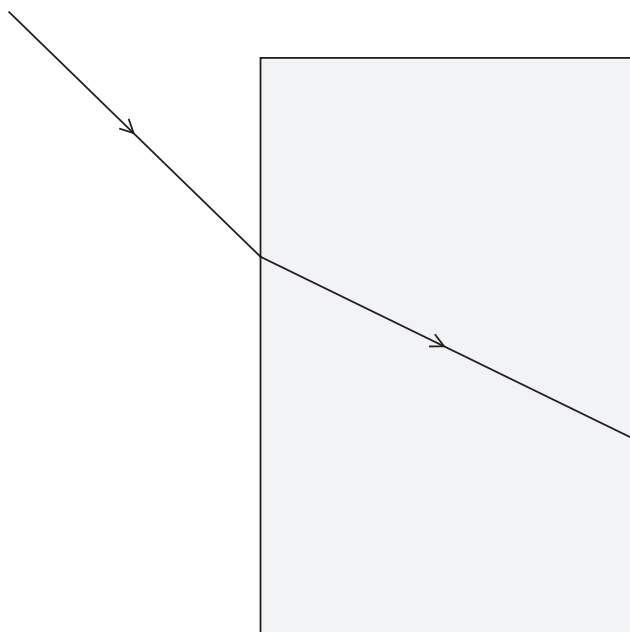
1

2

- (b) The diagram shows the path of a ray of light as it travels towards and then through the glass block.

- (i) Draw the path of the ray of light when it leaves the glass block. (2)

- (ii) Draw the normal line at the point where the ray of light enters the glass block. (1)



- (iii) Determine the angle of incidence and the angle of refraction at the point where the ray of light enters the glass block.

(2)

angle of incidence = ... °

angle of refraction = ... °

- (iv) State the formula linking refractive index, angle of incidence and angle of refraction.

(1)

- (v) Calculate the refractive index of the glass block.

(2)

refractive index = ...



- (c) A teacher suggests that a more accurate value for the refractive index can be found using a graphical method.

Design a method to obtain a value for the refractive index of the glass block using a graph.

You may draw a diagram to support your answer.

(3)

(Total for Question 6 = 13 marks)

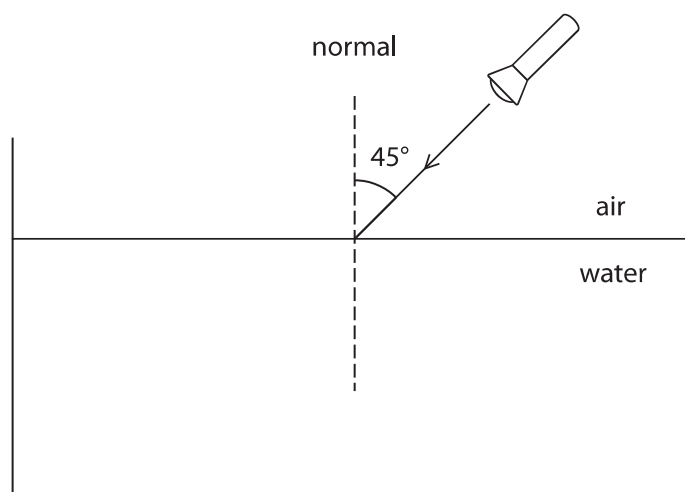


7 This question is about refraction.

(a) State what is meant by the term **refraction**.

(1)

(b) The diagram shows a ray of light from a torch incident on the surface of a pool of water.



The angle of refraction of the ray of light is 33°

(i) Draw the path of the ray of light in the water.

(2)

(ii) State the formula linking refractive index, angle of incidence and angle of refraction.

(1)

(iii) Show that the refractive index of water is about 1.3

(2)

(c) The torch is moved below the surface of the water. Light from the torch is incident on the water surface at an angle greater than the critical angle.

(i) Explain the meaning of the term **critical angle**.

You may draw a diagram to help your answer.

(2)

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(ii) State the formula linking critical angle and refractive index.

(1)

(iii) Calculate the critical angle of water.

Assume the refractive index of water is 1.3

(3)

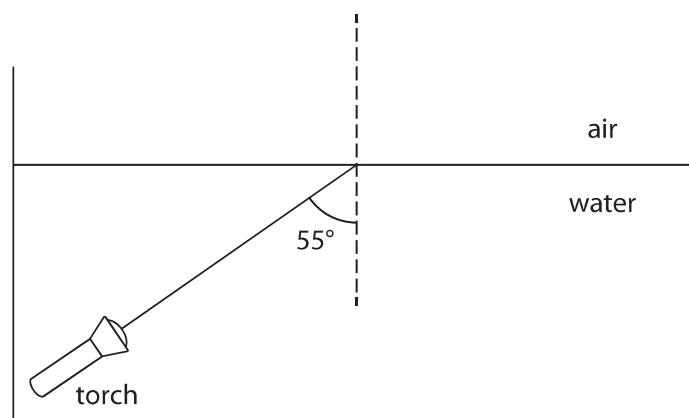
critical angle = ...°



(iv) A ray of light leaves the torch as shown in the diagram.

Complete the path of the ray of light.

(2)



(Total for Question 7 = 14 marks)



10 This is a question about refraction.

(a) (i) State the formula linking critical angle and refractive index.

(1)

(ii) Diamond has a critical angle of 26 degrees.

Calculate the refractive index of diamond.

(2)

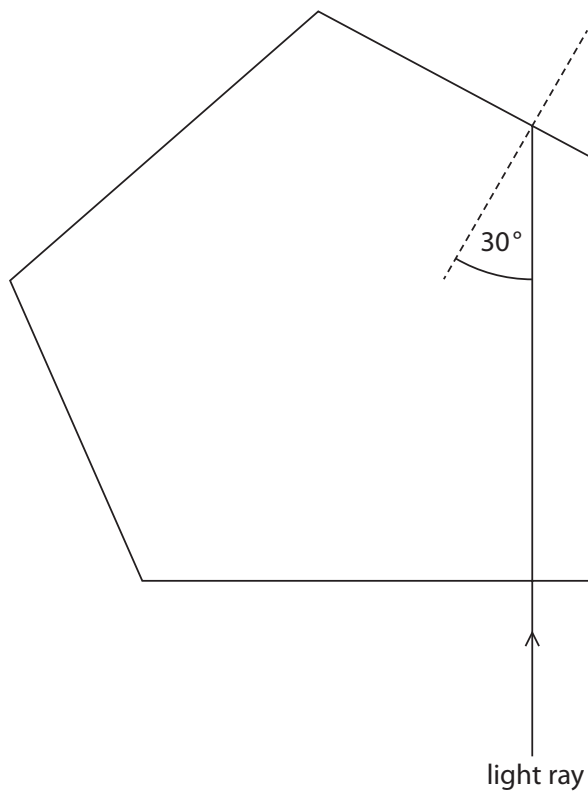
refractive index = ...



(iii) The diagram shows a light ray entering a block of diamond.

Complete the diagram to show the light ray emerging from the block.

(3)



(b) A student plans an investigation to determine the refractive index of glass.

The student uses a graph of $\sin(i)$ against $\sin(r)$ to determine the refractive index.

(i) The student uses this equipment

- a ray box
- a rectangular glass block
- a protractor
- a pencil

Describe how the student should collect her data.

You may draw a diagram to support your answer.

(4)

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(ii) The table shows the student's results.

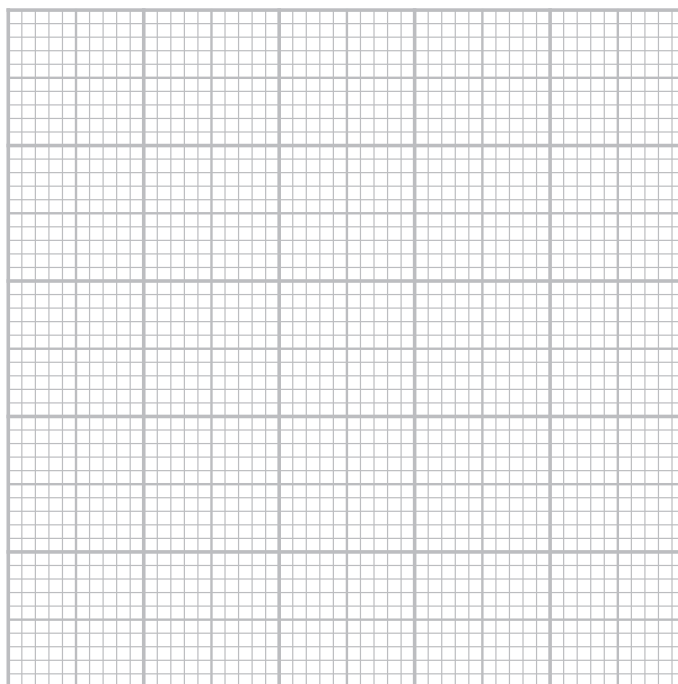
$\sin(i)$	$\sin(r)$
0.10	0.06
0.30	0.19
0.50	0.31
0.70	0.44
0.90	0.56

Plot a graph of the student's results.

(3)

(iii) Draw a line of best fit.

(1)



(iv) Use the graph to calculate the refractive index of the glass block.

(2)

refractive index = ...

(Total for Question 10 = 16 marks)



7 This question is about light.

(a) Light is an example of a transverse wave.

Describe a transverse wave.

You may draw a diagram to help your answer.

(2)

(b) Diagram 1 shows a ray of light in a section of optical fibre.

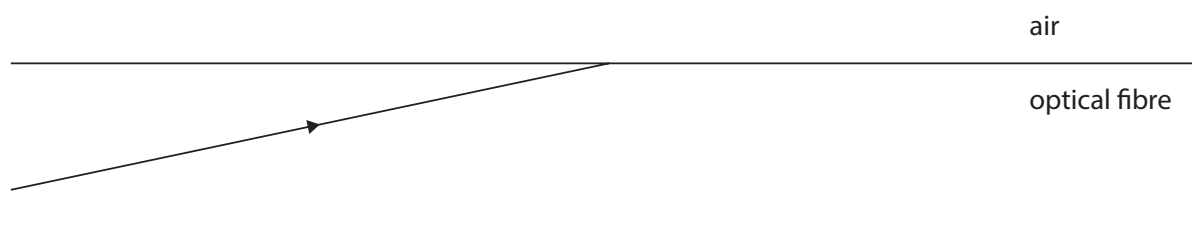


Diagram 1

(i) The ray of light is incident at the boundary between the optical fibre and air.

The ray of light reflects at the boundary.

Complete diagram 1 by drawing the reflected ray of light.

(2)

- (ii) Explain why no light leaves the optical fibre when the light reflects at the boundary between the optical fibre and air.

(3)

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- (c) Diagram 2 shows a different ray of light, incident on the boundary between water and air.

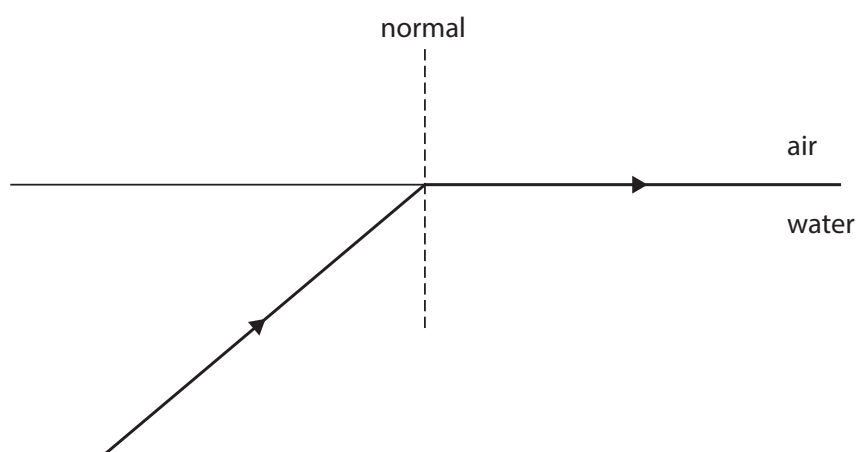


Diagram 2

Using diagram 2, show that the refractive index of water is approximately 1.3

(4)

(Total for Question 7 = 11 marks)



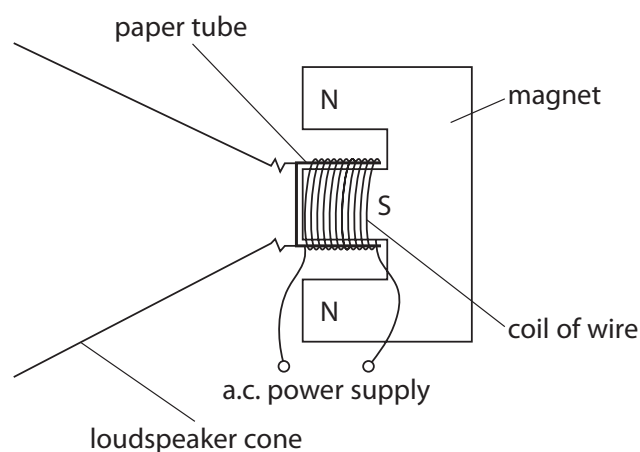
SUB-TOPIC 3.4

SOUND WAVES AND OSCILLOSCOPES

Sub-topic 3.4 · 16 questions · 154 marks · lowest tariff first



7 The diagram shows the construction of a simple loudspeaker.



A coil of wire is wrapped around a paper tube attached to the loudspeaker cone.

When there is an alternating current (a.c.) in the coil, the cone moves.

Explain how the loudspeaker produces a sound wave.

(5)

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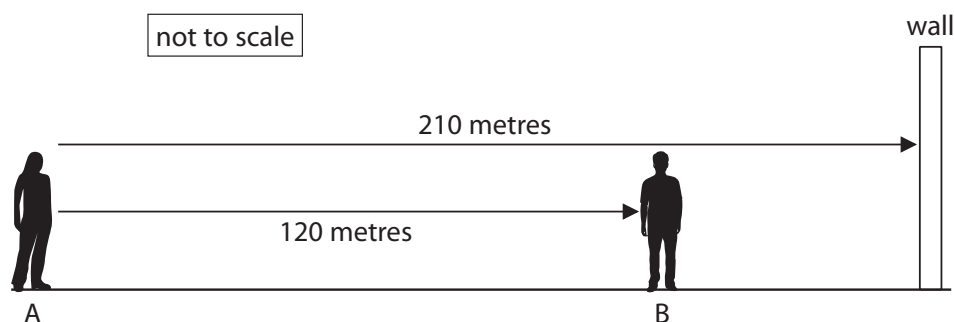
(Total for Question 7 = 5 marks)

2 Two students investigate the speed of sound.

Student A has a device that makes a loud sound.

Student B has a stopwatch.

A sound wave travels from student A to the wall and is reflected back to student B.



- (a) Calculate the total distance the sound wave travels from student A to the wall and back to student B.

(1)

distance = ... m

- (b) Student B hears the sound before and after the sound wave reflects from the wall.

When student B hears the sound before reflection, he starts the stopwatch.

When student B hears the sound after reflection, he stops the stopwatch.

The students repeat this experiment five times.

The table shows the students' results.

Time in s				
0.50	0.62	0.52	0.58	0.55

Calculate the mean (average) time.

Give your answer to 2 significant figures.

(2)

mean time = ... s

(c) Calculate the speed of sound for this investigation.

(4)

speed = ... m/s

(d) Suggest a reason why the students' results are not always the same.

(1)

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(Total for Question 2 = 8 marks)

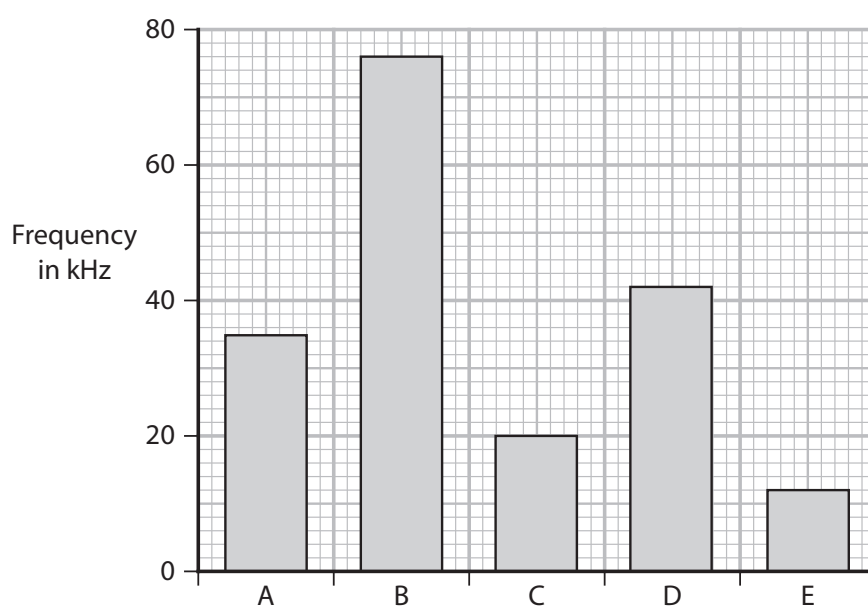


5 This question is about sound.

(a) State which wave property determines the pitch of a sound.

(1)

(b) The bar chart shows the maximum frequency of sound heard by four animals and a human.



Explain which of the bars is most likely to show the results for a human.

(2)

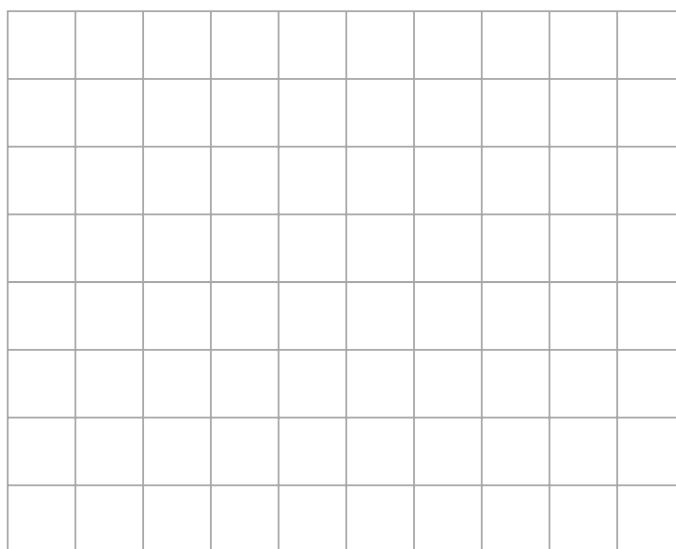
(c) A sound wave has a frequency of 500 Hz.

(i) Show that the time period of the sound wave is 2.0 ms.

(3)

(ii) The diagram shows the screen of an oscilloscope.

The timebase of the oscilloscope is 0.50 ms per square.



Draw the trace on the oscilloscope screen when the sound wave is detected.

(2)

(Total for Question 5 = 8 marks)

8 The photograph shows an oscilloscope.



© dny3d/Shutterstock

An oscilloscope can be used to determine the frequency of a sound wave.

(a) (i) Name the piece of equipment that should be used with an oscilloscope to detect a sound wave.

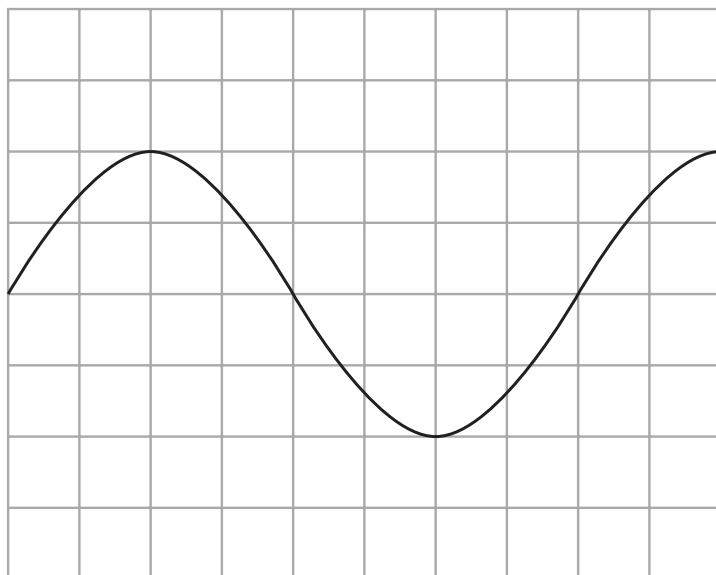
(1)

(ii) Describe how an oscilloscope can be used to measure the time period of a sound wave.

(2)

(b) Diagram 1 shows an oscilloscope screen when a sound wave is detected.

It also shows the settings of the oscilloscope.



Oscilloscope settings

y direction: 1 square = 2 V

x direction: 1 square = 5×10^{-6} s

Diagram 1

(i) Determine whether the sound can be heard by humans.

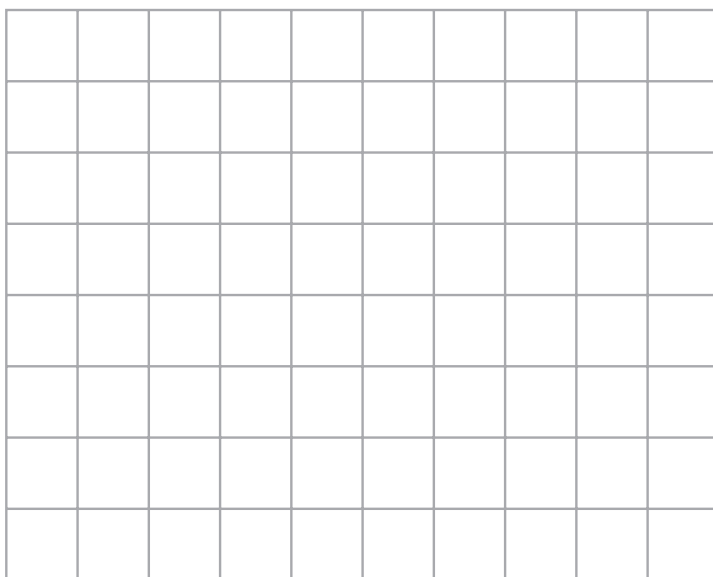
Include a calculation of frequency in your answer.

(4)

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.....

(ii) The oscilloscope settings are changed, as shown in Diagram 2.

**Oscilloscope settings**

y direction: 1 square = 1 V
x direction: 1 square = 1×10^{-5} s

Diagram 2

On Diagram 2, draw the wave that would be displayed on the oscilloscope screen if the same sound wave is detected using these new settings.

(2)

(Total for Question 8 = 9 marks)



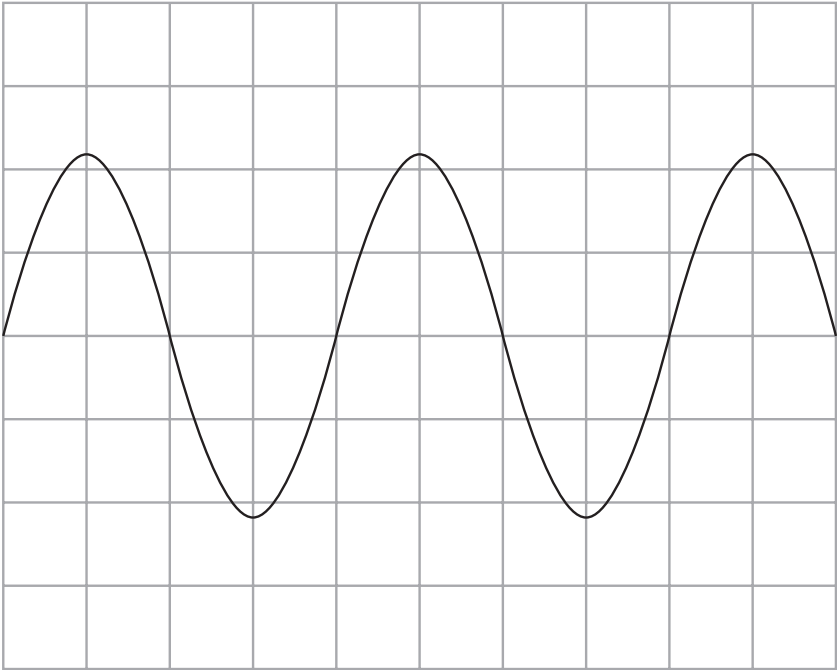
- 7 This question is about sound waves.
- (a) The table gives the frequencies of some different sound waves.

Place ticks (✓) in the table to show which sound waves can be heard by humans. (2)

Sound wave	Frequency in Hz	Can be heard by humans
A	10	
B	30	
C	500	
D	2000	
E	10 000	
F	25 000	

- (b) The diagram shows the screen of an oscilloscope when a sound wave is detected.

Add to the diagram by drawing the trace of another sound wave that has a lower pitch and is quieter than the sound wave shown. (2)



- (c) The speed of sound in air varies with temperature.

A student finds a formula in a textbook that links the speed of sound waves in air to the temperature of the air, measured in kelvin.

$$\text{speed of sound in air} = (0.606 \times \text{temperature in kelvin}) + 166$$

- (i) Calculate the speed of sound when the air temperature is 46°C.

(2)

$$\text{speed of sound} = \dots\dots\dots \text{ m/s}$$

- (ii) Calculate the wavelength of a sound wave with a frequency of 15 000 Hz when the air temperature is 46°C.

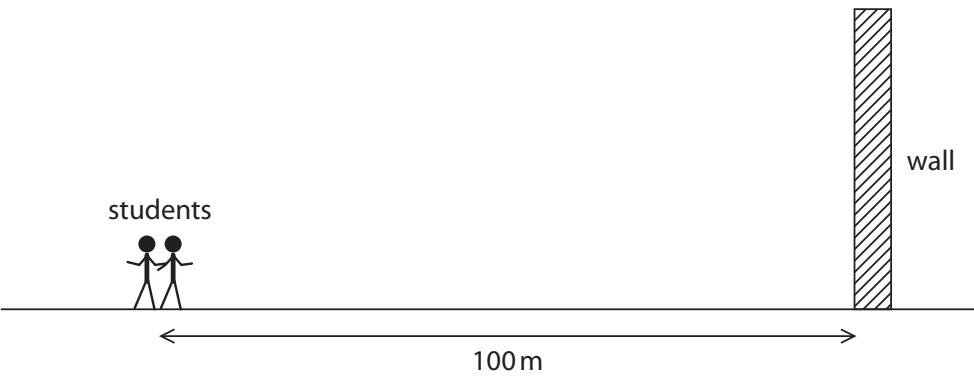
(3)

$$\text{wavelength} = \dots\dots\dots \text{ m}$$

(Total for Question 7 = 9 marks)



7 The diagram shows two students doing an experiment to measure the speed of sound in air.



This is their method.

- both students stand 100 m away from a large flat wall
- student A makes a sound by hitting two blocks of wood together
- the sound waves travel to the wall and reflect back to the students as an echo
- student A hits the blocks together again when the echo is heard
- student A continues to hit the blocks together every time an echo is heard
- student B starts a timer when the blocks are hit together and stops the timer when the blocks have been hit together 20 more times

(a) Give a reason why the students do not stand nearer to the wall.

(1)

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(b) The students repeat their method five times.

The table shows the students’ results.

Time between starting and stopping timer in seconds					
test 1	test 2	test 3	test 4	test 5	mean
11.80	11.18	11.76	11.75	11.72	

- (i) The students decide that one of their tests shows an anomalous result.

Circle the anomalous result in the table.

(1)

- (ii) Suggest a reason for the anomalous result.

(1)

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- (iii) Calculate the mean time between starting and stopping the timer.

Give your answer to a suitable number of decimal places.

(3)

mean time = ... s

- (iv) The speed of sound in air can be calculated using the formula

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

Use the students' results to calculate a value for the speed of sound in air.

(3)

speed of sound = ... m/s

(Total for Question 7 = 9 marks)

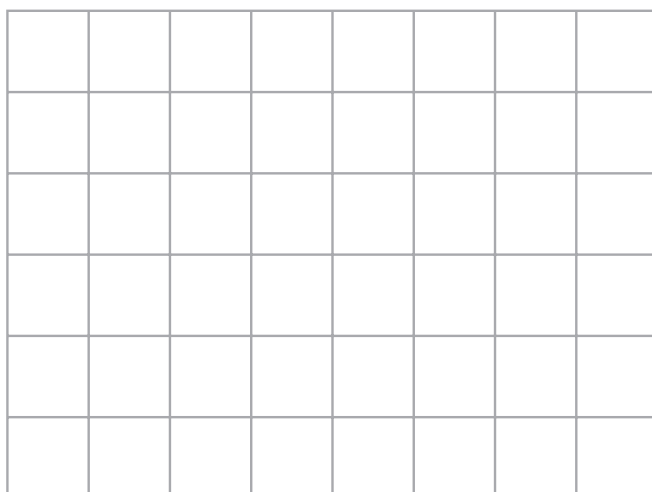


9 An oscilloscope can be used to determine the frequency of a sound wave.

- (a) Give the name of the piece of apparatus that must be connected to the oscilloscope to detect the sound wave.

(1)

- (b) The diagram shows the screen of the oscilloscope and the oscilloscope settings.



oscilloscope settings:

y direction: 1 square = 2V

x direction: 1 square = 0.001 s

A sound wave of frequency 250 Hz is detected.

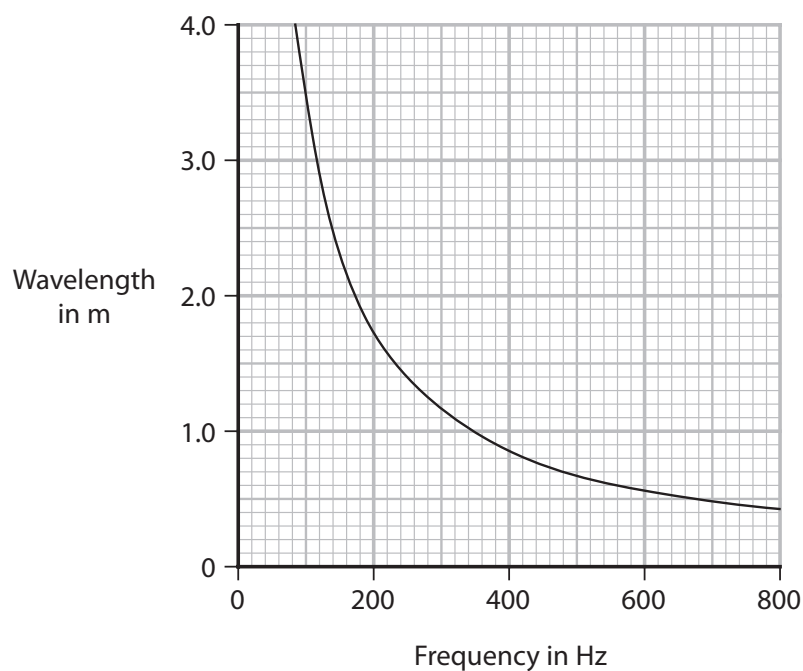
The sound wave produces a trace on the oscilloscope of amplitude 4V.

Complete the diagram by drawing the trace of this sound wave on the oscilloscope screen.

(5)



- (c) The graph shows how the wavelength of sound waves in air varies with their frequency.



If wavelength and frequency are inversely proportional, then

$$\text{wavelength} \times \text{frequency} = \text{constant}$$

Using the graph, evaluate whether the wavelength of sound waves in air is inversely proportional to their frequency.

(3)

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(Total for Question 9 = 9 marks)

3 This question is about sound waves.

(a) Describe an experiment to measure the speed of sound in air.

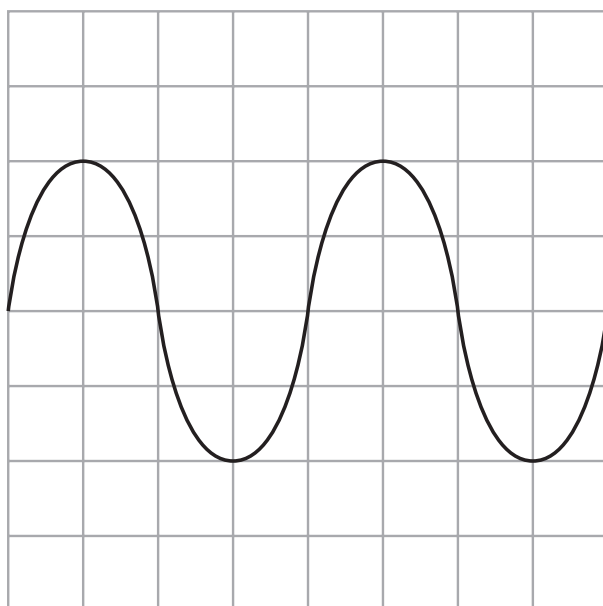
You may draw a diagram to help your answer.

(5)



(b) An oscilloscope can be used to determine the frequency of a sound wave.

The diagram shows an oscilloscope trace of a sound wave.



Oscilloscope settings

y direction: 1 square = 1 V

x direction: 1 square = 0.25 ms

(i) Calculate the period of this sound wave.

(3)

period = ... s

(ii) Calculate the frequency of this sound wave.

(2)

frequency = ... Hz

(Total for Question 3 = 10 marks)

3 When a meteor explodes, light waves and sound waves are produced at the same time.

(a) (i) State the formula linking average speed, distance moved and time taken.

(1)

(ii) A person standing 1860 m away from the site of a meteor explosion hears the sound of the explosion 5.6 s later.

Calculate the speed of sound in air.

(2)

speed of sound = ... m/s

(iii) A scientist stands a long way from the meteor explosion.

Explain why he hears the explosion at a different time to when he sees it.

(2)

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(b) Sound is a longitudinal wave.

Describe what is meant by the term **longitudinal wave**.

(2)

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(c) In 2013, a meteor exploded above Russia.

Just before the meteor exploded, it was travelling at a speed of 19.2 km/s.

The mass of the meteor was estimated to be 1.25×10^7 kg.

(i) State the formula linking kinetic energy, mass and speed.

(1)

(ii) Calculate the energy in the kinetic store of the meteor just before the meteor exploded.

(2)

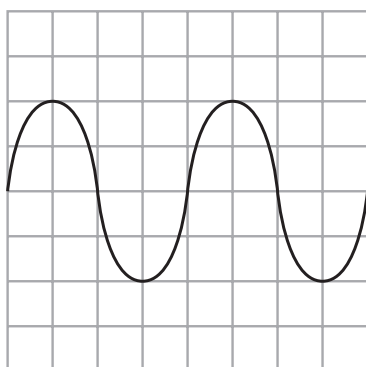
energy in kinetic store = ... J

(Total for Question 3 = 10 marks)



- 4 (a) A student uses an oscilloscope to determine the speed of sound.

The diagram shows the oscilloscope trace produced by the sound wave.



Oscilloscope settings

y direction: 1 square = 1 mV

x direction: 1 square = 1 ms

The student uses two microphones and a ruler to determine the wavelength of the sound wave.

He finds that the wavelength is 1.4 m.

- (i) State the formula linking the speed, frequency and wavelength of a wave.

(1)

- (ii) Use the oscilloscope trace to calculate the speed of the wave.

(5)

speed = ... m/s

2 This question is about sound waves.

(a) Sound is an example of a type of wave.

State the name of this type of wave.

(1)

(b) The speed of sound in liquids is greater than the speed of sound in gases.

(i) Describe the arrangement of particles in liquids and in gases.

You may use diagrams to help your answer.

(2)

(ii) Suggest why the speed of sound in liquids is greater than the speed of sound in gases.

(2)



(c) A buzzer is an electrical device that produces sound.

The frequency of sound produced by the buzzer is 1400Hz.

(i) State the formula linking speed, frequency and wavelength of a wave.

(1)

(ii) Sound travels at a speed of 340 m/s in air.

Calculate the wavelength of the sound wave from the buzzer.

(2)

wavelength = ... m



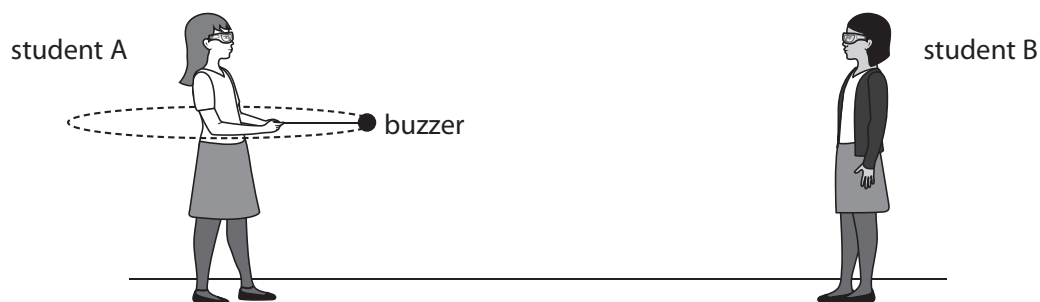
(iii) Two students use this method to investigate sound from a moving source.

Student A connects a piece of string to the buzzer.

She spins round so that the buzzer moves in a horizontal circular path.

- she spins round at a slow speed
- she then spins round at a high speed

Student B stands several metres away from student A.



The sound heard by student A is different to the sound heard by student B.

Discuss the differences in the sounds heard by student A and student B.

(5)

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(Total for Question 2 = 13 marks)

4 A student investigates the speed of sound in air.

(a) The student sets up two microphones, A and B, as shown in Diagram 1.



Diagram 1

The microphones are connected to a datalogger.

A sound is made to the left of microphone A.

The datalogger records the time when the sound wave reaches each microphone.

The student uses the data to calculate the time taken for the sound wave to travel from microphone A to microphone B.

(i) Describe how the student could determine the speed of sound in air using his calculated value of time taken.

(3)

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(ii) Suggest why the student does not use a stop clock in this investigation.

(1)

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(b) The student investigates how the speed of sound in air varies with temperature.

He places several Bunsen burners in the space between the microphones, as shown in diagram 2.

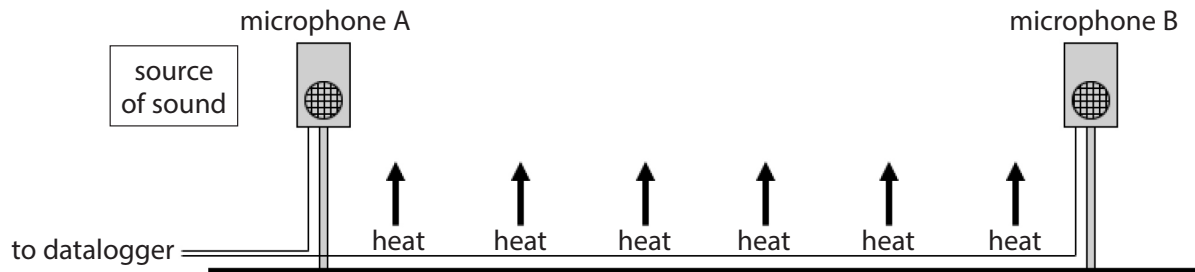


Diagram 2

He uses this method

- light all the Bunsen burners on a low heating flame
- measure the air temperature in three places between the microphones using three temperature sensors
- use the datalogger to record the time taken for a sound wave to travel from microphone A to microphone B
- determine the speed of sound

The student repeats this method as the air temperature increases.

- (i) Suggest why it is important for all the Bunsen burners to burn the same amount of gas each second.

(1)

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(ii) The table shows the student's results.

Temperature in °C				Time in ms	Speed in m/s
sensor 1	sensor 2	sensor 3	mean		
20.3	20.2	19.9	20.1	4.37	344
29.9	31.3	30.0	30.4	4.29	350
39.7	41.0	39.0	39.9	4.22	358
51.0	50.2	49.3	50.2	4.15	362
59.8	61.5	58.6		4.08	368

Calculate the mean temperature for the last row in the table.

Give your answer to a suitable number of decimal places.

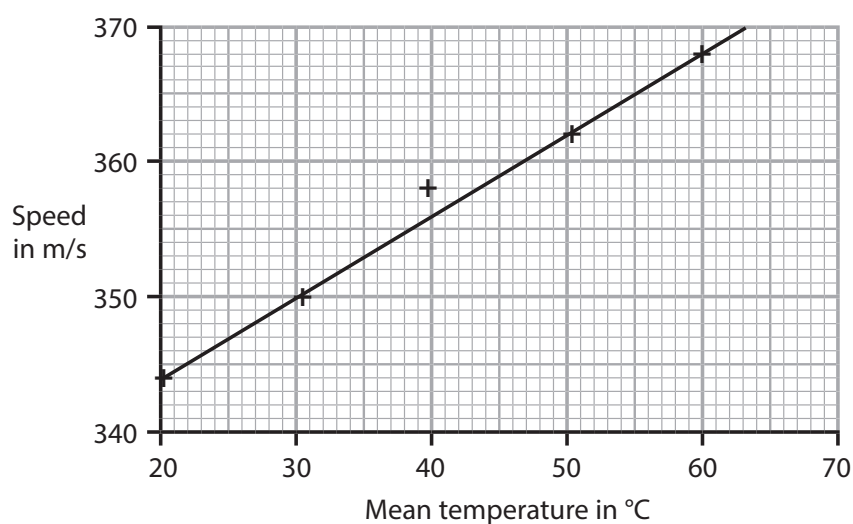
(2)

mean temperature = ... °C

(iii) The student plots his results and draws the line of best fit.

Draw a circle around the anomalous result.

(1)



(iv) State how the student should deal with the anomalous result.

(1)

(v) Explain why a line graph is the correct type of graph to display these results.

(2)

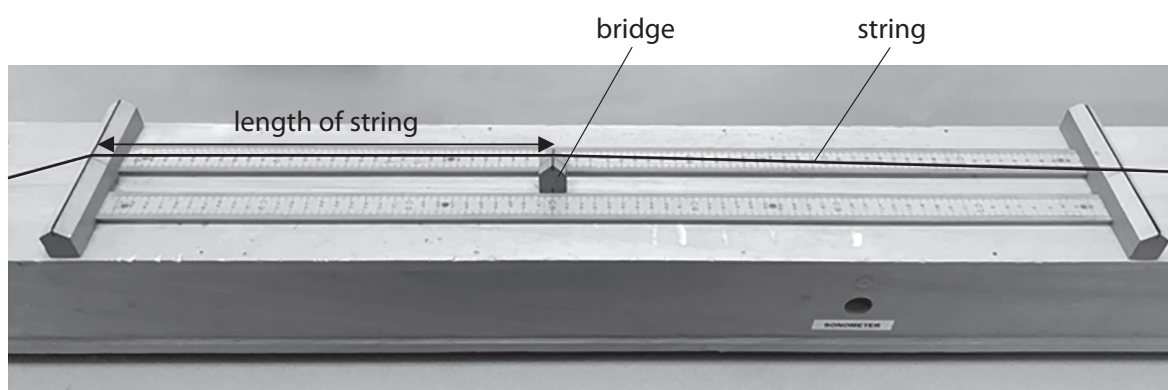
(vi) Describe the relationship between the speed of sound in air and temperature.

(2)

(Total for Question 4 = 13 marks)



- 5 A sonometer is a piece of equipment used to investigate the frequency of waves on a string. The photograph shows a sonometer.



The string is under tension. When the string is plucked it vibrates to produce a sound wave.

- (a) Describe how an oscilloscope should be used to measure the frequency of the sound wave from the sonometer.

(4)

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- (b) A student investigates how the frequency of sound from the sonometer varies with the length of the string.

This is the student's method.

- apply a constant tension force to the string
- pluck the string and measure the frequency of the sound wave produced
- move the bridge to change the length of the string
- pluck the string and measure the new frequency of the sound wave produced

Repeat the method for different lengths of string.

- (i) Give a control variable for the student's investigation.

(1)

- (ii) The table shows the student's results.

String length in cm	Frequency in Hz			
	Test 1	Test 2	Test 3	Mean
20	105	104	108	106
40	53	54	52	53
60	36	32	35	
80	25	28	26	26
100	22	20	21	21
120	20	17	18	18
140	15	15	14	15

Calculate the mean frequency for a string length of 60 cm.

(2)

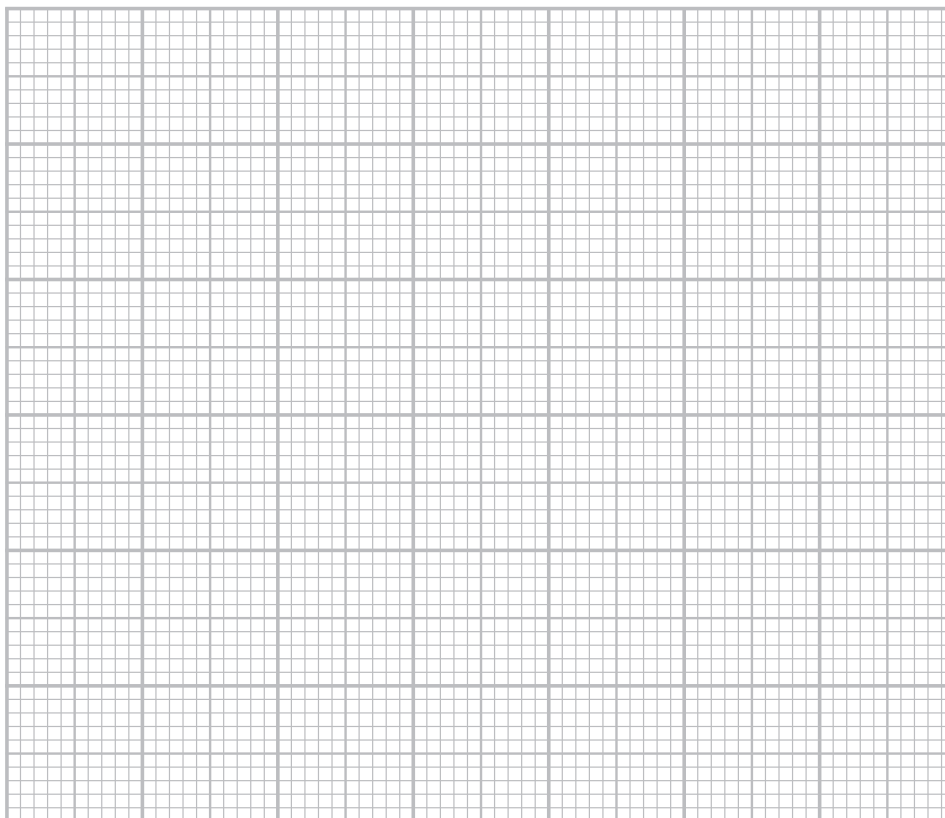
mean frequency = ... Hz

- (iii) Plot a graph of the mean frequency and string length data on the grid.

(3)

- (iv) Draw the curve of best fit.

(1)



- (v) Determine the string length needed to produce a sound wave of frequency 75 Hz. (1)

string length = ... cm

- (vi) The student cannot hear the sound from the sonometer for some of the string lengths tested.

Explain which of the string lengths produce sounds that humans cannot hear. (2)

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(Total for Question 5 = 14 marks)

4 (a) A student investigates a sound wave with a frequency of 25 000 Hz.

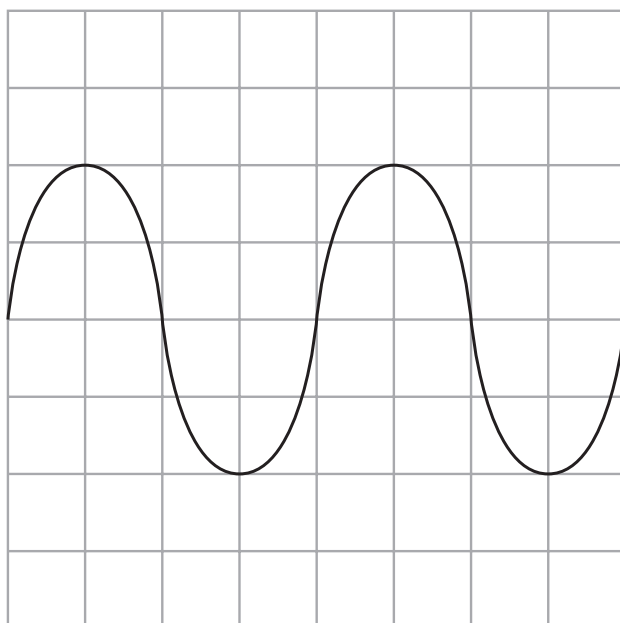
(i) Calculate the wavelength of this sound wave.

[speed of sound = 330 m/s]

(3)

wavelength = ... m

(ii) The oscilloscope trace represents the sound wave.



Oscilloscope settings

y direction: 1 square = 5V

x direction: 1 square = 0.01 ms

Determine the amplitude of the oscilloscope trace.

(2)

amplitude = ... V

(b) (i) Diagram 1 shows a coil of wire wrapped around a cardboard tube.

The coil is fixed to the cardboard tube.

On diagram 1, draw field lines to represent the magnetic field produced when the current is in the direction shown.

(3)

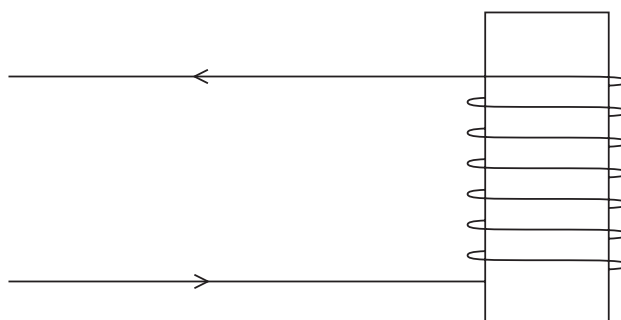


Diagram 1

(ii) Diagram 2 shows a model of a loudspeaker that uses the coil and the cardboard tube.

The cardboard tube is fixed to a thin piece of card, which is clamped at both ends.

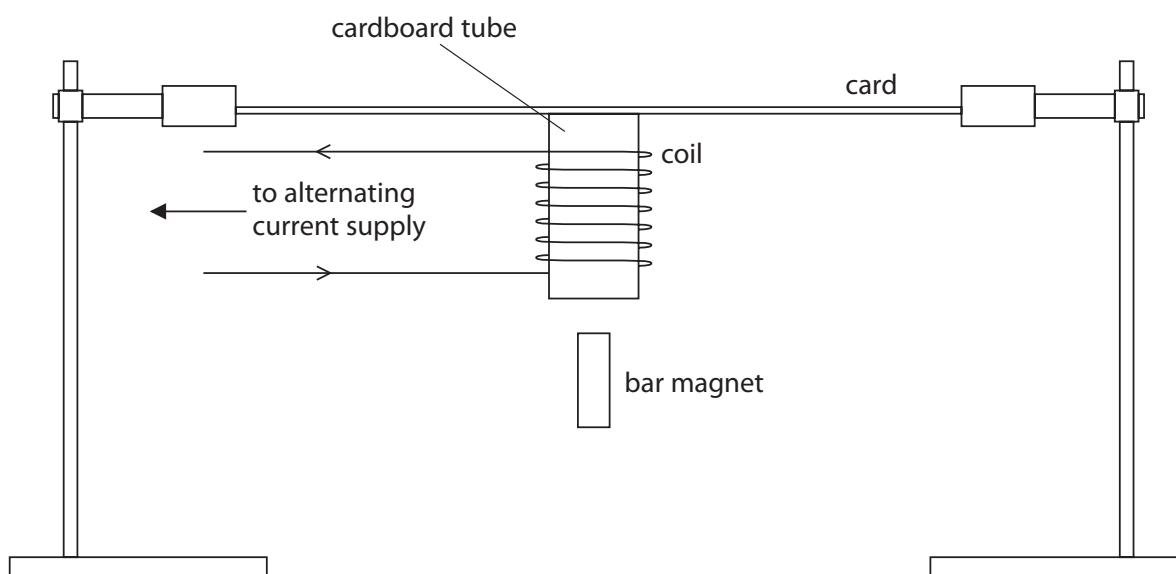


Diagram 2

The student holds a bar magnet near the bottom of the cardboard tube.

Explain why this causes the loudspeaker to produce a sound.

(3)

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(iii) When the frequency of the alternating current is 10 kHz, the student hears a sound.

The student increases the frequency of the alternating current to 25 kHz.

Explain why the student cannot hear a sound now, even though the card is still vibrating.

(2)

(iv) Suggest a change to the apparatus that would increase the loudness of the sound when the frequency of the alternating current is 10 kHz.

(1)

(Total for Question 4 = 14 marks)



2 This question is about sound waves.

(a) Which range of frequencies of sound waves can be heard by humans? (1)

- ☐ A 2 Hz to 20 000 Hz
- ☐ B 2 Hz to 200 000 Hz
- ☐ C 20 Hz to 20 000 Hz
- ☐ D 20 Hz to 200 000 Hz

(b) The table gives some statements about sound waves.

Complete the table by placing a tick (✓) next to each correct statement. (2)

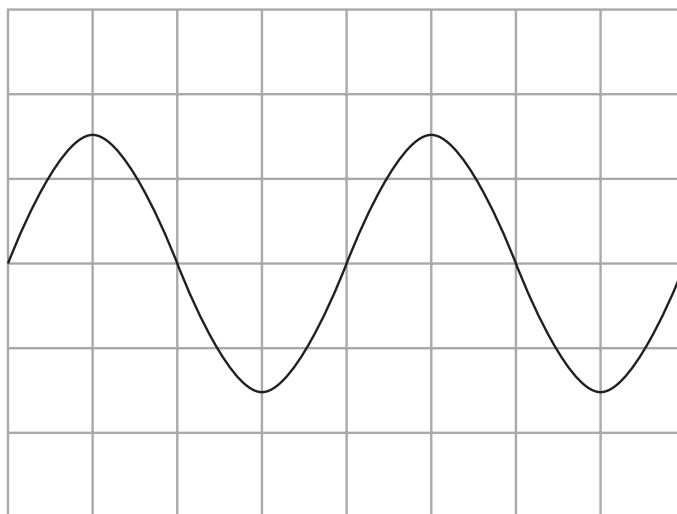
Statement	Correct (✓)
sound waves are longitudinal	
sound waves can travel through a vacuum	
sound waves are part of the electromagnetic spectrum	
sound waves can be reflected and refracted	

(c) An oscilloscope can be used to display a sound wave.

(i) Give the name of the variable that is measured on the x-axis of the oscilloscope screen. (1)

.....

- (ii) The diagram shows the trace on an oscilloscope screen when a sound wave is detected.



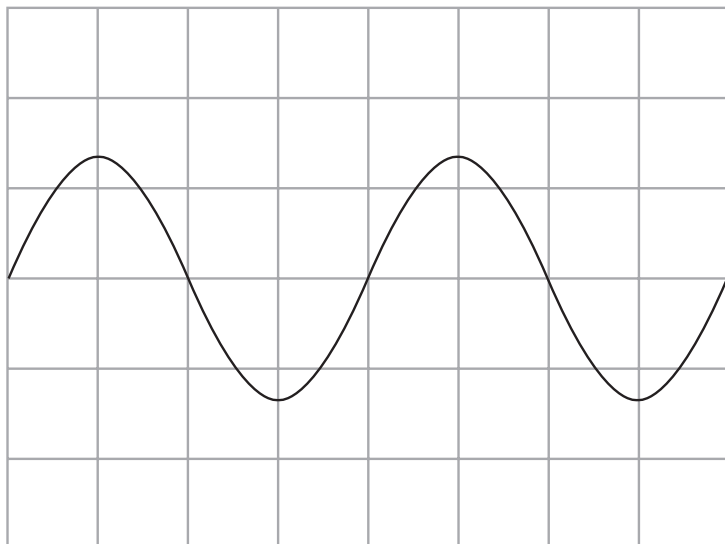
On the screen, draw the trace for a quieter sound wave with a lower frequency.

(2)

(Total for Question 2 = 6 marks)

- 8** A high-frequency sound wave is detected by a microphone and displayed on an oscilloscope.

The diagram shows the oscilloscope screen when the sound wave is detected. It also shows the oscilloscope settings.



oscilloscope settings:

x direction: 1 square = $20 \times 10^{-6} \text{ s}$

y direction: 1 square = 10 mV

- (a) Give the maximum frequency of sound that can be heard by humans.

(1)

- (b) Determine if the sound wave displayed on the oscilloscope could be heard by humans.

(4)

(c) A student changes the settings of the oscilloscope to alter the displayed wave in these two ways.

- increase the amplitude of the wave
- only display one time period of the wave on the screen

The table shows some possible settings for the oscilloscope.

Which row of the table gives the student's new oscilloscope settings?

(1)

	x direction setting / seconds per square	y direction setting / mV per square
☐ A	10×10^{-6}	5
☐ B	10×10^{-6}	20
☐ C	40×10^{-6}	5
☐ D	40×10^{-6}	20

(Total for Question 8 = 6 marks)

MARK SCHEMES

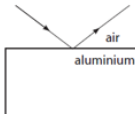
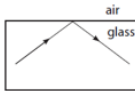
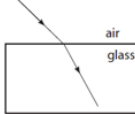
official mark schemes



Question number	Answer	Notes	Marks
5 (a)	An arrow drawn from left to right by eye;		1
(b)	Comparative statements for side containing A: Wavefronts closer together/EQ; (therefore) wavelength smaller; Same speed; ($v = f \times \lambda$ so) frequency larger;	Allow RA for B Allow e.g. "waves more compressed together" Condone mention of the Doppler effect for 1 mark if no other mark scored.	4

Question number	Answer	Notes	Marks
1 (a)	D - arrow S; A is incorrect as arrow P shows twice the amplitude B is incorrect as arrow Q shows the wavelength C is incorrect as arrow R shows half of the wavelength		1
(b)	B - arrow Q; A is incorrect as arrow P shows twice the amplitude C is incorrect as arrow R shows half of the wavelength D is incorrect as arrow S shows the amplitude		1
(c)	D - transverse; A is incorrect as water waves are not electromagnetic B is incorrect as gravitational waves are not detectable by water C is incorrect as the water molecules vibrate at right angles to the direction of travel of the wave.		1
(d)	substitution into given equation ' $f = 1/T$ '; evaluation; e.g. frequency = $1/2.7$ frequency = 0.37 (Hz)	accept any value that rounds to 0.37 Hz	2

Total for Question 1 = 5 marks

Question number	Answer	Notes	Marks
1 (a)	one mark for each correct line drawn;;; Wave behaviour total internal reflection refraction reflection Example  air aluminium  air glass  air glass allow line for reflection drawn to first or second example diagram allow two lines drawn from reflection to first and second diagrams only reject mark if two lines drawn from either TIR or refraction		3
(b)	any two from: (all waves) reflect; (all waves) refract; idea that (all waves) transfer energy (without transferring matter); (all waves) have amplitude/wavelength/frequency;	allow higher level common properties e.g. diffraction, interference etc. allow 'information' for energy	2

Total for Question 1 = 5 marks

Question number	Answer	Notes	Marks
2 (a)	substitution OR rearrangement; evaluation; e.g. $1.25 \times 10^{18} = 1 / T$ OR $T = 1 / f$ ($T =$) 8.00×10^{-19} (s)	-1 for POT error allow 8×10^{-19} (s)	2
(b)	use of $v = f \times \lambda$; substitution OR rearrangement; evaluation; e.g. $v = f \times \lambda$ $3.00 \times 10^8 = 1.25 \times 10^{18} \times \lambda$ OR $\lambda = v / f$ ($\lambda =$) 2.40×10^{-10} (m)	seen as a formula or implied by working allow v , c , s for speed allow λ for wavelength -1 for POT error allow 2.4×10^{-10} (m)	3

Total for Question 2 = 5 marks



Question number	Answer	Notes	Marks
9	Any FIVE from: MP1 reference to Doppler effect; MP2 wavefronts are emitted at constant frequency by buzzer; MP3 wavefronts arrive at student (A) further apart than when they were emitted; MP4 distance between wavefronts is the wavelength; MP5 speed = frequency $\times$ wavelength; MP6 speed of waves is constant; MP7 as speed is constant and wavelength has increased, frequency must decrease; MP8 decrease in frequency is experienced as a decrease in pitch;	Allow 'wavelength increases' if MP3 or MP4 not awarded	5

(Total for Question 9 = 5 marks)

Question number	Answer	Notes	Marks
5 (a)	use/substitution of distance = average speed x time; total distance travelled = 2 x distance to plane; evaluation of distance to at least 2s.f.; e.g. total distance = $1.9 \times 10^{-3} \times 3.0 \times 10^5$ total distance = 570 km = 2 x distance to plane distance to plane = $570/2 = 285$ (km)	reject use of $v=f\lambda$ allow idea that time required is half of total time.	3
(b)	substitution into given equation $\Delta\lambda/\lambda = v/c$; rearrangement; evaluation; e.g. $1.1 \times 10^{-6} / 1.2 = v/3 \times 10^8$ $v = 3 \times 10^8 \times 1.1 \times 10^{-6} / 1.2$ $v = 280$ (m/s)	-1 POT error allow ecf from wrong change in wavelength condone premature rounding allow 275 (m/s)	3

Total for Question 5 = 6 marks

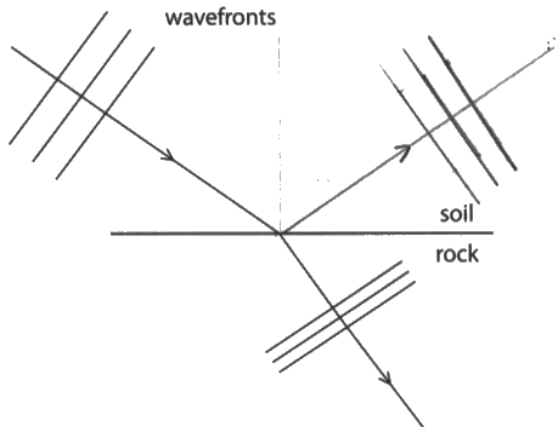
Question number	Answer	Notes	Marks
5	at least one from: in relation to driver: MP1. (frequency) does not change; MP2. no (relative) movement between driver and horn; PLUS up to five from: in relation to person at the side of the road: MP3. recognition that the Doppler effect applies; MP4. frequency heard by person at side of the road is different to that heard by driver; MP5. frequency is higher as car approaches; MP6. because wavefronts become closer together; MP7. frequency is lower as car moves away; MP8. because wavefronts become further apart; MP9. speed of sound remains constant; MP10. relevant mention of $v = f \times \lambda$;	allow pitch does not change i.e. driver and car travelling at same speed / distance between car (horn) and driver constant allow pitch as alternative to frequency reject just 'different' allow pitch of sound is higher allow wavelength decreases allow pitch of sound is lower allow wavelength increases must link to a previous MP, not merely quoting the formula	6

Total for Question 5 = 6 marks

Question number	Answer	Notes	Marks
8 (a) (i)	acceleration = change in velocity / time;	allow rearrangements and standard symbols e.g. $a = v \cdot u / t$, $a = \Delta v / t$, $a = \Delta v / \Delta t$	1
(ii)	substitution; rearrangement; evaluation; e.g. $1.2 = (35 - 26) / t$ $t = 9 / 1.2$ ($t =$) 7.5 (s)		3
(b)	any four from: MP1. frequency increases; MP2. due to Doppler effect; MP3. idea that car behaves as the source of the (reflected) waves; MP4. (reflected) wavefronts closer together; MP5. (reflected) wavelength decreased; MP6. speed (of waves) stays constant;	allow “waves become bunched up” allow quotation of $v = f \times \lambda$	4

Total for Question 8 = 8 marks



Question number	Answer	Notes	Marks
4 (a) (i)	speed = frequency $\times$ wavelength;	allow rearrangements and standard symbols e.g. $\lambda = v/f$ allow s for speed	1
(ii)	substitution; rearrangement; evaluation; e.g. $3.0 \times 10^8 = 170 (\times 10^6) \times \lambda$ $\lambda = v/f$ OR $\lambda = 3.0 \times 10^8 / 170 (\times 10^6)$ (wavelength =) 1.8 (m)	ignore units -1 for POT error from not converting units or an incorrect attempt at converting units allow 1.76(4...) (m)	3
(b) (i)	reflected ray/wavefronts drawn to right of 'normal' and above rock; wavefronts perpendicular to reflected ray; wavefronts parallel to each other and spacing consistent with incident wavefronts; e.g. 	normal does not need to be drawn reflection angle does not need to be correct ignore if wavefronts extended in to the rock can only be scored if first mark awarded judge by eye can only be scored if first mark awarded judge by eye	3
(ii)	any three from:		3

	MP1. wavefronts closer together; MP2. idea that rock is (optically) denser than soil; MP3. idea of reduction in speed; MP4. idea of constant frequency; MP5. correct reference to wave speed equation / speed = frequency × wavelength;	ignore wavelength is smaller allow wave refracts towards normal allow idea that rock has a larger refractive index can only be scored if MP3 or MP4 awarded	
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Total for Question 4 = 10 marks



Question number	Answer	Notes	Marks
8 (a)	oscillations / vibrations; perpendicular to direction of wave/travel/energy;	allow 90 degrees, right angles for perpendicular	2
(b) (i)	measurement of 0.9-1.1 cm; use of scale factor to give 1.8-2.2 (cm);	allow 2 (cm) allow ecf if clear that scale factor is being used	2
(ii)	conversion of cm to m; substitution into $v = f \times \lambda$; evaluation; e.g. $2.0 \text{ cm} = 0.020 \text{ m}$ $v = 15 \times 0.020$ (wave speed =) 0.30 (m/s)	allow $\div 100$ seen anywhere allow ecf from (i) not converting cm to m scores 2 marks max. allow 0.27 to 0.33 (m/s) allow 0.3 (m/s)	3
(c)	frequency is greater (at point X); {wavefronts / peaks / crests} closer together; wavelength decreases; wave speed does not change;	allow wavefronts more bunched up/compressed ignore wave is compressed ignore speed of dipper	4

Total for Question 8 = 11 marks

Question number	Answer	Notes	Marks
11 (a)	conversion of units from g to kg; substitution; evaluation; evaluation given to 3 s.f.; e.g. $159 \text{ g} = 0.159 \text{ kg}$ $(KE =) \frac{1}{2} \times 159 (\times 10^{-3}) \times 54.82$ $(KE =) 238.74... \text{ (J)}$ $(KE =) 239 \text{ (J)}$	allow 0.159 seen anywhere in working ignore units note: take care not to penalise POT error twice here independent mark	4
(b) (i)	substitution; rearrangement; evaluation to 3 or more s.f.; e.g. $54.8 = \Delta f / 2.90 \times 10^{10} \times 3.00 \times 10^8 / 2$ $\Delta f = 54.8 \times 2.90 \times 10^{10} \times 2 / 3.00 \times 10^8$ $(\Delta f =) 10.59... \times 10^3 \text{ (Hz)}$	allow in either order allow any value that rounds to 1.06×10^4 accept non-standard form e.g. 10.6×10^3 accept answer not in standard form $10594.6... \text{ (Hz)}$ award 1 mark max for a successful attempt at calculating the speed that gives a shift of $1.1 \times 10^4 \text{ (Hz)}$ i.e. $56.8... \text{ (m/s)}$	3
(ii)	frequency (of radio waves) decreases; wavelength increases; speed of (radio) waves stays the same;	condone 'waves stretch'	3

Total for Question 11 = 10 marks



Question number	Answer	Notes	Marks
6 (a) (i)	(wave) speed = frequency × wavelength;	allow standard symbols and rearrangements i.e. $\lambda = v / f$ allow v, c and s for speed	1
(ii)	substitution; rearrangement; evaluation in mm to at least 2s.f.; e.g. $3.0 \times 10^8 = 1.6 \times 10^{11} \times \lambda$ $\lambda = 3.0 \times 10^8 / 1.6 \times 10^{11}$ $\lambda = (0.0019 \text{ (m)}) = 1.9 \text{ (mm)}$	allow 1.88, 1.875 (mm) condone 1.87 (mm)	3
(b)	idea that wavelength has increased (over time); because <u>Universe</u> is expanding;	allow wavelength has stretched ignore wavelength has expanded ignore red-shift	2
(c)	(most galaxies show a) red-shift because they are moving away (from Earth / each other); further galaxies show a greater red-shift; further galaxies are travelling (away from Earth) faster; idea that all matter must have originated from a single point;	condone use of stars, planets, objects for galaxies for this marking point only allow faster galaxies have greater red-shift	4

Total for Question 6 = 10 marks

Question number	Answer	Notes	Marks
1 (a)	(i) infrared;	allow IR	1
	(ii) ultraviolet;	allow UV	1
(b)	(i) heating food / eq; communication; radar;		1
	(ii) sterilising (equipment or food); treating cancer; medical imaging; medical tracing techniques;	ignore cleaning (equipment) ignore chemotherapy	1

Total for Question 1 = 4 marks

Question number	Answer	Notes	Marks										
1 (a) (i)	C (sound waves); A is incorrect because it is a transverse wave B is incorrect because it is a transverse wave D is incorrect because it is a transverse wave		1										
(ii)	one mark for each correct line;; <table><thead><tr><th>Electromagnetic wave</th><th>Hazard</th></tr></thead><tbody><tr><td> microwave </td><td> skin burns </td></tr><tr><td> infrared </td><td> blindness </td></tr><tr><td></td><td> internal heating of body tissue </td></tr><tr><td></td><td> cell mutation </td></tr></tbody></table>	Electromagnetic wave	Hazard	microwave	skin burns	infrared	blindness		internal heating of body tissue		cell mutation	two lines from any left hand box is a contradiction and scores zero for that box	2
Electromagnetic wave	Hazard												
microwave	skin burns												
infrared	blindness												
	internal heating of body tissue												
	cell mutation												
(b) (i)	A (checking for broken bones); B is incorrect because microwaves and infrared have this use C is incorrect because ultraviolet has this use D is incorrect because alpha radiation has this use		1										
(ii)	B (cooking food); A is incorrect because x-rays has this use C is incorrect because ultraviolet has this use D is incorrect because gamma has this use		1										

Total for Question 1 = 5 marks

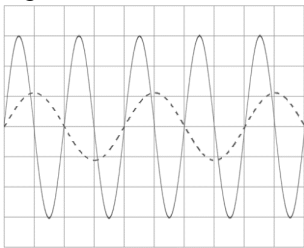
Question number	Answer	Notes	Marks												
1 (a)	<table><thead><tr><th>EM wave</th><th>Use</th></tr></thead><tbody><tr><td>gamma</td><td>long range communication</td></tr><tr><td>infrared</td><td>cooking</td></tr><tr><td>radio waves</td><td>sterilising food</td></tr><tr><td>ultraviolet</td><td>observing internal structures</td></tr><tr><td>x-rays</td><td>fluorescent lamps</td></tr></tbody></table> all four correct;;;;	EM wave	Use	gamma	long range communication	infrared	cooking	radio waves	sterilising food	ultraviolet	observing internal structures	x-rays	fluorescent lamps	gamma use is given so only judge other four EM waves for marks three or two correct scores 2 marks one correct scores 1 mark	3
EM wave	Use														
gamma	long range communication														
infrared	cooking														
radio waves	sterilising food														
ultraviolet	observing internal structures														
x-rays	fluorescent lamps														
(b)	C (internal heating of tissue); A is incorrect because this is a hazard of visible and ultraviolet radiation B is incorrect because this is a hazard of x-ray and gamma radiation D is incorrect because this is a hazard of infrared radiation		1												
(c)	radio (waves);		1												

Total for Question 1 = 5 marks

Question number	Answer		Notes	Marks
2 (a)	thermometer	part of spectrum	allow all valid colours/ visible	3
	P	infrared;		
	Q	red		
	R	green / yellow;		
	S	violet		
	T	ultraviolet;		
(b)	any reference to absorption; black is the better/best/good absorber;		allow reference to reflection allow reference to 'poor reflector'	2
(c)	infrared/IR;			1

(Total for Question 2 = 6 marks)

Question number	Answer	Notes	Marks
1 (a)	any two from: MP1. light waves are transverse and sound waves are longitudinal; MP2. light travels faster than sound; MP3. light can travel through vacuum but sound waves can't;	ignore references to frequency and wavelength condone 'different speeds'	2
(b) (i)	B (microwaves); A is incorrect because gamma rays have a shorter wavelength than infrared C is incorrect because ultraviolet rays have a shorter wavelength than infrared D is incorrect because visible light waves have a shorter wavelength than infrared		1
(ii)	B (heating lamps); A is incorrect because ultraviolet rays are used in fluorescent lamps C is incorrect because there is too much interference from the Earth for infrared to be used for satellite transmissions D is incorrect because gamma rays are used to sterilise medical equipment		1
(iii)	D (skin burns); A is incorrect because infrared is not absorbed by the retina B is incorrect because infrared is non-ionising C is incorrect because infrared cannot penetrate into the body to cause internal heating		1

(c)	trace drawn with higher amplitude throughout; trace drawn with higher frequency throughout; e.g. 	allow variable amplitude allow variable amplitude	2
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Total for Question 1 = 7 marks

Question number	Answer	Notes	Marks														
1 (a)	3 correct ticks;; 2 correct ticks;; 1 correct tick; <table><thead><tr><th>Statement</th><th>Correct</th></tr></thead><tbody><tr><td>all electromagnetic waves are longitudinal</td><td></td></tr><tr><td>all electromagnetic waves travel at the same speed in free space</td><td>✓</td></tr><tr><td>radio waves have the longest wavelength in the electromagnetic spectrum</td><td>✓</td></tr><tr><td>x-rays have the highest frequency in the electromagnetic spectrum</td><td></td></tr><tr><td>all electromagnetic waves transfer energy</td><td>✓</td></tr><tr><td>all electromagnetic waves can cause cancer</td><td></td></tr></tbody></table>	Statement	Correct	all electromagnetic waves are longitudinal		all electromagnetic waves travel at the same speed in free space	✓	radio waves have the longest wavelength in the electromagnetic spectrum	✓	x-rays have the highest frequency in the electromagnetic spectrum		all electromagnetic waves transfer energy	✓	all electromagnetic waves can cause cancer		-1 for each additional tick if more than three ticks shown	3
Statement	Correct																
all electromagnetic waves are longitudinal																	
all electromagnetic waves travel at the same speed in free space	✓																
radio waves have the longest wavelength in the electromagnetic spectrum	✓																
x-rays have the highest frequency in the electromagnetic spectrum																	
all electromagnetic waves transfer energy	✓																
all electromagnetic waves can cause cancer																	
(b) (i)	microwaves: one valid use; - communication /eq - heating food /eq one valid harmful effect; - internal heating (of body tissue) / eq	allow other valid uses e.g. radar, locating rain clouds etc. reject "cancer" apply "list principle"	2														
(ii)	gamma rays: one valid use; - sterilising {food / medical equipment} - kill microbes or bacteria; - treating cancer / radiotherapy; - medical tracing one valid harmful effect; - ionisation / mutation of cells /eq - risk of cancer	allow other valid uses e.g. gamma photography, identifying cancer etc. condone damages or kills cells or tissues	2														

Total for Question 1 = 7 marks

Question number	Answer	Notes	Marks
3 (a)	{skin / eye / tissue} burns;	allow damage to surface cells, skin damage reject skin cancer, cell mutation, sunburn	1
(b) (i)	any two from: - both electromagnetic waves; - both transfer energy; - both transverse waves; - both are non-ionising; - both can travel through vacuum; - both have same speed (in a vacuum);	allow EM waves allow both part of EM spectrum allow both can be reflected / refracted / diffracted	2
(ii)	- infrared has longer/higher wavelength; - infrared has lower frequency;	allow RA allow RA condone infrared has lower energy	2
(c)	substitution into speed = distance / time; rearrangement; evaluation; e.g. $3.0 \times 10^8 = 1.5 / \text{time}$ $\text{time} = 1.5 / 3.0 \times 10^8$ (time =) 5.0×10^{-9} (s)	-1 for POT error allow 5×10^{-9} (s), 0.000 000 005 (s)	3
(d)	black is a better/good absorber (of infrared radiation); idea that more energy/heat transferred to black car (in the same time);	allow RA e.g. white is a poor absorber allow white is a better/good reflector (of infrared radiation) allow RA e.g. less energy/heat transferred to white car allow black car warms up quicker black car absorbs more energy/heat scores 2 marks	2

Total for Question 3 = 10 marks

Question number	Answer	Notes	Marks
6 (a) (i)	(travel at) {same speed/speed of light/in vacuum}; OR idea that waves can travel through space / a vacuum;	allow can be reflected / refracted / diffracted allow don't need a medium to travel	1
(ii)	(excessive exposure may cause) cancer;	allow cell mutations, cell damage, DNA damage, DNA mutations, radiation sickness	1
(iii)	mention of oscillations/vibrations; {oscillation/vibrations/particle movement} are parallel to {direction of wave (travel) / direction of energy transfer} of wave for longitudinal; {oscillation/vibrations/particle movement} are perpendicular to {direction of wave (travel) / direction of energy transfer} of wave for transverse;	all marks can be awarded from clearly labelled diagram allow along the line of travel allow right angles, 90° for perpendicular	3
(b)	use of relevant pieces of measuring apparatus for mass AND volume; idea of use of displacement method for volume; further correct detail of displacement method; further experimental accuracy detail;	e.g. • balance • measuring cylinder ignore scale(s) e.g. • using a eureka can • placing in a measuring cylinder e.g. • collect displaced water from eureka can to measure volume • measure initial and final volumes in measuring cylinder to calculate volume e.g. • not splashing • totally submerged • filling eureka can completely to the spout • collecting all drips from eureka can spout • reading measuring cylinder at eye level • balance on flat surface • ensure balance is zeroed • measure mass of dry bone	4

(c)	correct formula selected; substitution; evaluation; answer given to 2 sf; e.g. density = mass / volume density = 17 / 13 density = 1.3... (g/cm ³) density = 1.3 (g/cm ³)	seen or implied by working -1 for POT error mark independently	4
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Total for Question 6 = 13 marks

Question number	Answer	Notes	Marks
11 (a) (i)	energy (transferred) per unit charge (passed);	allow $V = E/Q$ only if all terms defined allow work done for energy transferred allow coulomb for unit charge ignore joules per coulomb (equivalent to the volt)	1
(ii)	substitution into $E = Q \times V$; rearrangement; evaluation to at least 2s.f.; e.g. $1.0 \times 10^{-16} = 1.6 \times 10^{-19} \times V$ $V = 1.0 \times 10^{-16} / 1.6 \times 10^{-19}$ $V = 625 \text{ (V)}$		3
(iii)	substitution into $KE = \frac{1}{2} \times m \times v^2$; rearrangement for v^2 ; rearrangement for v ; evaluation; e.g. $1.0 \times 10^{-16} = 0.5 \times 9.1 \times 10^{-31} \times v^2$ $v^2 = 2 \times 1.0 \times 10^{-16} / 9.1 \times 10^{-31}$ $v = \sqrt{[2 \times 1.0 \times 10^{-16} / 9.1 \times 10^{-31}]}$ $v = 1.5 \times 10^7 \text{ (m/s)}$	allow standard form or decimal $2.1978... \times 10^{14} \text{ (m/s)}$ scores 3 marks ... allow $1.48... \times 10^7$, $14824986.33 \text{ (m/s)}$	4
(b) (i)	idea that humans can't see ultraviolet; fluorescent coating emits/produces visible light;	allow idea that coating produces light that humans can see	2
(ii)	any two from: MP1. idea that mercury/ultraviolet would escape from the tube; MP2. UV is ionising (radiation); MP3. named harmful effect of UV; MP4. idea that mercury (vapour) is poisonous/toxic/harmful;	e.g. skin cancer, damage/mutation to skin cells, skin burns, damage to eyes, blindness	2

Total for Question 11 = 12 marks



Question number	Answer	Notes	Marks
6 (a)	17 (degrees);	Allow in range 15-19 degrees	1
(b)	refractive index = $\sin(i) / \sin(r)$;	accept n or n for refractive index accept any valid rearrangement	1
(c)	substitution; evaluation of either sine correctly; evaluation; e.g. refractive index = $\sin(29)/\sin(17)$ refractive index = 0.484.../0.292... refractive index = 1.7	allow ecf from (a) 0.48480962/0.292371705 1.6581961	3

(Total for Question 6 = 5 marks)

Question number	Answer	Notes	Marks
8	any six from: MP1. ray A is refracted and changes direction; MP2. ray B is refracted and changes direction; MP3. correctly measured angle of incidence for either ray; MP4. correctly calculated angle of refraction for either ray A or ray B; MP5. water and air have different (optical) densities; MP6. light travels slower in water than air; MP7. TIR does not happen because water is more (optically) dense than air;	may be shown on diagram by ray passing through boundary ignore reflected rays allow 1 mark max. from MP1 and MP2 if either ray is refracted in the wrong direction allow 34° - 38° for ray A, 58° - 62° for ray B may be shown on diagram allow ecf from angles of incidence expect 24° - 28° for A and 39° - 42° for B condone air having a higher (optical) density than water allow RA ignore calculated values of the critical angle as not relevant	6

Total for Question 8 = 6 marks

Question number	Answer	Notes	Marks
12 (a) (i)	47 (°);		1
(ii)	$\sin(c) = 1 / n$;		1
(iii)	substitution OR rearrangement; evaluation; e.g. $\sin(47) = 1/n$ OR $n = 1/\sin(c)$ (n =) 1.4	allow ecf from (i) answer is 1.37 to 3sf if (i) is given as 43° then expected answer is 1.5 to 2sf /1.47 to 3 sf	2
(b)	ray is refracting / angle of incidence is less than critical angle; critical angle for water is greater than for acetone; refractive index of water is less than for acetone;	award full marks for a correct calculation of the refractive index of water with correct conclusion e.g. $n_{\text{water}} = 1.33 < n_{\text{acetone}}$ Allow correct conclusion with $n_{\text{water}} = 0.75...$ for 1 mark MAX reject response with otherwise incorrect calculation of n_{water}	3

Total for Question 12 = 7 marks

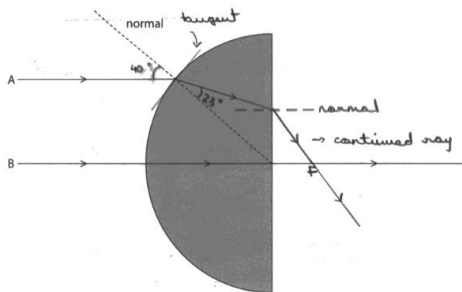
Question number	Answer	Notes	Marks
10 (a) (i)	light {refracts, bends, changes direction, changes speed, changes wavelength} = 1 mark; light {refracts/bends towards normal, slows down, wavelength decreases} = 2 marks;;		2
(ii)	normal;		1
(iii)	$\sin(c) = 1/n$;	allow in words and rearrangements	1
(iv)	substitution; rearrangement; evaluation; e.g. $\sin(c) = 1/1.6$ $(c =) \sin^{-1}(0.625)$ $(c =) 39 (^{\circ})$	allow 38.68...	3
(v)	TIR at the glass/air boundary; angle of incidence = angle of reflection;	allow ecf from (iv) that would suggest refraction e.g. if answer to (iv) is greater than 50° judge by eye	2
(b)	light ray is refracted out into the air; refracting away from the normal;	ray does not need to show deviation reject if ray emerges to the left of the normal	2

Total for Question 10 = 11 marks



Question number	Answer	Notes	Marks
8 (a) (i)	$\sin(c) = 1/n$;	allow rearrangements and/or words for symbols	1
(ii)	substitution; rearrangement; correct evaluation to 5 s.f.; e.g. $\sin(88.500) = 1/n$ $n = 1/\sin(88.500)$ $n = 1.0003$	answer of 1.00034... scores 2 marks	3
(b) (i)	straight line drawn passing into atmosphere above normal line; line bends towards normal;	DOP accept any bend towards normal however small	2
(ii)	angle of incidence is zero; angle of refraction must be zero also;	allow idea that ray 'hits' atmosphere at 90° , ray is travelling along the normal allow angle of refraction is equal to angle of incidence	2
(iii)	any two from: - reference to speed = frequency $\times$ wavelength; - frequency is constant; - speed decreases (so wavelength must decrease);		2
(iv)	any one from: - idea that rays of light from different parts of the Sun refract by different amounts; - amount of refraction very large (when Sun is close to the horizon);		1

Total for Question 8 = 11 marks

Question number	Answer	Notes	Marks
6 (a) (i)	angle of incidence = 40° ; angle of refraction = 23° ;	allow 38-42 allow 21-25	2
(ii)	$n = \sin(i)/\sin(r)$;	allow rearrangements reject $n = i/r$	1
(iii)	substitution of candidate's values into formula; evidence of sines of angles; evaluation; e.g. $n = \sin(40)/\sin(23)$ $n = 1.6(5)$	allow ecf from (i) i.e 0.642... for $\sin(40)$, 0.390... for $\sin(23)$ reject 1.73913 or any value clearly angle of incidence divided by angle of refraction NB - using extreme values from (i), n rounds the range 1.46 to 1.87	3
(b) (i)	single ray emerges and extended to horizontal ray; ray bends away from normal by eye; 		2

(ii)	idea that F moves away from the prism; idea that red ray bends less than green at either interface; idea that red ray bends less than green at both interfaces;	i.e. the crossing point is further away or moves out allow angle of refraction is smaller at second interface allow angle of refraction is larger at first interface allow angle of refraction is closer to angle of incidence/eq condone 'less refraction'	3
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Total for Question 6 = 11 marks

Question number	Answer	Notes	Marks
9 (a) (i)	correctly reflected ray of light drawn at A;	judge angle of reflection = angle of incidence by eye allow dotted lines, lines without arrowheads ignore lines inside the block	1
(ii)	$i = 60 (^{\circ})$; $r = 31 (^{\circ})$;	allow 59-61 inclusive allow 30-32 inclusive	2
(iii)	$n = \sin(i) / \sin(r)$;	allow in words and rearrangements	1
(iv)	substitution; evaluation; e.g. $(n =) \sin(60) / \sin(31)$ $(n =) 1.68$	allow ECF from (ii) allow 1.61-1.75	2
(v)	any three from: MP1. take repeat readings at a specific angle ; MP2. vary angle of incidence; MP3. find mean values for one angle i / mean refractive index; MP4. plot graph of $\sin(i)$ against $\sin(r)$; MP5. find refractive index from gradient of graph;	ignore bald "repeat and average" ignore "repeat investigation"	3
(b)	ray drawn with smaller angle of refraction than red light when it enters block; ray bends away from the normal when it leaves the glass block; ray drawn parallel to red light as it leaves block;		3

Total for Question 9 = 12 marks

Question number	Answer	Notes	Marks
11 (a) (i)	line drawn in top-right quadrant; correct angle by eye;	accept if drawn on diagram 1 instead of diagram 2 DOP	2
(ii)	32 (degrees);	allow in range 31-33 (degrees)	1
(iii)	refractive index = $\sin(\text{angle of incidence}) / \sin(\text{angle of refraction})$;	allow standard symbols and rearrangements e.g. 'i' for angle of incidence 'r' for angle of refraction 'n' for refractive index	1
(iv)	substitution; evaluation to at least 3s.f.; e.g. $n = \sin(64) / \sin(32)$ $n = 1.70$	allow ecf from (ii) allow 1.696...	2
(v)	$\sin(c) = 1 / n$;	allow standard symbols and rearrangements	1
(vi)	substitution OR rearrangement; evaluation; e.g. $\sin(c) = 1/1.7$ OR $c = \sin^{-1}(1/n)$ (c =) 36 (degrees)	allow ecf from (iv) allow 36.03...(degrees)	2
(b)	light undergoes total internal reflection; angle of incidence is above the critical angle; light (would be) going from more (optically) dense to less (optically) dense;	allow TIR for 'total internal reflection' allow idea that light would speed up if it travelled through the boundary / light travels faster in air than in material	3

Total for Question 11 = 12 marks

Question number	Answer	Notes	Marks
7 (a) (i)	protractor;		1
(ii)	angle of incidence between 42 and 46 degrees; angle of refraction between 26 and 30 degrees;		2
(iii)	refractive index = $\sin(\text{angle of incidence}) \div \sin(\text{angle of refraction})$	allow standard symbols i.e. n or eta for ref. index i , r etc	1
(iv)	substitution; correct evaluation; correct answer: 1.5 e.g. $n = \sin(i) \div \sin(r)$ $n = \sin() \div \sin() = 1.479...$	Allow ecf from (ii) allow full credit for correct answer with no working reject division of i and r giving approx 1.5-1.6 range of values with 'in tolerance' values for i and r is 1.34-1.64	2
(b) (i)	15 (nm);		1
(ii)	substitution into given formula; re-arrangement; correct evaluation; correct answer: 7 100 000 (m/s) e.g. $\Delta\lambda \div \lambda = v/c$ $15 \div 630 = v \div (3.0 \times 10^8)$ $v = (3.0 \times 10^8) \times (15 \div 630)$ $v = 7.14 \times 10^6 \text{ (m/s)}$	ecf from (i) allow in either order allow full credit for correct answer with no working -1 POT error use of observed wavelength instead of 630 nm i.e. 645 nm giving 6.976... $\times 10^6 \text{ (m/s)}$ gives 1 mark max	3

(iii)	link between twice the redshift and twice the speed; PLUS one from: link between larger speed and larger distance; (which in turn means that) galaxies are moving apart /moving away from each other;	ignore references to single point/singularity, universe expansion, Big Bang itself accept redshift and speed are directly proportional condone link between larger redshift and larger speed accept quotation of Hubble's Law condone stars for galaxies reject planets etc for galaxies	2
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Total for question 7: 12 marks

Question number	Answer	Notes	Marks
9 (a) (i)	light ray refracting and bending in the correct direction;	ignore any response in the air e.g. reflected wavefronts or direction of travel of reflected ray	3
	wavefronts in water drawn closer together by eye; wavefronts drawn in water join up with wavefronts in air;	allow wherever seen in diagram	2
(ii)	wavelength decreases; (because) wave speed decreases and frequency remains constant;		
(b) (i)	normal drawn at right angles where light ray meets boundary;	judge by eye	1
	(ii) 55° ;	allow range $54-56^\circ$	1
	(iii) substitution into $\sin c = 1/n$; rearrangement; evaluation;	condone intermediate rounding	3
	e.g. $\sin c = 1/1.6$ (c =) $\sin^{-1}(1/1.6)$ (c =) 39°	allow 38.682...	
(iv)	(path shows) total internal reflection; (because) ray is travelling from high to low refractive index; (and) angle of incidence is greater than the critical angle;	allow TIR however expressed e.g. reduction of (optical) density / increase in speed from glass to air	3

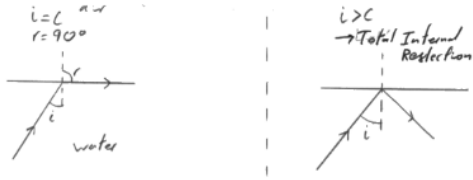
Total for Question 9 = 13 marks



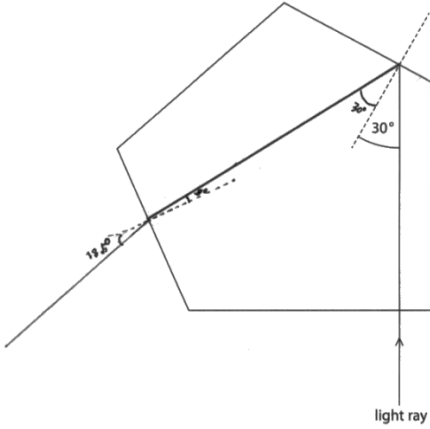
Question number	Answer	Notes	Marks
6 (a)	any two from: MP1. ruler; MP2. protractor; MP3. named suitable light source; MP4. optical pin(s);	e.g. ray box, light box, laser ignore torch	2
(b) (i)	ray drawn bending in the correct direction; ray drawn parallel to ray before it enters the block;	judge by eye	2
(ii)	normal drawn perpendicular to block's surface where light ray enters;	judge by eye normal must be drawn in both air and block	1
(iii)	angle of incidence = 44 (degrees); angle of refraction = 26 (degrees);	allow 43-45 allow 25-27	2
(iv)	refractive index = $\frac{\sin(\text{angle of incidence})}{\sin(\text{angle of refraction})}$;	allow standard symbols and rearrangements e.g. $n = \sin(i) \div \sin(r)$	1
(v)	substitution; evaluation; e.g. (n =) $\sin 44 / \sin 26$ (n =) 1.6	allow ecf from (iii) allow range 1.5-1.7	2
(c)	idea that multiple angles (of incidence) measured; graph of $\sin(i)$ against $\sin(r)$ plotted; gradient of graph = refractive index;	can be gained from diagram ignore orientation of axes can be gained from diagram reject if inconsistent with graph. However, accept if $\sin(r)$ on y-axis then gradient = $1/n$	3

Total for Question 6 = 13 marks

Question number	Answer	Notes	Marks
7 (a)	waves change {speed / wavelength / direction} when they change medium;	allow waves bending allow any reasonable alternative to 'change medium' i.e. changing (optical) density, pass from one material to another etc.	1
(b)	(i) straight ray bent towards normal at the air-water boundary; correct angle of refraction by eye;	judge straightness of ray by eye	2
	(ii) refractive index = $\sin i / \sin r$;	allow rearrangements and standard symbols e.g. $n = \sin i / \sin r$	1
	(iii) substitution; evaluation to at least 3s.f.; e.g. (n =) $\sin 45 / \sin 33$ (n =) 1.30	reject 45/33 reject 1.36 reverse argument scores 1 mark only e.g. calculating i or r using n allow 1.298... condone 1.29	2

Question number	Answer	Notes	Marks
(c) (i)	the angle of incidence (in the slower medium); above which gives total internal reflection OR gives an angle of refraction of 90°; 	allow ideas if clear from diagram allow TIR for total internal reflection	2
(ii)	$\sin c = 1 / n;$	allow rearrangements and mixture of symbols and words	1
(iii)	substitution; rearrangement; evaluation; e.g. $\sin c = 1/1.3$ $c = \sin^{-1}(1/1.3)$ $(c =) 50 (^{\circ})$	allow 50.3, 50.28...	3
(iv)	single straight ray reflected downwards from water surface; angle correct by eye;	any ray above water surface scores zero	2

Total for Question 7 = 14 marks

Question number	Answer	Notes	Marks
10 (a) (i)	$n = 1/\sin(c)$;	accept any rearrangement or word equation	1
(ii)	substitution; evaluation; e.g. $n = 1/\sin(26)$ $n = 2.3$	allow 2.28...	2
(iii)	correct TIR at first boundary; refraction at boundary at 7 o'clock; refraction away from the normal at exit point; 	allow ECF for incorrect TIR and correct subsequent boundaries.	3

(b)	(i) any FOUR from: MP1 any method of recording an incident ray; MP2 any method of recording a refracted ray; MP3 range of angle of incidences; MP4 normal lines drawn; MP5 angles measured using a protractor; (ii) axes labelled; appropriate scale with data enclosed by 3 x 3 grid or larger; points plotted correctly within $\frac{1}{2}$ a square; (iii) best fit straight line drawn with ruler; (iv) evidence of gradient triangle used; evaluation of 1.6;	accept marks on a clear, labelled diagram judge by eye accept markings on graph or evidence of a gradient calculation. accept answer in range 1.55 - 1.65 consistent with candidate's LoBF allow ecf from candidate's LoBF	4 3 1 2
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Total for Question 10 = 16 marks

Question number	Answer	Notes	Marks
7 (a)	mention of vibrations / oscillations; (vibrations are) at right angles to direction of energy transfer;	accept either noun or verb allow wave travel or wave propagation or wave velocity for energy transfer diagram(s) must be labelled such that direction of vibration and direction of travel are clear ignore unlabelled diagrams	2
(b) (i)	any reflecting ray drawn; angle or reflection approximately equal to angle of incidence;	condone lack of arrowhead reject arrowhead in wrong direction judge by eye	2
(ii)	idea that refractive index of air is less than refractive index of optical fibre; angle of incidence is greater than critical angle; reference to <u>total internal reflection</u> ;	allow (optical) density for refractive index accept idea of going from (optically) more dense to (optically) less dense accept 'TIR' (whatever case) for 'total internal reflection'	3
(c)	angle of incidence measured correctly;	allow 48-52 seen anywhere in working	4

	substitution into $\sin c = 1/n$; rearrangement; evaluation to 3 or more s.f.; e.g. angle of incidence = 50° $\sin 50 = 1/n$ $n = 1/\sin 50$ $n = 1.305\dots$	allow clear RA that gives $c = 50.28\dots$ allow $\sin(90)$ for '1' or correct substitution into $n = \sin(i)/\sin(r)$ ($i = 50$ and $r = 90$) allow substitution and rearrangement in either order accept value consistent with candidate's value for angle of incidence i.e. 48 degrees gives 1.345... 52 degrees gives 1.269... arriving at $n = 0.766$ scores 2 marks max correct evaluation (e.g. 1.305) without working scores 1 mark only	
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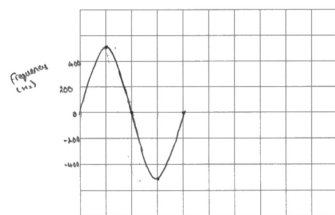
Total for Question 7 = 11 marks

Question number	Answer	Notes	Marks
7	any five from: MP1. current in coil produces magnetic field; MP2. direction of this magnetic field is (continuously) changing; MP3. field of coil interacts with field of magnet; MP4. producing a force on coil/wire; MP5. direction of the force changes; MP6. cone/coil/wire vibrates; MP7. air particles (next to the cone) are made to vibrate;	allow coil is magnetised / becomes an electromagnet allow cone moves in and out / backwards and forwards	5

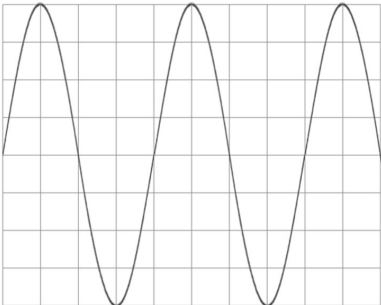
Total for Question 7 = 5 marks

Question number	Answer	Notes	Marks
2 (a)	300 (metres);		1
(b)	0.554; any answer given to 2 sf; correct answer = 0.55 (s) e.g. $(0.50+0.62+0.52+0.58+0.55)/5 = 0.554$ (s) = 0.55 (s) to 2 s.f.	mark independently	2
(c)	difference in distance is 180 m; recall of equation: speed = distance / time taken; substitution; correct evaluation; correct answer = 330 (m/s) e.g. speed = $(300 - 120)/0.55$ speed = $180/0.55$ speed = 327.2727... (m/s)	allow use of standard symbols e.g. $v = d/t$ condone s for v, s for d ECF incorrect distance and ECF incorrect time from (b) answer is 327.2727... (m/s) answer is 324.90... (m/s) if 0.554(s) is used	4
(d)	human reaction time;	accept alternative valid variables e.g. wind speed, temperature, humidity, air pressure	1

Total for Question 2: 8 marks

Question number	Answer	Notes	Marks
5 (a)	frequency;	ignore unit for frequency reject response with more than one quantity/property	1
(b)	C chosen;	condone E chosen condone 'C and E' condone 'C or E'	2
	(because) humans can hear up to 20 kHz / 20 000Hz;	accept additional reasonable qualification e.g. idea of upper range decreasing with age or hearing loss	
(c) (i)	substitution into $f = 1/T$;	accept use of standard form throughout working required	3
	rearrangement;	working required	
	evaluation in seconds and appropriate conversion to ms;	-1 for POT error	
	e.g. $500 = 1/T$ $T = 1/500$ $T = 0.002 \text{ s} = 2(.0) \text{ (ms)}$ (ii) one or more complete wave(s) drawn with consistent period by eye; each cycle is 4 squares; 	accept reverse argument i.e. converted to 0.002; substituted i.e. $f = 1/0.002$; evaluated to get 500 Hz; ignore amplitude e.g. all half-cycles the same number of squares horizontally mark independently	2

Total for Question 5 = 8 marks

Question number	Answer	Notes	Marks
8 (a) (i)	microphone;		1
(ii)	measure number of squares for a number of complete cycles / waves and find average number of squares for one cycle; multiply number of squares for one cycle by the time base / eq;	condone 'find number of squares for one cycle' accept 'period' for 'cycle' condone use of 'wavelength' for 'period' or 'cycle' ignore reference to $T = 1/f$	2
(b) (i)	evaluation of time period of wave; substitution into $f = 1 \div T$; evaluation of frequency; conclusion consistent with frequency value; e.g. time period = 4×10^{-5} s $f = 1 \div 4 \times 10^{-5}$ $f = 25\,000$ (Hz) (therefore) sound cannot be heard (since frequency is greater than 20 000 Hz)	reject if candidate uses y-axis allow ecf if frequency is incorrect conclusion must be consistent with candidate's frequency value to be awarded the mark	4
(ii)	wave has amplitude of 4 squares; wave has time period of 4 squares; e.g. 		2

Total for Question 8 = 9 marks

Question number	Answer	Notes	Marks																					
7 (a)	C and D ticked with A and F unticked = 1 mark; all of B, C, D and E ticked with A and F unticked = 2 marks;; <table><tr><th>Sound wave</th><th>Frequency in Hz</th><th>Can be heard by humans</th></tr><tr><td>A</td><td>10</td><td></td></tr><tr><td>B</td><td>30</td><td>✓</td></tr><tr><td>C</td><td>500</td><td>✓</td></tr><tr><td>D</td><td>2000</td><td>✓</td></tr><tr><td>E</td><td>10 000</td><td>✓</td></tr><tr><td>F</td><td>25 000</td><td></td></tr></table>	Sound wave	Frequency in Hz	Can be heard by humans	A	10		B	30	✓	C	500	✓	D	2000	✓	E	10 000	✓	F	25 000		if either A or F ticked then award 0 marks	2
Sound wave	Frequency in Hz	Can be heard by humans																						
A	10																							
B	30	✓																						
C	500	✓																						
D	2000	✓																						
E	10 000	✓																						
F	25 000																							
(b)	wave drawn with lower amplitude throughout; wave drawn with lower frequency throughout;	ignore vertical position of wave in the grid peak to peak should be less than 4 squares vertically throughout trace should be less than 2½ waves in the trace	2																					
(c) (i)	conversion of temperature into kelvin; substitution and evaluation; e.g. temperature = 46 + 273 = 319 K speed = (0.606 × 319) + 166 = 360 (m/s)	allow 319 seen anywhere in working apply ecf if 46 used as kelvin temperature giving 194, 193.9, 193.876 (m/s) for 1 mark allow 359, 359.3... (m/s)	2																					
(ii)	substitution into speed = frequency × wavelength; rearrangement; evaluation; e.g. 360 = 15 000 × wavelength wavelength = 360 / 15 000 (wavelength =) 0.024 (m)	allow ecf from (i) use of 194 (m/s) from (i) gives an answer of 0.013 (m) answer of 0.023 gets 2 marks only allow 0.02, 0.0239... (m)	3																					

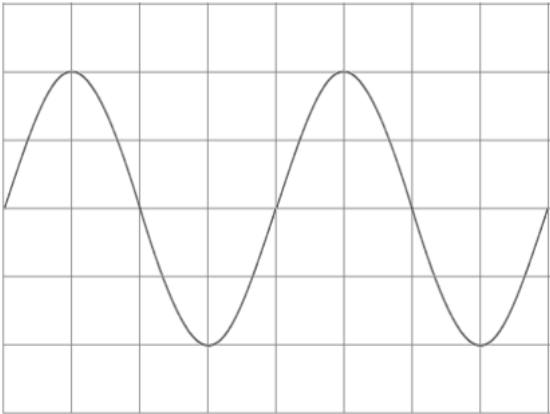
Total for Question 7 = 9 marks



Question number	Answer	Notes	Marks
7 (a)	idea that time (between hits) is too short / reaction/thinking time is an issue;	ignore thinking distance, human error	1
(b) (i)	11.18 circled;		1
(ii)	idea that student miscounted the number of block hits;	ignore “reaction time”, human error allow idea that timer was started late / stopped early allow idea that distance to wall is different	1
(iii)	evaluation of a mean value; evaluation of a mean value excluding anomaly; final answer correctly given to 2 decimal places; e.g. mean = 11.642 (s) mean = 11.7575 (s) mean = 11.76 (s)	allow even if anomaly included allow ecf from (i) independent mark 11.642 scores 1 mark 11.64 scores 2 marks 11.75 scores 2 marks	3
(iv)	substitution into given formula; evidence of doubling distance OR dividing time by 20; evaluation; e.g. speed = $(2 \times) 100 / 11.76(\div 20)$ distance = 200m OR time = 0.59s speed = $(200 / 0.59) = 340$ (m/s)	allow ecf from (iii) condone lack of $\times 2$ and $\div 20$ 8.5 (m/s) scores 1 mark 17, 170 (m/s) scores 2 marks allow 340.2..., 340.1... (m/s)	3

Total for Question 7 = 9 marks



Question number	Answer	Notes	Marks
9 (a)	microphone;		1
(b)	any roughly sine-shaped wave drawn on the screen; amplitude of trace = 2 squares; substitution into $f = 1 / T$; evaluation of time period = 0.004 (s); trace drawn on oscilloscope has period of 4 squares; e.g. 	allow triangle wave e.g. $250 = 1/T$ or $T = 1/250$ automatically scores last three marking points	5
(c)	single use of data from graph to show that frequency $\times$ wavelength = constant; second use of data from graph to show that frequency $\times$ wavelength = constant; clear comparison of constants to show they are (approximately) equal AND conclusion that the relationship is inversely proportional;	constant should be between 320 and 360 depending on data used	3

Total for Question 9 = 9 marks

Question number	Answer	Notes	Marks
3 (a)	Any FIVE from: MP1. measure time for a set distance; MP2. realistic values suggested for experiment to work; MP3. suitable measuring instrument named; MP4. further detail of setup; MP5. idea of repeats AND average; MP6. speed = distance / time;	A fully labelled diagram can score all the marks. allow measuring wavelength for a known frequency e.g. - at least 1m for microphones and oscilloscope method - at least 100m for seeing and hearing a clap method - at least 50m for wall and echo method - wavelength measured at least 10cm e.g. stop clock, stopwatch, ruler, tape measure, oscilloscope, trundle wheel, timer e.g. - two microphones on bench connected to oscilloscope - start timing when see a clap and stop when hear it - clap by wall and time how long for clap to come back - moving a microphone until waveforms line up on oscilloscope - For echo method, idea time and distance is "there and back" allow speed = frequency × wavelength for appropriate method	5

(b) (i)	Measurement of one period on oscilloscope; Use of x-scale; Evaluation of period in s; e.g. Period = 4 squares Period = 4×0.25 (ms) Period = 1.0×10^{-3} (s)	-1 POT error Allow 1 SF answer Condone period = 0.0005 (s) or 0.002 (s) or in standard form for 2 marks MAX.	3
(ii)	Substitution into given equation $f = 1/T$; Evaluation; i.e $f = 1/(1.0 \times 10^{-3})$ $f = 1000$ (Hz)	Allow ECF from b) (i)	2

Question number	Answer	Notes	Marks
3 (a) (i)	(average) speed = distance / time;	allow standard symbols and rearrangements e.g. $v = s/t$ allow s for speed and d for distance	1
	(ii) substitution; evaluation; e.g. (speed =) $1860 / 5.6$ (speed =) $330(\text{m/s})$	allow $332.14\dots(\text{m/s})$	2
	(iii) light travels faster than sound; he sees explosion before hearing it;	allow idea that they travel at different speeds but not that sound travels faster Allow RA	2
(b)	vibrations (of particles) are parallel; to direction the wave travels;	allow oscillations for vibrations DOP allow direction of energy transfer	2
(c) (i)	kinetic energy = $\frac{1}{2} \times \text{mass} \times \text{speed}^2$;	allow standard symbols and rearrangements e.g. $\text{KE} = \frac{1}{2} \times m \times v^2$	1
	(ii) substitution; evaluation; e.g. (KE =) $0.5 \times 1.25 \times 10^7 \times 19200^2$ (KE =) $2.30 \times 10^{15} \text{ (J)}$	-1 for POT error allow $2.304 \times 10^{15} \text{ (J)}$	2

Total for Question 3 = 10 marks

Question number	Answer	Notes	Marks
4 (a) (i)	speed = frequency $\times$ wavelength;	allow standard symbols and rearrangements e.g. $v = f \times \lambda$	1
(ii)	determination of period; conversion from ms to s; evaluation of frequency; substitution into $v = f \times \lambda$; evaluation of speed; e.g. period = 4 squares period = $(4 \times 1 =) 4$ ms frequency $(= 1/4 \times 10^{-3}) = 250$ (Hz) speed = 1.4×250 speed = 350 (m/s)	allow ECF from incorrect frequency -1 for POT error 175, 700 (m/s) = 3 marks allow 0.004 (s)	5
(b)	any five from: MP1. reference to reaction time; MP2. suggestion that light flash and sound may not be at the same time; MP3. idea that distance is too short (to give accurate value); MP4. idea that ruler is not appropriate to measure this distance; MP5. idea of mis-counting the number of ruler lengths; MP6. idea of zero error on ruler; MP7. idea of ruler not going in a straight line; MP8. idea of lack of repeats; MP9. idea that time of travel is too short to be measured by a human;	ignore descriptions of different experimental methods allow description of reaction time issues allow suggestion that trundle wheel/tape measure should be used allow ground not being level	5

(Total for Question 4 = 11 marks)



Question number	Answer	Notes	Marks
2 (a)	longitudinal;		1
(b) (i)	particles arranged randomly; particles further apart in gas than in liquid;	allow either mark if clear from diagrams allow irregularly for randomly mark can be given for description of liquid, gas, or both allow RA ignore diagram for this mark if gaps in liquid bigger than one particle	2
(ii)	(sound travels by) vibrations; idea that {vibrations / sound / waves / energy} are passed on more effectively because particles are closer together;	allow alternatives for vibrations e.g. oscillations allow "sound vibrates particles" allow equivalents for effectively e.g. faster, easily, efficiently etc.	2

(c)	(i)	(wave) speed = frequency $\times$ wavelength;	allow correct use of symbols and rearrangements e.g. $v = f \times \lambda$ condone s as symbol for speed	1
	(ii)	substitution OR rearrangement; evaluation; e.g. $340 = 1400 \times \lambda$ OR $\lambda = v / f$ $(\lambda =) 0.24 \text{ (m)}$	allow 0.243, 0.242857... etc. condone 0.242	2
	(iii)	any five from: MP1. sound heard by student A is louder; MP2. sound heard by student A is constant pitch; MP3. no change in sound heard by student A when speed of rotation is varied; MP4. sound heard by student B varies in pitch; MP5. sound heard by student B is high pitch when buzzer is moving towards them AND low pitch when moving away from them; MP6. change of pitch for student B is greater when speed of rotation is greater; MP7. sound varies in loudness for student B;	allow use of frequency instead of pitch throughout allow RA allow RA i.e. constant loudness for student A	5

Total for Question 2 = 13 marks

Question number	Answer	Notes	Marks
4 (a)	(i) measure the distance between microphones; suitable instrument to measure distance; use of speed = distance ÷ time;	e.g. ruler / tape measure	3
	(ii) idea that time will be very small / too hard to measure by a human;	allow idea that human reaction time is an issue ignore speed of sound is very fast / eq.	1
(b)	(i) idea that air needs to be same temperature at all points between microphones;	allow idea that speed will change if temperature not constant ignore 'fair test'	1
	(ii) correctly calculate average; given to 1 decimal place; e.g. 59.97 = 1 mark 60.0 = 2 marks	DOP 59.9 scores 1 mark allow 59.96, 60	2
	(iii) point at (40, 358) circled;		1
	(iv) repeat it / discard it;	allow repeat experiment condone 'ignore it'	1
	(v) line graph suitable for continuous data; both variables are continuous;	allow 'data is continuous'	2
	(vi) idea that speed increases as temperature increases; idea of a linear relationship;	ignore positive correlation reject mark if relationship described as directly proportional	2

Total for Question 4 = 13 marks

Question number	Answer	Notes	Marks
5 (a)	any 4 of: MP1. connect oscilloscope to microphone; MP2. adjust the oscilloscope to get a steady trace / eq; MP3. adjust time base / oscilloscope to give a minimum of 1 complete cycle (on the screen); MP4. measure number of squares for a number of complete cycles / waves; MP5. multiply number of squares by the time base / eq. (to find T); MP6. use $f = 1/T$;	ignore references to wavelength, amplitude, finding number of waves passing a point allow 'use oscilloscope to measure/find the time period / time for one wave' if neither MP4 or MP5 scored	4
(b) (i)	any 1 of: MP1. force / tension (on the string); MP2. material string is made from; MP3. diameter / thickness of the string; MP4. temperature;		1
(ii)	correctly calculated mean; given to nearest whole number; e.g. 34.3... gains first mark 34 gains both marks	mark independently	2
(iii)	suitable linear scale chosen (>50% of grid used); axes labelled with quantities and unit; <u>all</u> plotting correct to nearest half square;	ignore orientation ignore point at 60cm	3
(iv)	acceptable curve of best fit drawn;	i.e. smooth curve within 1 small square of each point ignore parts of curve outside plotted points if extrapolated	1
(v)	string length in range 26-31cm;	allow ecf from candidate's line	1
(vi)	both 120cm and 140cm strings / eq; (because) humans cannot hear frequencies lower than 20Hz;	allow correctly read string length from graph for 20Hz frequency	2

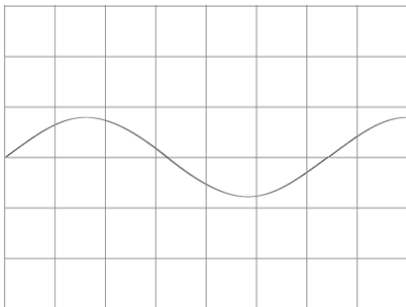
Total for Question 5 = 14 marks



Question number	Answer	Notes	Marks
4 (a)	(i) recall of equation: speed = frequency × wavelength; substitution or re-arrangement; correct evaluation; correct answer = 0.013 (m) e.g. speed = frequency × wavelength wavelength = speed ÷ frequency wavelength = 330 ÷ 25000 wavelength = 0.0132... (m)	allow use of standard symbols e.g. $v = f \times \lambda$ condone s for speed reject w for wavelength answer to 3sf is 0.0132 (m)	3
	(ii) amplitude corresponds to 2 squares; 2 squares gives 10 V for amplitude;	ecf incorrect number of squares for amplitude e.g. 4 squares giving 20V scores 1 mark	2
(b)	(i) field lines outside of coil appear to loop from end to end; arrow directions self-consistent; no overlapping field lines;	allow field lines approximately uniform through solenoid condone incorrect poles	3
	(ii) any THREE from: MP1. idea of force on coil from magnet; MP2. idea of alternating force on card; MP3. card vibrates; MP4. idea that card forces air to vibrate; MP5. longitudinal wave formed;	allow idea of interaction between fields of bar magnet and coil allow idea of series of compressions and rarefactions	3
	(iii) idea that 25 kHz is outside the range of human hearing; upper limit of human hearing is 20 kHz;	ignore reference to 20Hz or lower limit	2
	(iv) increase current (amplitude)/ increase strength of (bar) magnet/ increase number of turns on coil;	allow increase density of turns on coil condone change card for a different material allow change size or shape of card allow moving magnet closer to the coil allow higher order answers in terms of resonance	1

Total for Question 4: 14 marks



Question number	Answer	Notes	Marks										
2 (a)	C (20 Hz to 20 000 Hz); A is incorrect because the lower range is too low B is incorrect because both the lower and upper ranges are incorrect D is incorrect because the upper range is too high		1										
(b)	1 mark for each correctly ticked row;; <table><tr><th>Statement</th><th>Correct (✓)</th></tr><tr><td>sound waves are longitudinal</td><td>✓</td></tr><tr><td>sound waves can travel through a vacuum</td><td></td></tr><tr><td>sound waves are part of the electromagnetic spectrum</td><td></td></tr><tr><td>sound waves can be reflected and refracted</td><td>✓</td></tr></table>	Statement	Correct (✓)	sound waves are longitudinal	✓	sound waves can travel through a vacuum		sound waves are part of the electromagnetic spectrum		sound waves can be reflected and refracted	✓	if more than two ticks then -1 for each incorrect tick	2
Statement	Correct (✓)												
sound waves are longitudinal	✓												
sound waves can travel through a vacuum													
sound waves are part of the electromagnetic spectrum													
sound waves can be reflected and refracted	✓												
(c) (i)	time;	ignore any unit given reject time base reject time period accept lower case 't' reject upper case 'T'	1										
(ii)	trace has lower amplitude throughout; trace has larger time period throughout; e.g. 		2										

Total for Question 2 = 6 marks

Question number	Answer	Notes	Marks
8 (a)	20 000 (Hz);	allow if full range given i.e. 20 - 20 000 (Hz) allow 20 kHz but matching unit needed	1
(b)	evaluation of time period; use of $f = 1/T$; evaluation of frequency; consistent conclusion comparing calculated frequency to answer in (a); e.g. $T = 4 \times 20 \times 10^{-6} = 8 \times 10^{-5} \text{ (s)}$ $f = 1 / 8 \times 10^{-5}$ $f = 12\,500 \text{ (Hz)}$ this is within human hearing range so can be heard	allow ecf from incorrect T for this mark only this mark can only be awarded if a frequency calculation has been attempted allow ecf from (a)	4
(c)	A (10×10^{-6} seconds per square, 5 mV per square); <i>B is incorrect because this will cause the amplitude to decrease</i> <i>C is incorrect because this will cause there to be four waves on the screen</i> <i>D is incorrect because this will cause there to be four waves on the screen and the amplitude to decrease</i>		1

Total for Question 8 = 6 marks