# Wave Motion

**1.** Which statement is **not** correct about an electromagnetic wave?

**A** It can be diffracted.
**B** It can be polarised.
**C** It is a longitudinal wave.
**D** It can travel through a vacuum.

Your answer [1]

**2.** Which definition is correct and uses only quantities rather than units?

**A** Acceleration is the change in velocity per second.
**B** Resistance is potential difference per ampere.
**C** Intensity is energy per unit cross-sectional area.
**D** Electromotive force is energy transferred per unit charge.

Your answer [1]

**3.** The stationary wave shown below is formed on a stretched string.

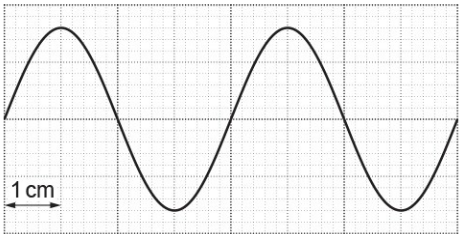
The frequency of this stationary wave is 72 Hz.

What is the fundamental frequency for a stationary wave on the same string?

**A** 18 Hz
**B** 24 Hz
**C** 48 Hz
**D** 72 Hz

Your answer [1]

**4.** The diagram below shows the oscilloscope trace for an electrical signal.




The time-base setting of the oscilloscope is 2 μs $cm^{-1}$.
What is the frequency of the signal?

A 125 Hz
B 250 Hz
C 125 kHz
D 250 kHz

Your answer ☐ **[1]**

**5.** In which region of the electromagnetic spectrum is radiation of frequency 300 MHz?

**A** radio wave
**B** microwave
**C** visible
**D** X-ray

Your answer ☐ **[1]**

**6.** A progressive wave of amplitude *a* has intensity *I*. This wave combines with another wave of amplitude 0.6*a* at a point in space. The phase difference between the waves is 180°.

What is the resultant intensity of the combined waves in terms of *I*?

**A** 0.16 *I*
**B** 0.4 *I*
**C** 1.6 *I*
**D** 2.6 *I*

Your answer ☐ **[1]**

**7.** A student views the display of a laptop screen through a polarising filter. The intensity of the light changes when the filter is rotated.

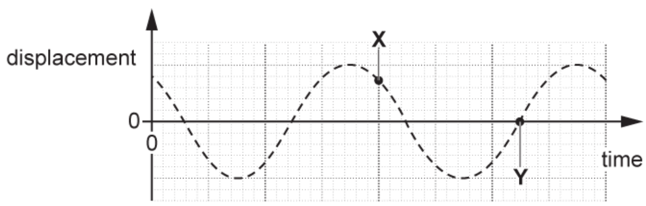
Which property of light is demonstrated in this experiment?

**A** It has wavelength of about $5 \times 10^{-7}$ m.
**B** It travels at the speed of light.
**C** It is a transverse wave.
**D** It is a longitudinal wave.

Your answer

**[1]**

**8.** The displacement against time graph for a progressive wave is shown below.




Which statement is correct about the phase difference ***z*** between points **X** and **Y**?

**A** $0 < \phi < 90°$
**B** $\phi = 90°$
**C** $\phi = 180°$
**D** $180° < \phi < 270°$

Your answer

**[1]**

**9.** The intensity of a laser beam is 2.0 W m$^{-2}$. The cross-sectional area of the beam is 1.0 mm$^2$.

What is the energy delivered by the laser beam in a time of 100 s?

**A** $2.0 \times 10^{-6}$ J
**B** $2.0 \times 10^{-4}$ J
**C** $2.0 \times 10^{-1}$ J
**D** $2.0 \times 10^{1}$ J

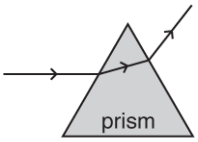
Your answer

**[1]**

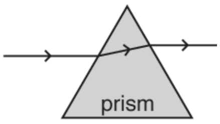
**10.** A narrow beam of light in air is directed at the surface of a triangular glass prism.

Which is the correct diagram for the light refracted by the prism?

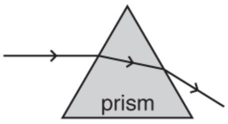
**A**



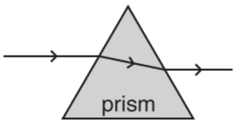

**B**




**C**

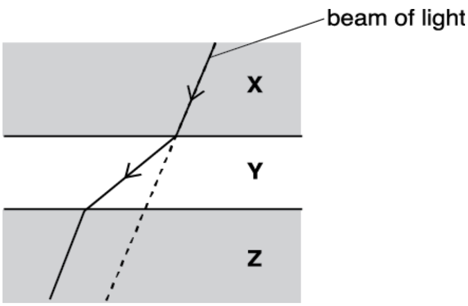



**D**




Your answer ☐ **[1]**

**11.** The diagram below shows the path of a narrow beam of light as it is refracted at the boundaries between three different transparent materials **X**, **Y** and **Z**.




The beam of light in **X** and the beam of light in **Z** are parallel.
The wavelength of the light in **X** is 640 nm.

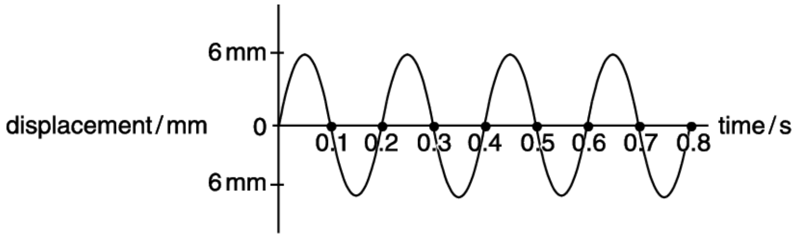
Which statement is correct?

**A** The light travels faster in **X** than in **Y**.
**B** The wavelength of light in **Y** is shorter than 640 nm.
**C** Materials **X** and **Z** have the same value of refractive index.
**D** The refractive index of **Y** is greater than the refractive index of **X**.

Your answer ☐

**[1]**

**12.** The graph shows the variation of displacement with time for a progressive wave.



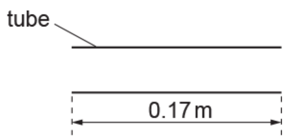

Which of the following statements can be deduced from the graph?

A. The frequency of the wave is 5 Hz.
B. The graph represents a transverse wave motion.
C. The amplitude of the wave is 12 mm.
D. The wavelength of the wave is 60 m.

Your answer

**[1]**

**13.** A stationary sound wave, in its fundamental mode of vibration, is formed in a tube open at both ends.




The length of the tube is 0.17 m. The speed of sound in air is 340 m $s^{-1}$.

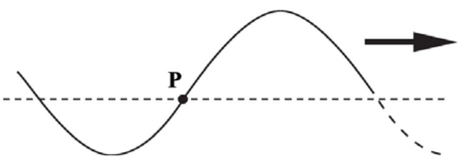
Which row for this stationary wave is correct?

| | Number of nodes | Frequency of stationary wave / Hz |
|---|---|---|
| **A** | 1 | 500 |
| **B** | 1 | 1000 |
| **C** | 2 | 1000 |
| **D** | 2 | 2000 |

Your answer

**[1]**

**14.** The figure shows part of a transverse progressive wave which is travelling to the right along a string.
The horizontal dotted line shows the position of the string when there is no wave present.
In which direction is the string at the point **P** moving at the instant shown?




A. upwards
B. downwards
C. to the right
D. it is at rest

Your answer

**[1]**

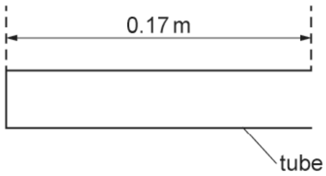
**15.** A small loudspeaker emits sound uniformly in all directions.
The amplitude of the sound is 12 μm at a distance of 1.5 m from the loudspeaker.

What is the amplitude of the sound at a distance of 4.5 m from the loudspeaker?

**A** 1.3 μm
**B** 4.0 μm
**C** 6.9 μm
**D** 12 μm

Your answer [1]

**16.** A stationary sound wave, of fundamental mode of vibration, is formed in a tube closed at one end.



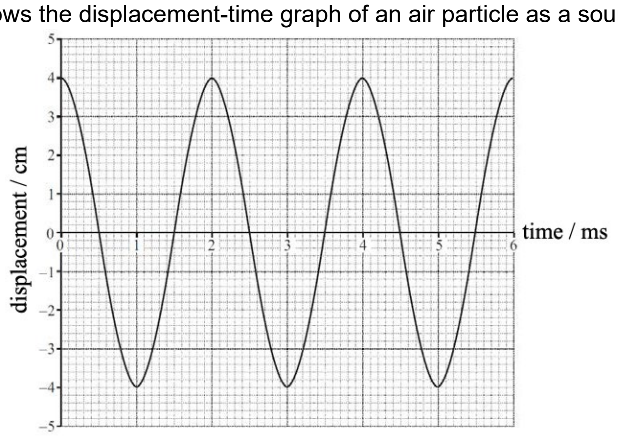

The length of the tube is 0.17 m. The speed of sound in air is 340 m $s^{-1}$.

What is the fundamental frequency of the stationary wave?

**A** 500 Hz
**B** 1000 Hz
**C** 2000 Hz
**D** 4000 Hz

Your answer [1]

**17.** The diagram below shows the displacement-time graph of an air particle as a sound wave passes.




The speed of the sound wave is 340 m $s^{-1}$.
What is the wavelength of the sound wave?

A. 0.68 m
B. 1.7 m
C. 170 m
D. 680 m

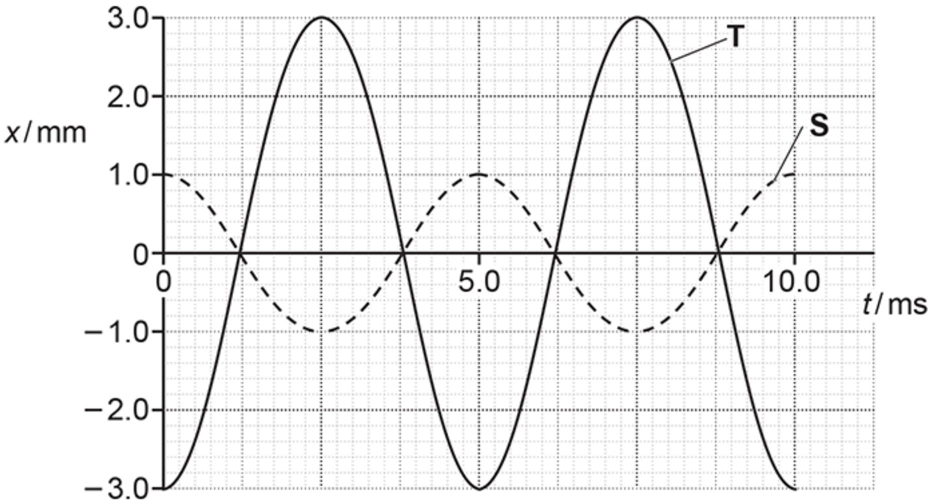
Your answer [1]

**18.** What is the S.I. unit for electrical charge?

**A** ampere
**B** coulomb
**C** ohm
**D** volt

Your answer [ ] **[1]**

**19.** The diagram below shows the graphs of displacement $x$ against time $t$ for two waves **S** and **T**.



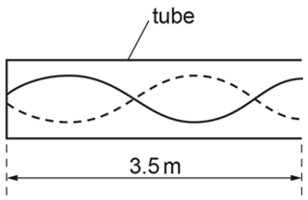

The waves meet at a point in space.
The superposition of these two waves produces a resultant wave.

What is the frequency $f$ and the amplitude $A$ of the resultant wave?

**A** $f$ = 100 Hz, $A$ = 2.0 mm
**B** $f$ = 100 Hz, $A$ = 4.0 mm
**C** $f$ = 200 Hz, $A$ = 2.0 mm
**D** $f$ = 200 Hz, $A$ = 4.0 mm

Your answer [ ] **[1]**

**20.** A stationary sound wave formed in a tube is shown below.



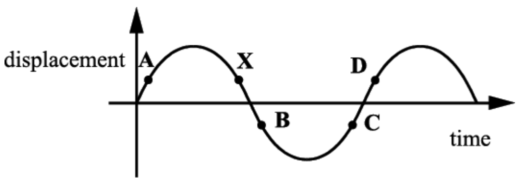

The tube is closed at one end. The length of the tube is 3.5 m.
The speed of sound is 340 m $s^{-1}$.

What is the frequency of the sound wave?

**A** 97 Hz
**B** 120 Hz
**C** 240 Hz
**D** 486 Hz

Your answer [1]

**21.** The diagram below shows the displacement-time graph of a particle as a progressive wave travels through a medium.




Which point **A**, **B**, **C**, or **D** has a phase difference of 180° with reference to point **X**?

Your answer

[1]

**22.** Monochromatic light from a laser is incident normally on a diffraction grating. A series of bright dots are formed on a distant screen.

Which **two** terms can be used to explain these bright dots?

**A** diffraction, interference
**B** reflection, interference
**C** refraction, diffraction
**D** refraction, reflection

Your answer [1]

**23.** Which of the following waves can be polarised and has a typical wavelength of about a few centimetres?

**A** microwaves
**B** ultraviolet
**C** sound
**D** visible light

Your answer [ ] **[1]**

**24.** Power has base units kg $m^2$ $s^{-3}$.

What are the base units for intensity?

**A** kg $s^{-3}$
**B** kg $ms^{-3}$
**C** kg $m^2s^{-3}$
**D** kg $m^4s^{-3}$

Your answer [ ] **[1]**

**25.** This question is about waves.

The **period** of a progressive wave can be determined from Fig. 16.1. Add a correct label to the horizontal axis so that the period can be found.

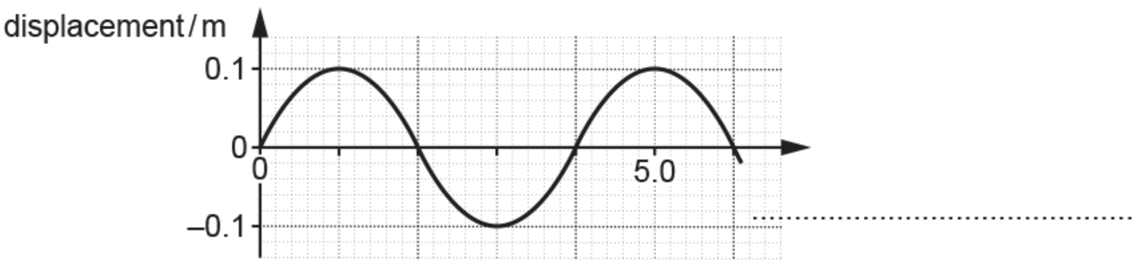
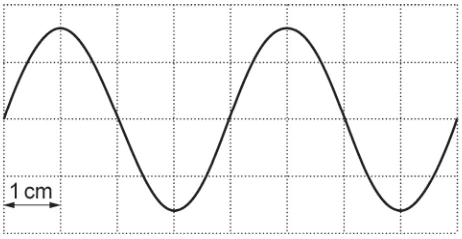



**Fig. 16.1**

**[1]**

**26.** The diagram below shows the oscilloscope trace for an electrical signal.




The frequency of the signal is 250 Hz.

What is the time-base setting of the oscilloscope?

**A** 1 ms $cm^{-1}$
**B** 2 ms $cm^{-1}$
**C** 4 ms $cm^{-1}$
**D** 8 ms $cm^{-1}$

Your answer ☐ **[1]**

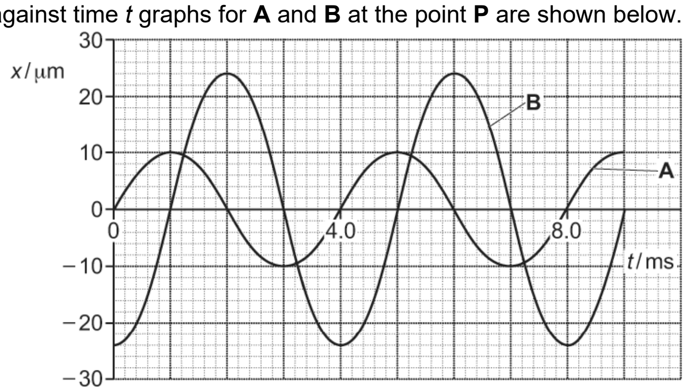
**27.** This question is about a progressive wave and a stationary wave.

Which statement is correct?

A A progressive wave has at least one node.
B All progressive waves are longitudinal.
C All particles oscillating between two adjacent nodes in a stationary wave are in phase.
D The superposition of two waves travelling in the same direction produces a stationary wave.

Your answer ☐ **[1]**

**28 (a).** Two progressive waves **A** and **B** meet at a point **P**.
The displacement *x* against time *t* graphs for **A** and **B** at the point **P** are shown below.




Explain how the graphs show that the waves are coherent.

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**[1]**

**(b).** Determine the frequency $f$ of the wave **A**.

$f$ = ..................................................... Hz **[2]**

**(c).** The intensity of wave **A** is $I_0$.

Determine the intensity of wave **B** in terms of $I_0$.

intensity = ..................................................... $I_0$ **[2]**

**(d).** Determine the resultant displacement at the point **P** at time $t$ = 2.5 ms.

resultant displacement = ..................................................... μm **[1]**

**29.** An exploding star in a distant galaxy emitted a burst of electromagnetic radiation. X-rays and ultraviolet radiation from this burst were detected simultaneously at the Earth.
The wavelength of the X-rays was $2.5 \times 10^{-11}$m.

Calculate the frequency $f$ of the X-rays.

$f$ = .............................. Hz **[2]**

**30 (a).** A loudspeaker emits a sound wave. A microphone is connected to an oscilloscope. The trace produced on the screen of the oscilloscope due to the sound wave is shown in Fig. 1.

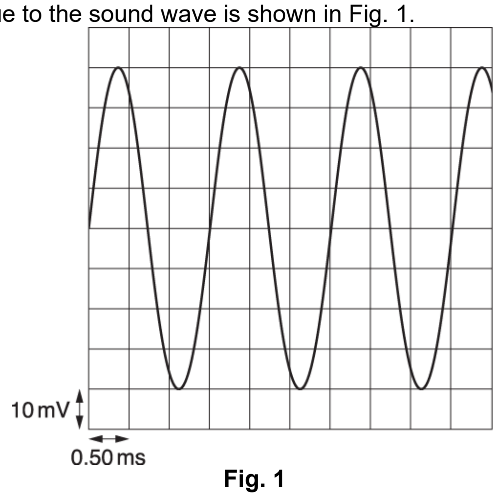


**Fig. 1**

The vertical *y*-sensitivity of the oscilloscope is set to 10 mV $div^{-1}$ and the horizontal time-base is set to 0.50 ms $div^{-1}$.

i. Determine the amplitude of the signal displayed on the oscilloscope.

amplitude = ........................................................... mV **[1]**

i. The frequency *f* of the sound wave is the same as the frequency of the signal shown in Fig. 1. Determine *f*.

*f* = ........................................................... Hz **[2]**

ii. The speed of sound in air is 330 m $s^{-1}$. Calculate the wavelength *λ* of the sound wave.

λ = ........................................................... m **[1]**

**(b).** The output from the loudspeaker is adjusted so that the **intensity** of the sound wave at the microphone is a quarter of its original value. The controls on the oscilloscope are not altered.

Describe and explain how the signal displayed on the oscilloscope will be different from Fig. 1.

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**[2]**

**31.** A progressive wave has wavelength $\lambda$, frequency $f$ and period $T$.

Show that the speed $v$ of the wave is given by the equation $v = f\lambda$.

**[2]**

**32.** A narrow beam of unpolarised light is incident at the boundary between air and glass.

Fig. 18 shows the incident ray, the reflected ray and the refracted ray at the air-glass boundary.

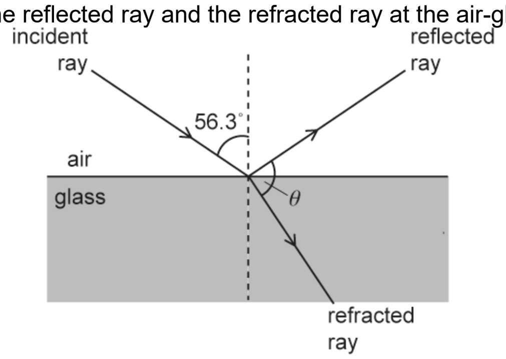


**Fig. 18 (not to scale)**

The refractive index of air is 1.00 and the refractive index of the glass is 1.50.
The angle of incidence of the light is 56.3°.

Describe how you can demonstrate in the laboratory that reflected light is plane polarised.

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**[2]**

**33.** In an experiment using microwaves, a metal grille **G** consisting of a series of long metal rods is placed between a transmitter **T** and a detector **D** as shown in Fig. 7.2.

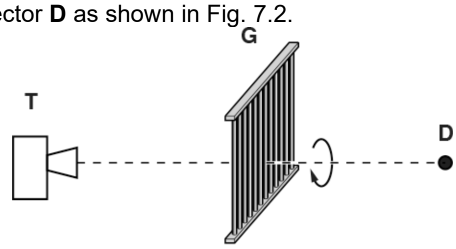


**Fig. 7.2**

The grille is slowly rotated through 180° about the line joining **T** and **D**. The detected signal at **D** varies from zero to maximum and back to zero again.

Explain why the detected signal behaves in this way.

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**[2]**

**34.** This question is about a laser pen.

Define the terms *phase difference* and *coherence*.

*phase difference*

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*coherence*

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**[2]**

**35.** This question is about investigations involving an electromagnetic wave.

A vertical transmitter aerial emits a **vertically polarised** electromagnetic wave which travels towards a vertical receiver aerial. The wavelength of the wave is 0.60 m.

**Fig. 5.1** shows a short section of the oscillating electric field of the electromagnetic wave.

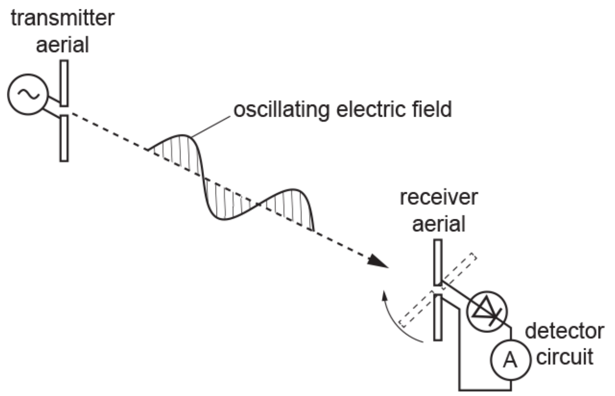


**Fig. 5.1**

Calculate the frequency *f* of the transmitted wave.

*f* = ...................................................... Hz **[2]**

**36.** An oscilloscope is connected to a microphone. The oscilloscope is used to determine the frequency of sound waves emitted from a loudspeaker.
Describe how the trace on the oscilloscope screen can be used to determine the frequency *f* of the sound waves.

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**[2]**

**37.** Describe the difference between longitudinal and transverse waves.

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**[2]**

**38.** The speed $v$ of the transverse waves on the string is directly proportional to $\sqrt{T}$, where $T$ is the tension in the string.
The tension $T$ in the string is increased by 14 %. The frequency $f$ of the oscillator is adjusted to get the same stationary wave pattern as **Fig. 18.1**.

Calculate the percentage increase in the frequency $f$.

increase = .......................................... % **[2]**

**39.** Fig. 19.1 shows the image from an experiment using a ripple tank.

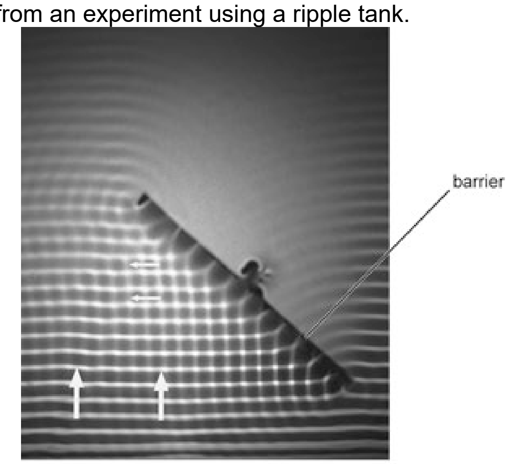


**Fig. 19.1**

A straight ruler repeatedly hits the surface of water. Waves on the surface of the water travel in the direction shown by the two large upward white arrows. The waves are incident at a solid barrier.

Closely examine the image shown in Fig. 19.1.

State **two** wave phenomena (properties) that can be observed in this image. You may annotate Fig. 19.1 to support your answer.

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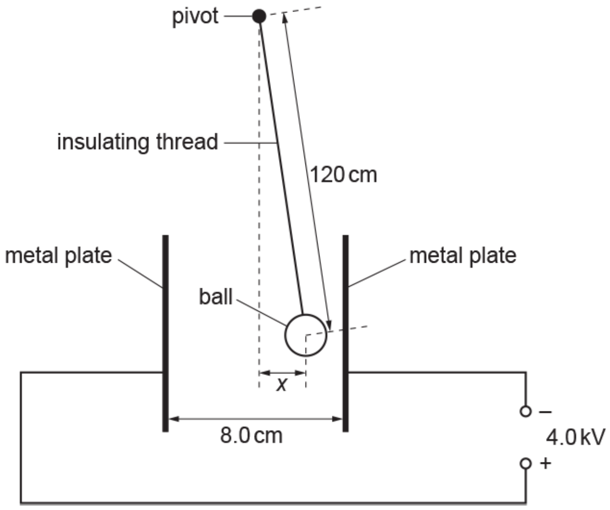
**[2]**

**40 (a).** A ball coated with conducting paint has weight 0.030 N and radius 1.0 cm. The ball is suspended from an insulating thread. The distance between the pivot and the centre of the ball is 120 cm.

The ball is placed between two vertical metal plates. The separation between the plates is 8.0 cm. The plates are connected to a 4.0 kV power supply.

The ball receives a positive charge of 9.0 nC when it is made to touch the positive plate. It then repels from the positive plate and hangs in equilibrium at a displacement *x* from the vertical, as shown below. The diagram is **not** drawn to scale.




i. Show that the electric force acting on the charged ball is $4.5 \times 10^{-4}$ N.

**[2]**

ii. Draw, on the diagram above, arrows which represent the **three** forces acting on the ball. Label each arrow with the name of the force it represents.

**[2]**

iii. By taking moments about the pivot, or otherwise, show that $x = 1.8$ cm.

**[2]**

**(b).** The ball is still positively charged.

The plates are now moved slowly towards each other whilst still connected to the 4.0 kV power supply. The plates are stopped when the separation is 5.0 cm.

Explain the effect that this has on the deflection of the ball and explain why the ball eventually starts to oscillate between the plates.

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**[4]**

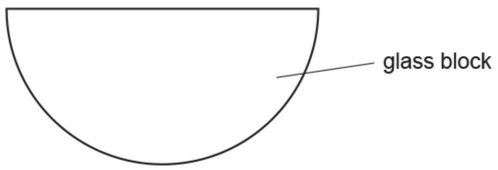
**(c).** When the ball oscillates between the plates, the current in the external circuit is $3.2 \times 10^{-8}$ A.

A charge of 9.0 nC moves across the gap between the plates each time the ball makes one complete oscillation.

Calculate the frequency *f* of the oscillations of the ball.

*f* = ...................................................... Hz **[2]**

**41.** A student is given a semi-circular glass block.
Describe with the aid of a ray diagram how an experiment can be conducted to accurately determine the critical angle for light within the glass block and hence the refractive index of the glass.

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**[3]**

**42.** The table shows the refractive index *n* of air and glass for blue light. It also shows the speed *v* and the wavelength *λ* of blue light in air.

| | **air** | **glass** |
|---|---|---|
| refractive index *n* | 1.00 | 1.53 |
| speed of light $v$ / m $s^{-1}$ | $3.00 \times 10^8$ | |
| wavelength λ/m | $4.69 \times 10^{-7}$ | |

i. Show that the frequency *f* of blue light in air is $6.40 \times 10^{14}$ Hz.

**[1]**

ii. Complete the table by determining the missing values for *v* and *λ* for glass. Write your answers to 3 significant figures.

**[2]**

**43 (a).**

Fig. 25.2 shows an arrangement used to demonstrate the interference of transverse waves on the surface of water.

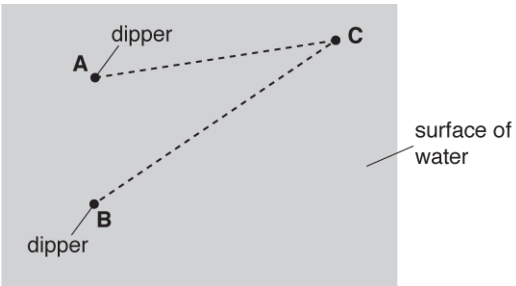


**Fig. 25.2 (not to scale)**

The dippers **A** and **B** oscillate in phase. Each dipper creates waves of wavelength 3.0 cm. **C** is a point on the surface of the water. The distance **AC** is 10.5 cm and the distance **BC** is 15.0 cm.

i. Explain what is meant by *interference*.

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**[1]**

ii. State and explain the type of interference occurring at **C**.

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**[2]**

**(b).** In a ripple tank experiment, a dipper vibrates on the surface of water.
Circular waves spread out in all directions from the dipper.
The variation of displacement of the water with distance $x$ from the dipper at one instant in time is shown in Fig. 25.1.

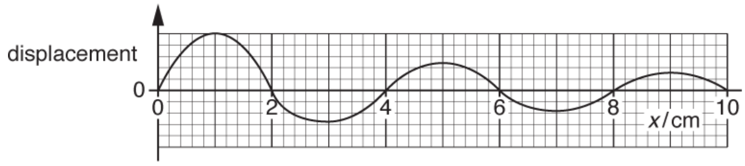


**Fig. 25.1**

i. Determine the wavelength $\lambda$ of the wave in cm.

$\lambda$ = .......................................... cm **[1]**

ii. Explain why the **intensity** of the wave changes as the distance $x$ increases.

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**[2]**

**44 (a).** A student investigates the path of a light ray through ethanol. Fig. 8.1 shows ethanol in a rectangular glass container. Light of wavelength $5.2 \times 10^{-7}$ m is incident on the container as shown.


**Fig. 8.1 (not to scale)**

The table below shows the refractive indices *n* and speeds of light *v* in various transparent media.

| **medium** | ***n*** | ***v* / m s$^{-1}$** |
|---|---|---|
| air | 1.00 | $3.00 \times 10^8$ |
| ethanol | | $2.20 \times 10^8$ |
| glass | 1.52 | |
| vacuum | 1.00 | $3.00 \times 10^8$ |

**[2]**

(i) Complete the table by calculating the missing values of *n* and *v*.

(ii) Determine the wavelength $\lambda$ of the light in glass.

$\lambda$ = ------------------------------------ m **[1]**

**(b).** Fig. 8.2 shows an enlarged version of a section of the left hand side of the glass container.

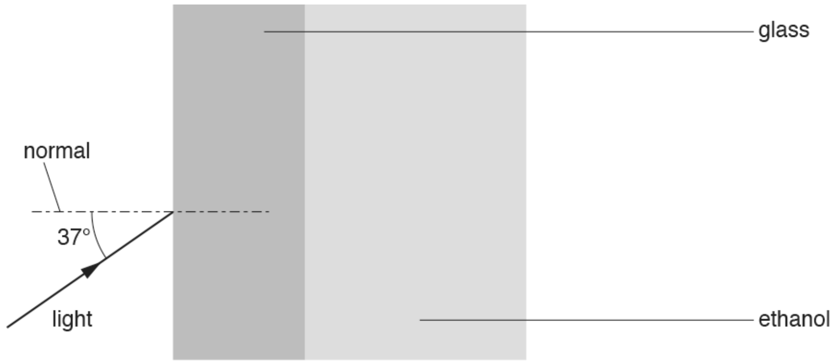


**Fig. 8.2 (not to scale)**

(i) The light is incident on the glass at an angle of 37°.
Determine the angle of refraction *θ* in the glass.

*θ* = ........................................ ° **[2]**

**[1]**

(ii) Without any further calculation, sketch the ray of light as it passes through the glass into the ethanol.

**45.** A stretched wire of fixed length is used in an experiment to demonstrate stationary waves. The tension in the wire is kept **constant**.
Fig. 26 shows the three stationary wave patterns that can be formed on the stretched wire.

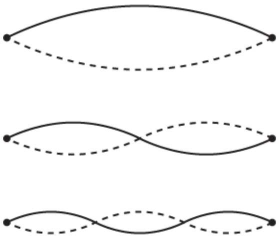


**Fig. 26**

The frequency $f$ of vibration of the stretched wire for each stationary wave is shown on Fig. 26. Use Fig. 26 to describe and explain how the wavelength $\lambda$ of the progressive wave on the stretched wire depends on the frequency of vibration of the wire.

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**[3]**

**46.** A police speed detector gun works by firing short pulses of electromagnetic radiation, a time $t_0$ apart, at the front of the vehicle which is moving directly towards the gun. The reflected pulses are received at a time $t$ apart. A digital readout on the top of the gun displays the speed of the vehicle.

In the space below, by considering how far the vehicle moves in time $t_0$, show that the speed of the vehicle is given by the expression

$$v = \frac{c(t_0 - t)}{2t_0}$$

where $c$ is the speed of light.

**[3]**

**47.** A sound wave is an example of a longitudinal wave.

i. State what is meant by the term **longitudinal** wave.

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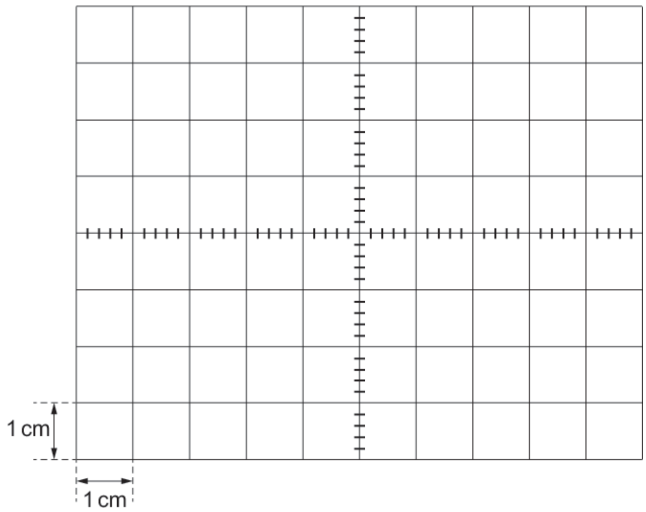
**[1]**

ii. A microphone is connected to an oscilloscope. Sound of frequency 500 Hz is incident on the microphone.
The oscilloscope time-base is set to 0.5 ms $cm^{-1}$ and the $y$-gain set to 1.0 mV $cm^{-1}$.
The signal displayed on the oscilloscope screen has an amplitude of 2.0 mV.
The oscilloscope grid is shown below.




Sketch the oscilloscope trace on the grid above. **[2]**

**48.** Light travels from air to water. The refractive index of water is greater than the refractive index of air. Compare the speed, frequency and wavelength of light in air and in water.

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**[3]**

**49.** A guitar manufacturer wants to investigate the quality of sound produced from a new uniform polymer string. **Fig. 18.1** shows the string which is kept in tension between a clamp and a pulley. The frequency of the mechanical oscillator close to one end is varied so that a stationary wave is set up on the string.

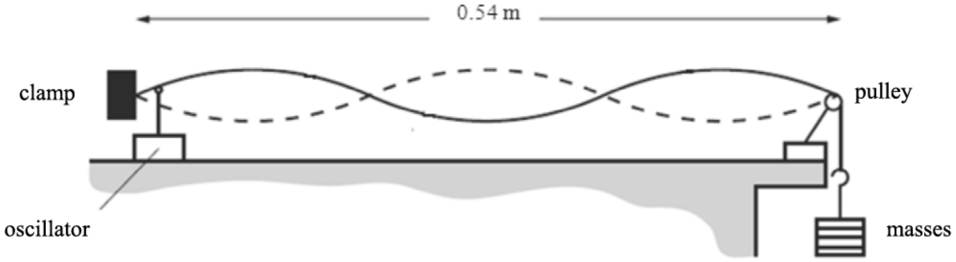


**Fig. 18.1**

The frequency of the oscillator is 60 Hz.

Use Fig. **18.1** to calculate the speed of the transverse waves on the string.

speed = .......................................... m s$^{-1}$ **[3]**

**50.** In Fig. 18.1 the solid line represents the displacement *s* against distance *x* graph for a **progressive** transverse wave on a stretched string at time $t = 0$. The dotted line shows the graph for the same wave at a later time $t = 2.5$ ms.

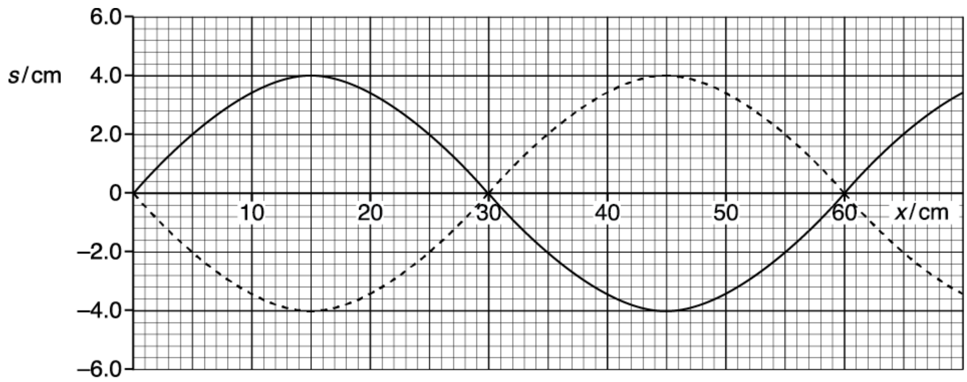


**Fig. 18.1**

Determine the frequency *f* of this wave.

*f* =............................................................ Hz **[3]**

**51.** Fig. 26.1 shows an arrangement used to demonstrate a particular wave phenomenon.

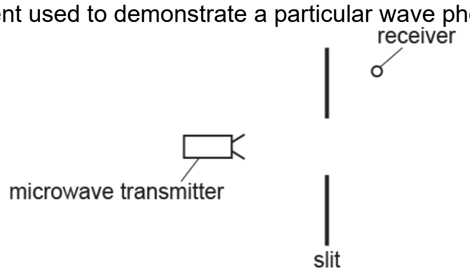


**Fig. 26.1**

A metal sheet with a wide slit is placed between a microwave transmitter and a receiver. The microwaves have a frequency of 11 GHz.

i. Calculate the wavelength $\lambda$ of the microwaves.

$\lambda$ = ____________________ m **[1]**

ii. The receiver detects no microwaves in the position shown in Fig. 26.1.
The metal sheet is replaced by another sheet with a narrow slit of width of a few centimetres, as shown in Fig. 26.2. The positions of the transmitter, receiver and the metal sheet are unchanged.

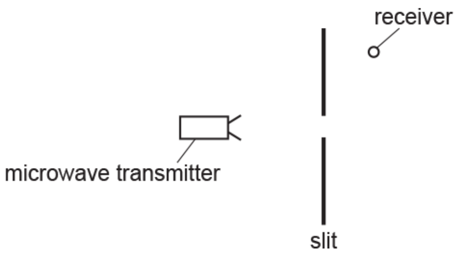


**Fig. 26.2**

Explain why the receiver now detects microwaves.

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**[2]**

**52.** Two loudspeakers **$S_1$** and **$S_2$** are connected to a signal generator. The loudspeakers emit coherent sound waves.

A microphone is connected to an oscilloscope. The wavelength of the sound waves is 0.16 m. The frequency of the sound is determined using the oscilloscope.

**i.** Explain how the oscilloscope is used to determine the frequency.

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**[2]**

ii. The frequency of the sound is 2.1kHz.

Determine the speed *v* of sound.

$v$ = ....................................... $ms^{-1}$ **[2]**

**53.** The diagram below shows a beam of X-rays incident normally on some soft tissue.

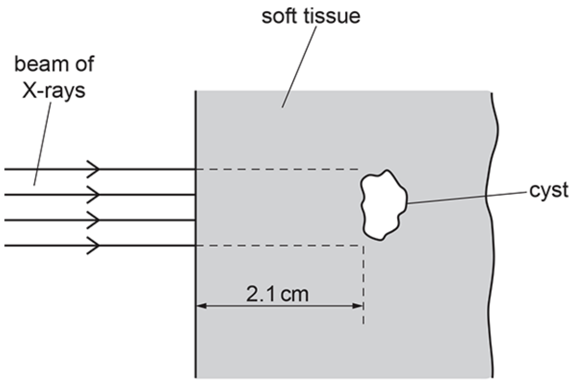


**Fig. 2**

The attenuation (absorption) constant of the soft tissue is 0.85 $cm^{-1}$.
The intensity of the beam is $4.6 \times 10^3$ W $m^{-2}$.
There is a small cyst 2.1 cm from the surface of the soft tissue. The cross-sectional area of the cyst normal to the beam is $3.4 \times 10^{-4}$ $m^2$.

The beam is switched on for 30 s.

Calculate the X-ray energy incident on the cyst in a period of 30 s.

energy = ........................................................ J **[4]**

**54.** A student is investigating stationary waves in the air column inside a tube, using the apparatus shown in **Fig. 5.1**.

The loudspeaker emits sound of frequency *f* and wavelength λ. The tube is initially fully immersed in the water. The student then slowly raises the tube until the oscilloscope trace shows its first maximum. A stationary wave of fundamental frequency *f* is produced in the air column. When this occurs, the student measures the length *l* of the tube above the water level.

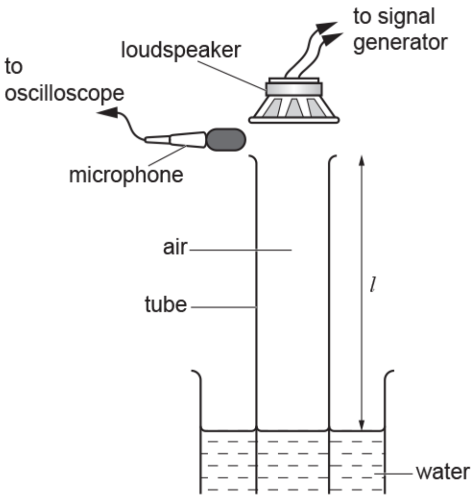


**Fig. 5.1**

Explain how a stationary wave of fundamental frequency is produced and state the relationship between *l* and λ.

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**[4]**

**55.** Sound waves cannot be polarised, but they do show diffraction.

i. State why sound waves **cannot** be polarised.

**[1]**

ii. Describe and explain how you could demonstrate the diffraction of sound waves in the laboratory.

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**[3]**

**56.** A sound wave is incident at the ear.

The amplitude of the sound wave is 7.8 nm. The intensity of the sound at the earhole is $4.8 \times 10^{-7}$ W m$^{-2}$.

i. Determine the power of the sound incident at the earhole by estimating the diameter of the earhole in mm.

diameter of earhole ≈ ........................................ mm

power = ...................................................... W **[2]**

ii. A different sound wave is now incident at the ear.
The intensity of this wave is $9.6 \times 10^{-7}$ W m$^{-2}$.

Calculate the amplitude $A$ in nm of this sound wave.

$A$ = .................................................... nm **[2]**

**57.** Fig. 26.1 shows the variation of displacement *y* with position *x* of a progressive transverse wave on a stretched string at a particular instant.

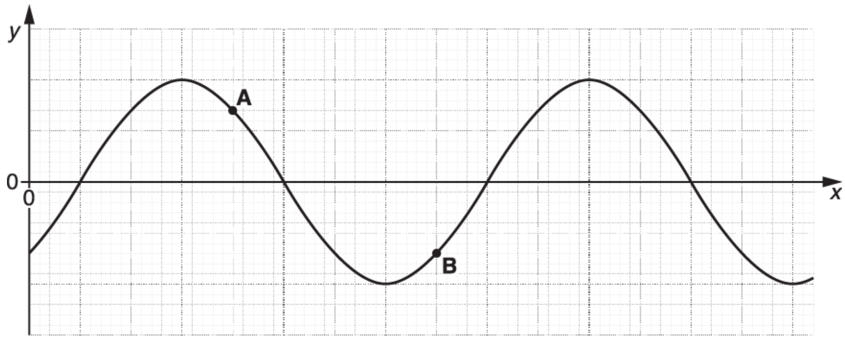


**Fig. 26.1**

The motions of particles **A** and **B** of the string is analysed over a short period of time. The distance between the positions of **A** and **B** is half a wavelength of the wave. The particles **A** and **B** have the same speed.

i. State **one** difference between the motions of these particles.

------------------------------------------------------------

------------------------------------------------------------ **[1]**

ii. The particle **A** oscillates with frequency 75 Hz.
The distance between the positions of **A** and **B** is (40.0 ± 2.0) cm.
Calculate the speed *v* of the transverse wave on the string and the absolute uncertainty in this value.

*v* = ............................ ± ............................ m s$^{-1}$ **[3]**

**58 (a).** The International Space Station (ISS) orbits the Earth at a height of $4.1 \times 10^5$ m **above** the Earth's surface.

The radius of the Earth is $6.37 \times 10^6$ m. The gravitational field strength $g_0$ at the Earth's surface is 9.81 N kg$^{-1}$.

Both the ISS and the astronauts inside it are in free fall.

Explain why this makes the astronauts feel **weightless**.

---------------------------------------------------------------------------------------------------------------------

--------------------------------------------------------------------------------------------------------------------- **[1]**

**(b).**

i. Calculate the value of the gravitational field strength $g$ at the height of the ISS above the Earth.

$g$ = ...................................................... N kg$^{-1}$ **[3]**

ii. The speed of the ISS in its orbit is 7.7 km s$^{-1}$. Show that the period of the ISS in its orbit is about 90 minutes.

**[2]**

**(c).** Use the information in **(b)(ii)** and the data below to show that the root mean square (r.m.s.) speed of the air molecules inside the ISS is approximately 15 times smaller than the orbital speed of the ISS.

- molar mass of air = $2.9 \times 10^{-2}$ kg mol$^{-1}$
  temperature of air inside the ISS = 20 °C

**[3]**

**(d).** The ISS has arrays of solar cells on its wings. These solar cells charge batteries which power the ISS. The wings always face the Sun.

Use the data below and your answer to **(b)(ii)** to calculate the **average** power delivered to the batteries.

- The total area of the cells facing the solar radiation is 2500 $m^2$.
- 7% of the energy of the sunlight incident on the cells is stored in the batteries.
- The intensity of solar radiation at the orbit of the ISS is 1.4 kW $m^{-2}$ outside of the Earth's shadow and zero inside it.
- The ISS passes through the Earth's shadow for 35 minutes during each orbit.

average power = ..................................................... W **[4]**

**59 (a).** In an investigation of standing waves, sound waves are sent down a long pipe, with its lower end immersed in water. The waves are reflected by the water surface. The pipe is lowered until a standing wave is set up in the air in the pipe. A loud note is then heard. See **Fig. 6.1**.

Length $l_1$ is measured. The pipe is then lowered further until a loud sound is again obtained from the air in the pipe. Length $l_2$ is measured.

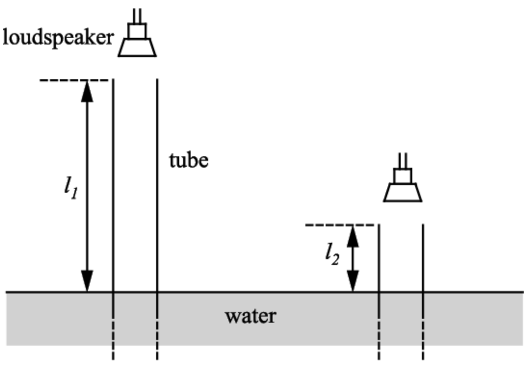


**Fig 6.1**

A student obtained the following results in the experiment.

| **frequency of sound / Hz** | **$l_1$ / m** | **$l_2$ / m** |
|---|---|---|
| 500 | 0.506 | 0.170 |

Use data from the table to calculate the speed of sound in the pipe.
Show your reasoning.

speed = .......................................... m $s^{-1}$ **[4]**

**(b).** The student repeats the experiment, but sets the frequency of the sound from the speaker at 5000 Hz.

Suggest and explain whether these results are likely to give a more or less accurate value for the speed of sound than those obtained in the first experiment.

**[2]**

**(c).** The pipe is removed from the water and laid horizontally on a bench as in **Fig. 6.2**. The frequency of the sound waves sent down the pipe is adjusted until a standing wave is set up in it. Point **P** is a distance of $\lambda / 4$ from point **Q** at the far end.

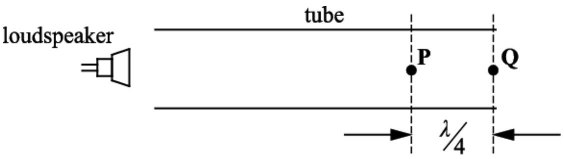


**Fig. 6.2**

Explain how and under what conditions a stationary sound wave is formed in the pipe. Describe and compare the motion of the air molecules at points **P** and **Q**.

[6]

**60.** A laser **A** is placed close to two slits as shown in **Fig. 25.2**.

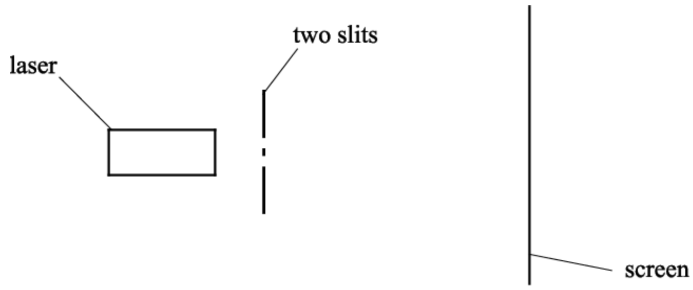


**Fig. 25.2**

The laser emits monochromatic light. Bright and dark fringes are observed on a screen.

i. Explain why bright and dark fringes are observed on the screen.

[3]

ii. The laser **A** is replaced with another laser **B**. Laser **B** emits light of a different colour with a much greater intensity.

The fringe patterns observed on the screen with these two lasers are shown in **Fig. 25.3**.

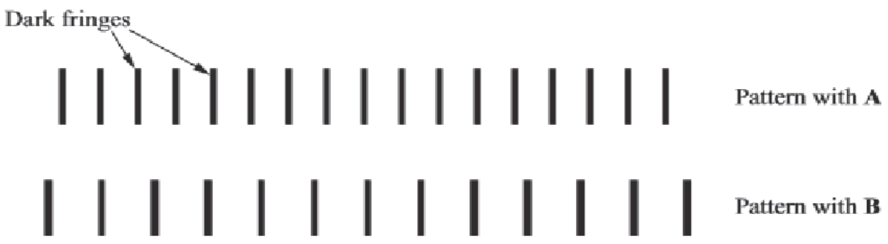


**Fig. 25.3 (drawn to scale)**

According to a student, laser **B** produces a more spread out fringe pattern because the intensity of its light is much greater than that of laser **A**.

This suggestion is incorrect. Give the correct explanation.

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**[1]**

iii. State the effect on the pattern of light seen on the screen when one of the slits is blocked.

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**[1]**

**61.** A grain of a radioactive powder which emits gamma rays accidentally falls onto the workbench.

A sensitive gamma-ray detector is used to look for this grain. The grain can be assumed to be a point source which emits radiation **uniformly in all** directions.

The background count-rate before the accident was negligible.

The detector registers a count-rate of 20 $s^{-1}$ when it is 1.0 m from the grain.

i. Explain why the count-rate rises to 320 $s^{-1}$ when the detector is moved to 0.25 m from the grain.

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**[2]**

ii. A thin lead sheet is now placed on the bench over the grain. This causes the count-rate to halve to 160 $s^{-1}$. The detector is moved from its position at 0.25 m towards the grain until the count-rate returns to 320 $s^{-1}$.

1 State the value of the count-rate if the sheet is now removed.

count-rate = .................... $s^{-1}$ **[1]**

2 Calculate the distance of the detector from the grain.

distance = .................... m **[2]**

**62.** A puddle of water reflects sunlight. A student knows that reflected light is partially polarised. She looks at the reflected light from the puddle of water through a polarising filter, see Fig.22.2.

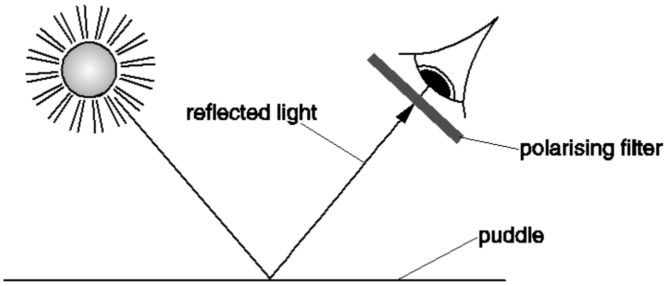


**Fig. 22.2**

**i.** Explain what is meant by the term ***polarised waves***.
You may wish to illustrate your answer with a labelled diagram.

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**[2]**

**ii.** Describe how the student can use the polarising filter to determine if the reflected light from the puddle is partially polarised. State clearly what she should observe.

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**[3]**

**63.** Fig. 25.1 shows two loudspeakers **L₁** and **L₂** connected to the same signal generator. The loudspeakers emit sound of the same wavelength but with different amplitudes. The points **P** and **Q** are at different distances from the loudspeakers.

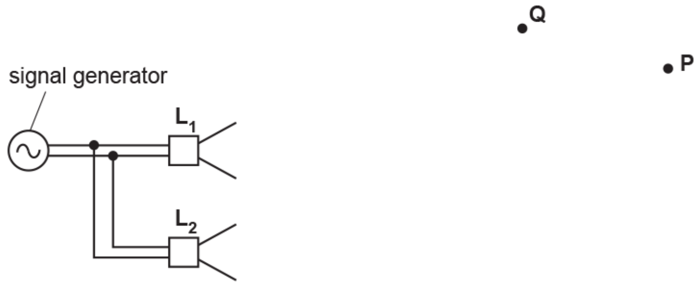


**Fig. 25.1**

The sound at point **P** from **L₁** alone has displacement $x_1$. The sound from **L₂** alone has displacement $x_2$. Fig. 25.2 shows the variation of $x_1$ with time $t$.

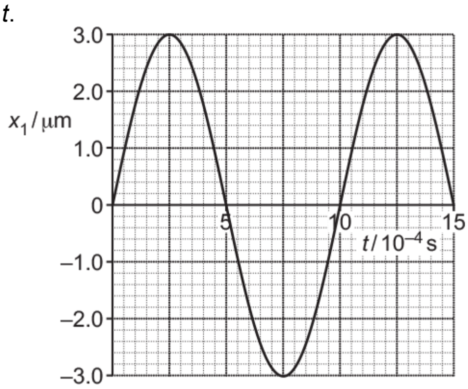


**Fig. 25.2**

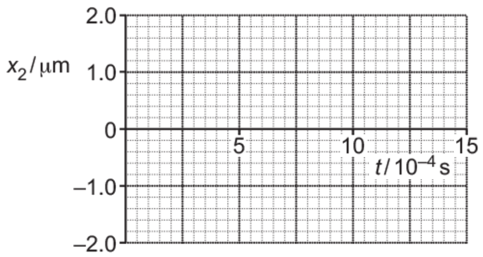


**Fig. 25.3**

The sound from **L₂** alone at point **P** has amplitude 1.0 μm, a phase difference of 180° compared with the sound from **L₁** and the same frequency as the sound from **L₁**.

i.

On Fig. 25.3, draw the variation of $x_2$ with time $t$ at point **P**. **[1]**

**ii.** Explain why the intensity at **P** due to the sound from both **L₁** and **L₂** is not the same as the intensity of the sound at **P** from only **L₁**.

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**[2]**

**iii.** The wavelength of the sound is 34 cm. The distance $L_1Q$ is 200 cm and the distance $L_2Q$ is 217 cm. Explain the type of interference occurring at point **Q**.

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**[2]**

**64.** Procyon is a star of radius $1.4 \times 10^9$ m. The total output power of the electromagnetic radiation from its surface is $2.7 \times 10^{27}$ W. The average wavelength of the electromagnetic waves from Procyon is $5.0 \times 10^{-7}$ m.

i. Show that the surface intensity of the radiation from Procyon is $1.1 \times 10^8$ W m$^{-2}$.

**[2]**

ii. Calculate the energy of a photon of wavelength $5.0 \times 10^{-7}$ m.

energy = ________________ J **[2]**

iii. Estimate the total number of photons emitted per second from the surface of Procyon.

number per second = ________________ s$^{-1}$ **[1]**

**65.** The normal frequency range of hearing for young people is from 20 Hz to 20 kHz.

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

Calculate the **shortest** wavelength a young person can hear.

wavelength = ..................................................... m **[2]**

**ii.** Describe how you can use an oscilloscope, and other additional laboratory equipment, to determine the actual upper limit of the frequency range for a young person.

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**[3]**

**66.** * A student carries out two investigations with these electromagnetic waves.

In **investigation 1**, the student rotates the receiver aerial about the horizontal axis joining the two aerials, as shown in **Fig. 5.1**.

In **investigation 2**, the student places a metal sheet behind the receiver aerial. The student moves the sheet backwards and forwards along the horizontal axis joining the two aerials, as shown in **Fig. 5.2**.

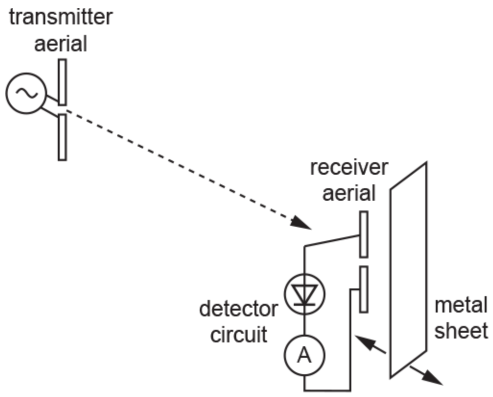



**Fig. 5.2**

For each of these two investigations:

- Explain why the ammeter sometimes gives a maximum reading and sometimes a zero (or near zero) reading.

- State the orientations of the receiver aerial in **investigation 1**, and the positions of the metal sheet in **investigation 2**, where these maximum and zero readings would occur.

**[6]**

**67 (a).** A scientist is investigating the interference of light using very thin transparent material.
A sample of the transparent material is placed in a vacuum.
Fig. 16.2 shows the path of two identical rays of light **L** and **M** from a laser.

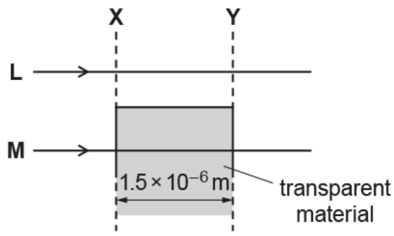



**Fig. 16.2**

The refractive index of the material is 1.20. The thickness of the material is $1.5 \times 10^{-6}$ m.
The wavelength of the light in vacuum is $6.0 \times 10^{-7}$ m.

i. Show that the difference in time t for the two rays to travel between the dashed lines **X** and **Y** is $1.0 \times 10^{-15}$ s.

$t$ = ...................................................... s **[3]**

ii. Calculate the period $T$ of the light wave.

$t$ = ...................................................... s **[2]**

iii. The rays of light are in phase at the dashed line **X**.

Use your two answers above to state the phase difference $\varphi$ in degrees between the light rays at **Y**.

$\varphi$ = ...................................................... ° **[1]**

**(b).** *The speed $v$ of surface water waves in shallow water of depth $d$ is given by the equation $v = \sqrt{gd}$, where g is the acceleration of free fall.

The speed $v$ is about 1 ms$^{-1}$ for a depth of about 10 cm.

You are provided with a rectangular plastic tray, supply of water and other equipment available in the laboratory.

Describe how an experiment can be conducted in the laboratory to test the validity of the equation above and how the data can be analysed to determine a value for *g*.

**[6]**

**68 (a).** Fig. 5 shows the variation with distance of the displacement for two progressive waves **P** and **Q**.

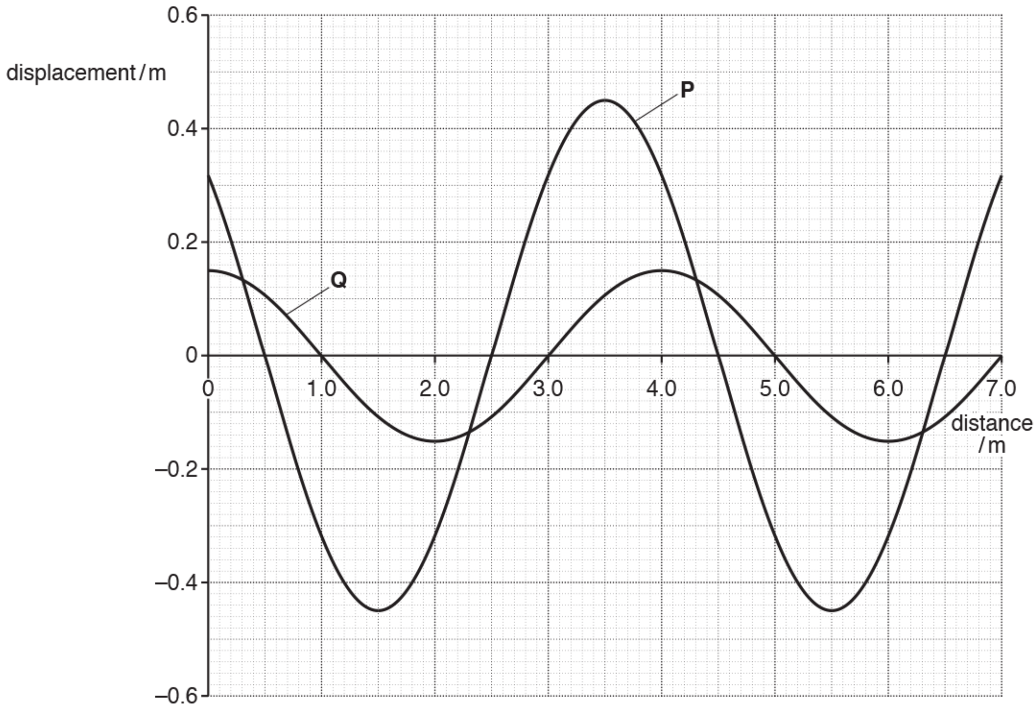



**Fig. 5**

i. State the amplitude of wave **P**.

amplitude = ..................................................... m **[1]**

i. State the wavelength of wave **P**.

wavelength = ..................................................... m **[1]**

iii. Determine the phase difference, in radians, between wave **P** and wave **Q**.

phase difference = .................................................. rad **[2]**

iv. Determine the ratio $\frac{\text{intensity of wave } \mathbf{P}}{\text{intensity of wave } \mathbf{Q}}$.

ratio = ......................................................... **[2]**

**(b).** *A student wishes to investigate how the fringe spacing x of an interference pattern produced by sound waves varies with the frequency *f* of the sound waves.

It is suggested that $\frac{v}{f} = \frac{ax}{D}$ where

*a* is the separation of the sources of sound
*D* is the distance from the sources of sound to the interference maxima and minima
*v* is the speed of sound in air.

Describe with the aid of a suitable diagram how an experiment can be safely conducted in the laboratory, and how the data can be analysed to determine *v*.

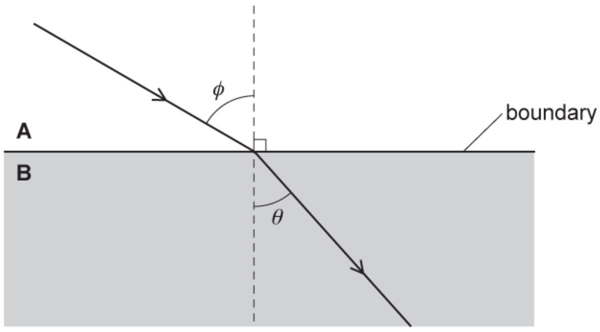
**[6]**

69. Light can be refracted. Light can also show total internal reflection.

i. Define **refractive index** of a material.

**[1]**

ii. The diagram below shows the path of light in two transparent materials **A** and **B**.




**Not to scale**

The refractive index of **B** is 1.3 times greater than the refractive index of **A**.
The wavelength of the light in **A** is $\lambda_A$ and the wavelength of the light in **B** is $\lambda_B$.

1. Explain how $\lambda_B$ compares with $\lambda_A$.

**[3]**

2. Calculate the angle of refraction $\theta$ when the angle $\varphi$ is 60°. Show your working.

θ = .................................. ° **[2]**

**3.** The angle $\varphi$ is now varied between 0° and 90° with the light still travelling from material A towards the boundary.

Explain whether or not total internal reflection will be observed at the boundary between the two materials.

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**[1]**

**70.** The speed of sound in air can be determined by forming stationary waves in the laboratory. Fig. 24.1 shows an arrangement used by a student to determine the speed of sound *v*.

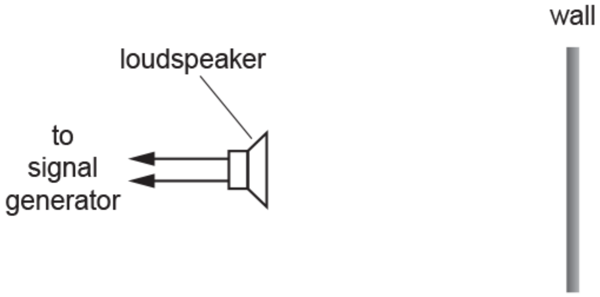


**Fig. 24.1**

A loudspeaker is placed in front of a smooth vertical wall in the laboratory. The loudspeaker is connected to a signal generator.
**Stationary waves** of frequency *f* are formed in the space between the wall and the loudspeaker.

A microphone is used to determine the mean separation *L* between adjacent nodes.

Fig. 24.2 shows the data plotted by the student.

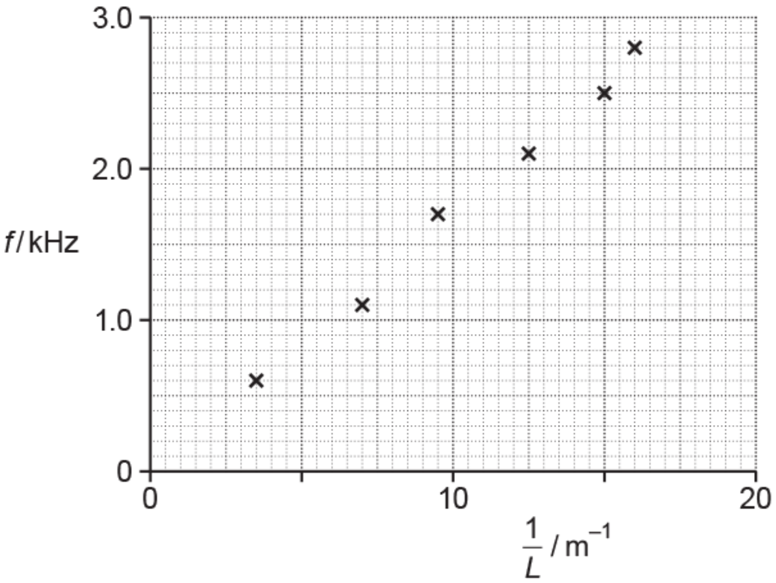


**Fig. 24.2**

i. Draw a straight line of best fit and determine the gradient of this line.

gradient = ............................................... Hzm **[2]**

ii. Explain why the gradient of the line is $\frac{v}{2}$, where *v* is the speed of sound.

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**[2]**

iii. Use your answer in part **(i)** and the information given in **(ii)** to determine *v*.

$v$ = ................................................ m s$^{-1}$ **[1]**

**iv.** The smaller values of *L* are much more difficult to determine with the microphone in this experiment and this produces large percentage uncertainty in the values of $\frac{1}{L}$.
Suggest how this percentage uncertainty may be reduced in this experiment.

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**[2]**

**71.** A loudspeaker mounted on a bench is emitting sound of frequency 1.7 kHz to a microphone. Fig. 5.1 shows an illustration of the bulk movement of the air at one instant of time.


**Fig. 5.1**

The maximum displacement of the air particles from their mean positions is $2.0 \times 10^{-6}$ m.

The speed of sound in air at 17 °C is 340 m s$^{-1}$.

i. On Fig. 5.2, sketch the sinusoidal variation of the displacement of the air with distance between **C** and **R**.

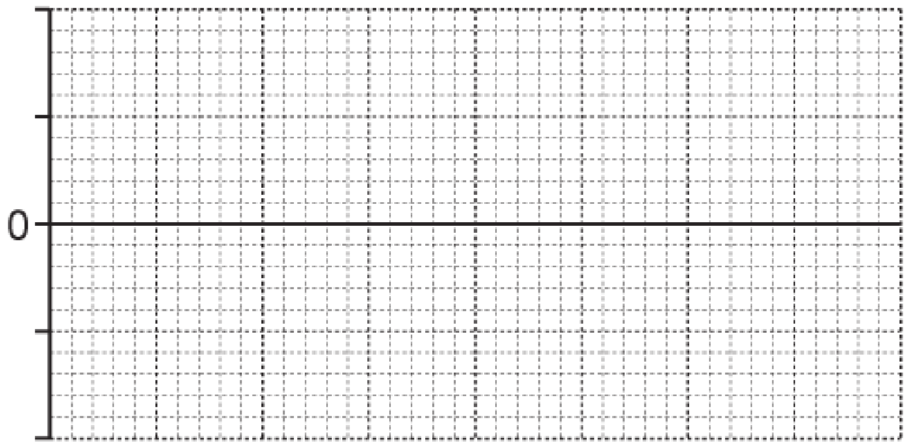


**Fig. 5.2**

1. Label the axes and include sensible scales.
2. On Fig. 5.2, mark one point where air particles are moving at maximum speed. Label it **X**.
3. On Fig. 5.2, mark one point where air particles are moving at maximum speed but travelling in the opposite direction to the air particles in **2**. Label it **Y**.

**[4]**

ii. Calculate

1. the maximum speed $v_{max}$ of the oscillating particles in the sound wave

$v_{max}$ = .......................................... m s$^{-1}$ **[2]**

2. the root mean square speed $c$ of the air molecules in the room.
The molar mass of air is $2.9 \times 10^{-2}$ kg mol$^{-1}$.

$c$ = .......................................... m s$^{-1}$ **[2]**

**72.** Some students are asked to use the laboratory 28 mm microwave transmitter **T** and receiver **R** apparatus to design a demonstration to illustrate the principle of a radar speed measuring device.

In **Fig. 3.1**, a movable hardboard sheet **H**, which is a partial reflector of microwaves, is placed in front of the metal sheet **M**, which is fixed.

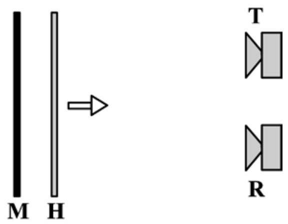


**Fig. 3.1**

The students expect the detected signal to change between maximum and minimum intensity when sheet **H** moves a distance of 7 mm towards the receiver.

When the detected signal is passed through an audio amplifier to a loudspeaker a sound should be heard. They claim that when the sheet moves at 2.8 m s$^{-1}$ the frequency heard should be 200 Hz. You are to evaluate whether their experiment is feasible and whether their conclusions are correct.

i. Explain why the detected signal strength should vary and discuss what factors will determine whether the difference between maxima and minima can be detected.

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**[6]**

ii. Justify the students' predictions of 7 mm between maxima and minima and a sound at 200 Hz for a speed of 2.8 m s$^{-1}$.

**[3]**

**73.** Fig. 18 shows a loudspeaker placed in front of two narrow slits in a metal plate.

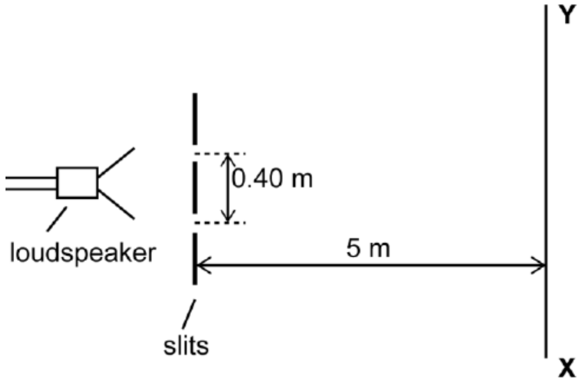


**Fig. 18**

The loudspeaker emits sound waves of frequency 2.8 kHz. The separation between the centres of the narrow slits is 0.40 m.

A microphone, moved along the line **XY** at a distance of 5.0 m from the slits, detects regions of low and high intensity sound.

The separation between adjacent regions of low and high intensity sound is 0.75 m.

i. Explain how you can use an oscilloscope set to a time-base of 0.1 ms div$^{-1}$ to check that the frequency of sound is 2.8 kHz.

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**[3]**

ii. Explain how the arrangement shown in Fig. 18 produces an interference pattern along the line **XY**.

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**[4]**

iii. Calculate the wavelength of sound.

wavelength = .......................................... m **[3]**

iv. Calculate the speed of sound.

speed = .......................................... m $s^{-1}$ **[1]**

v. State and explain the effect, if any, on the position and the intensity of the maxima when the amplitude of the transmitted waves is halved.

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**[3]**

**END OF QUESTION PAPER**