

1. Question part 1/3 | 9702 May-June 2016 P2 V1 Q5

- 5 The variation with time t of the displacement y of a wave X, as it passes a point P, is shown in Fig. 5.1.

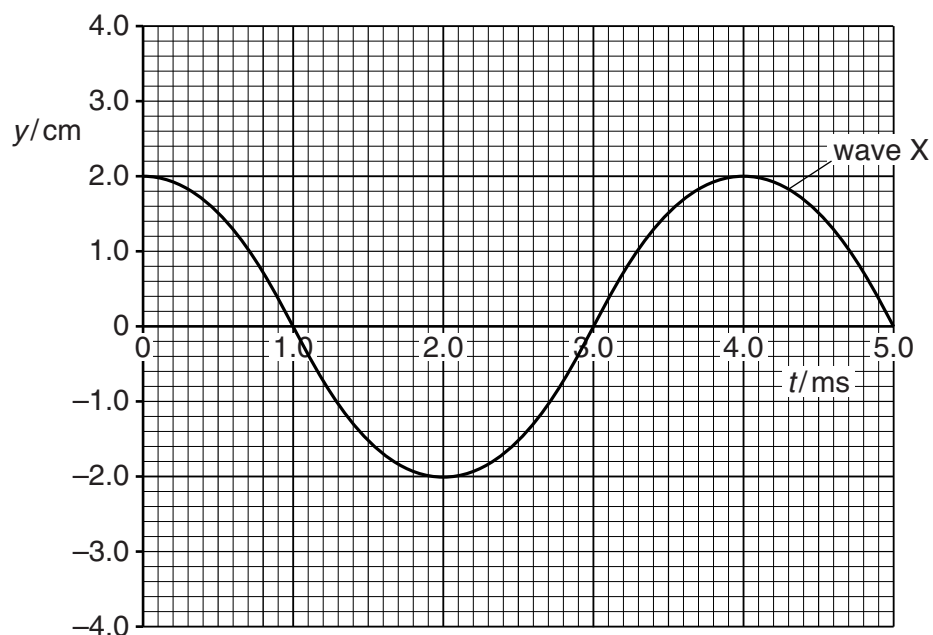


Fig. 5.1

The intensity of wave X is I .

- (a) Use Fig. 5.1 to determine the frequency of wave X.

frequency = ... Hz [2]

- (b) A second wave Z with the same frequency as wave X also passes point P. Wave Z has intensity $2I$. The phase difference between the two waves is 90° .

On Fig. 5.1, sketch the variation with time t of the displacement y of wave Z.

Show your working.

- (c) A double-slit interference experiment is used to determine the wavelength of light emitted from a laser, as shown in Fig. 5.2.

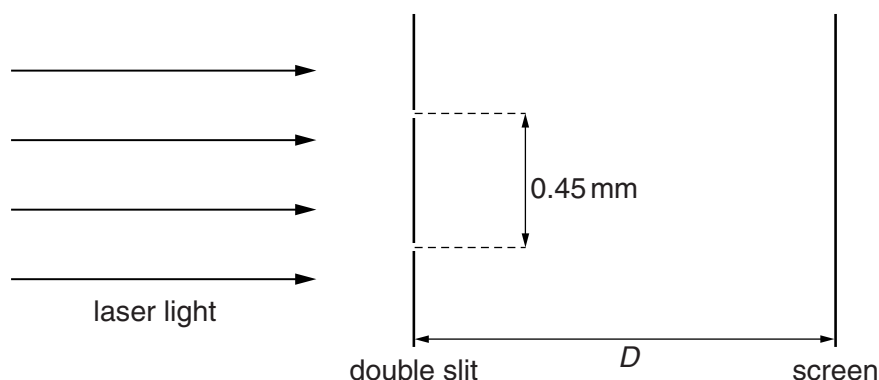


Fig. 5.2 (not to scale)

The separation of the slits is 0.45 mm. The fringes are viewed on a screen at a distance D from the double slit.

The fringe width x is measured for different distances D . The variation with D of x is shown in Fig. 5.3.

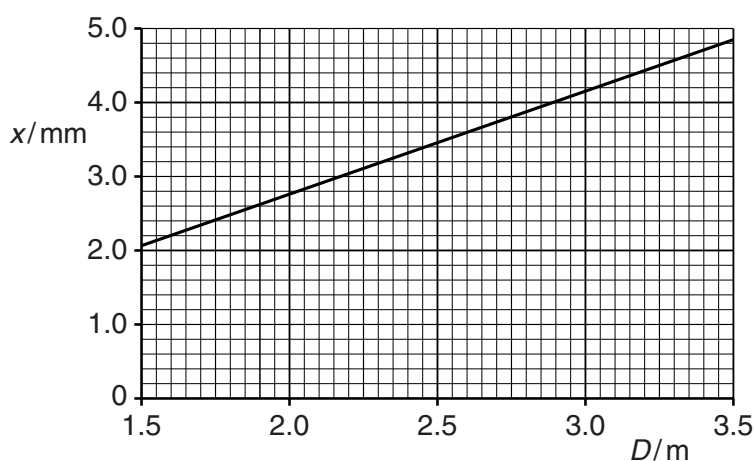


Fig. 5.3

- (i) Use the gradient of the line in Fig. 5.3 to determine the wavelength, in nm, of the laser light.

wavelength = ... nm [4]

(ii) The separation of the slits is increased. State and explain the effects, if any, on the graph of Fig. 5.3.

.....

.....

.....[2]

[Total: 11]

2. Question part 1/2 | 9702 May-June 2016 P2 V2 Q4

- 4 (a) By reference to the direction of the propagation of energy, state what is meant by a *longitudinal* wave and by a *transverse* wave.

longitudinal:

.....

.....

transverse:

.....

.....

[2]

- (b) The intensity of a sound wave passing through air is given by

$$I = Kv\rho f^2 A^2$$

where I is the intensity (power per unit area),

K is a constant without units,

v is the speed of sound,

ρ is the density of air,

f is the frequency of the wave

and A is the amplitude of the wave.

Show that both sides of the equation have the same SI base units.

[3]

(c) (i) Describe the *Doppler effect*.

.....
.....[1]

(ii) A distant star is moving away from a stationary observer.

State the effect of the motion on the light observed from the star.

.....
.....
.....[1]

(d) A car travels at a constant speed towards a stationary observer. The horn of the car sounds at a frequency of 510Hz and the observer hears a frequency of 550Hz. The speed of sound in air is 340ms⁻¹.

Calculate the speed of the car.

speed = ... ms⁻¹ [3]

[Total: 10]

3. Question part 1/2 | 9702 Oct-Nov 2016 P2 V1 Q4

4 (a) State what is meant by the *frequency* of a progressive wave.

.....

.....

.....[2]

(b) A cathode-ray oscilloscope (c.r.o.) is used to determine the frequency of the sound emitted by a loudspeaker. The trace produced on the screen of the c.r.o. is shown in Fig. 4.1.

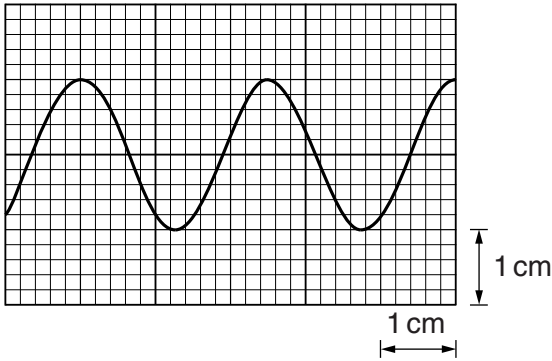


Fig. 4.1

The time-base setting of the c.r.o. is $250\mu\text{s cm}^{-1}$.

Show that the frequency of the sound wave is 1600 Hz.

[2]

(c) The loudspeaker in (b) emits the sound in all directions. A person attaches the loudspeaker to a string and then swings the loudspeaker at a constant speed in a horizontal circle above his head.

An observer, standing a large distance away from the loudspeaker, hears sound of maximum frequency 1640 Hz. The speed of sound in air is 330 m s^{-1} .

(i) Determine the speed of the loudspeaker.

speed = ... m s^{-1} [2]

(ii) Describe and explain, qualitatively, the variation in the frequency of the sound heard by the observer.

.....

.....

.....

.....

.....[2]

[Total: 8]

4. Question part 1/2 | 9702 Oct-Nov 2016 P2 V3 Q4

4 (a) State what is meant by the *frequency* of a progressive wave.

.....

.....

.....[2]

(b) A cathode-ray oscilloscope (c.r.o.) is used to determine the frequency of the sound emitted by a loudspeaker. The trace produced on the screen of the c.r.o. is shown in Fig. 4.1.

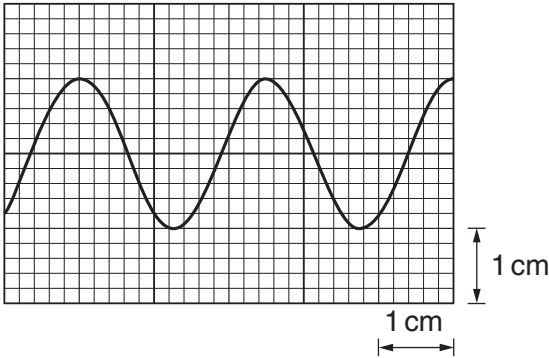


Fig. 4.1

The time-base setting of the c.r.o. is $250\,\mu\text{s cm}^{-1}$.

Show that the frequency of the sound wave is 1600 Hz.

[2]

(c) The loudspeaker in (b) emits the sound in all directions. A person attaches the loudspeaker to a string and then swings the loudspeaker at a constant speed in a horizontal circle above his head.

An observer, standing a large distance away from the loudspeaker, hears sound of maximum frequency 1640 Hz. The speed of sound in air is $330\,\text{ms}^{-1}$.

(i) Determine the speed of the loudspeaker.

speed = ... ms^{-1} [2]

(ii) Describe and explain, qualitatively, the variation in the frequency of the sound heard by the observer.

.....

.....

.....

.....

.....[2]

[Total: 8]

4 (a) State what is meant by the *Doppler effect*.

.....

.....

.....[2]

(b) A child sits on a rotating horizontal platform in a playground. The child moves with a constant speed along a circular path, as illustrated in Fig. 4.1.

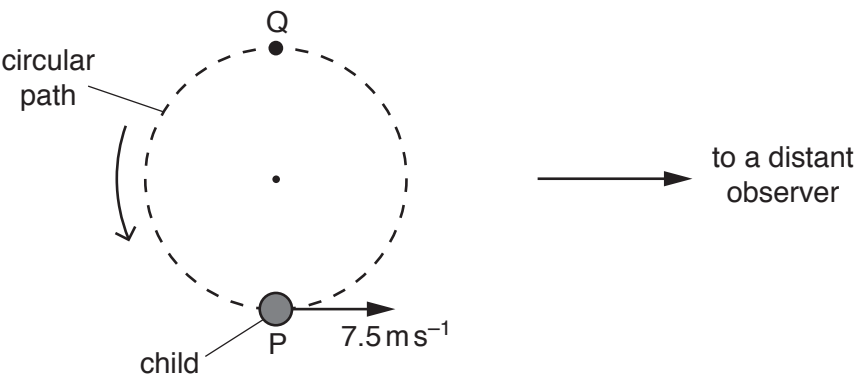


Fig. 4.1

An observer is standing a long distance away from the child. During one particular revolution, the child, moving at a speed of 7.5 m s^{-1} , starts blowing a whistle at point P and stops blowing it at point Q on the circular path.

The whistle emits sound of frequency 950 Hz . The speed of sound in air is 330 m s^{-1} .

(i) Determine the maximum frequency of the sound heard by the distant observer.

maximum frequency = ... Hz [2]

(ii) Describe the variation in the frequency of the sound heard by the distant observer.

.....

.....

.....

.....[2]

5 (a) Describe the Doppler effect.

.....

.....

.....[1]

(b) A car travels with a constant velocity along a straight road. The car horn with a frequency of 400 Hz is sounded continuously. A stationary observer on the roadside hears the sound from the horn at a frequency of 360 Hz.
The speed of sound is 340 ms⁻¹.

Determine the magnitude v , and the direction, of the velocity of the car relative to the observer.

$v =$ ms⁻¹

direction[3]

[Total: 4]

5 **(a)** Define the *frequency* of a sound wave.

.....
.....[1]

(b) A sound wave travels through air. Describe the motion of the air particles relative to the direction of travel of the sound wave.

.....
.....[1]

- (c) The sound wave emitted from the horn of a stationary car is detected with a microphone and displayed on a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

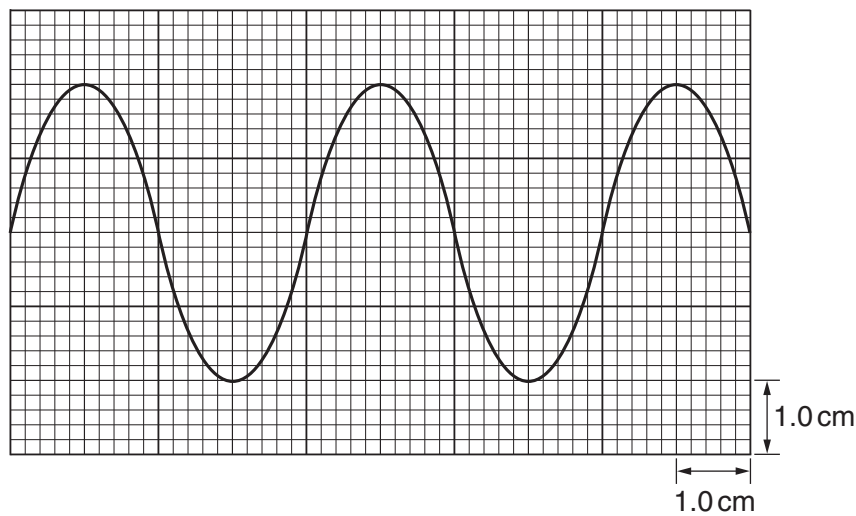


Fig. 5.1

The y-axis setting is 5.0 mV cm^{-1} .
The time-base setting is 0.50 ms cm^{-1} .

- (i) Use Fig. 5.1 to determine the frequency of the sound wave.

frequency = ... Hz [2]

- (ii) The horn of the car sounds continuously. Describe the changes to the trace seen on the c.r.o. as the car travels at constant speed

1. directly towards the stationary microphone,

.....
.....

2. directly away from the stationary microphone.

.....
.....

[3]

[Total: 7]

3 (a) State the difference between a stationary wave and a progressive wave in terms of

(i) the energy transfer along the wave,

.....
[1]

(ii) the phase of two adjacent vibrating particles.

.....
[1]

(b) A tube is open at both ends. A loudspeaker, emitting sound of a single frequency, is placed near one end of the tube, as shown in Fig. 3.1.

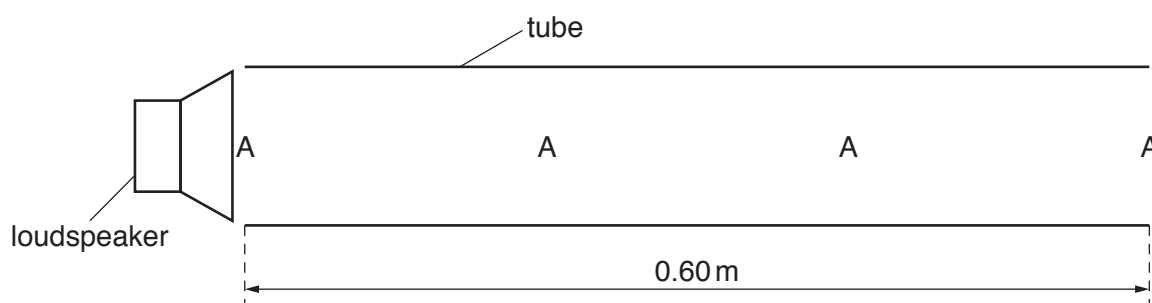


Fig. 3.1

The speed of the sound in the tube is 340 ms^{-1} . The length of the tube is 0.60 m. A stationary wave is formed with an antinode A at each end of the tube and two antinodes inside the tube.

(i) State what is meant by an *antinode* of the stationary wave.

.....
[1]

(ii) State the distance between a node and an adjacent antinode.

distance = ... m [1]

(iii) Determine, for the sound in the tube,

1. the wavelength,

wavelength = ... m [1]

2. the frequency.

frequency = ... Hz [2]

- (iv)** Determine the minimum frequency of the sound from the loudspeaker that produces a stationary wave in the tube.

minimum frequency = ... Hz [2]

[Total: 9]

9. Question part 1/2 | 9702 Oct-Nov 2017 P2 V3 Q4

- 4 (a) By reference to the direction of propagation of energy, explain what is meant by a *longitudinal* wave.

.....
.....[1]

- (b) A car horn emits a sound wave of frequency 800 Hz. A microphone and a cathode-ray oscilloscope (c.r.o.) are used to analyse the sound wave. The waveform displayed on the c.r.o. screen is shown in Fig. 4.1.

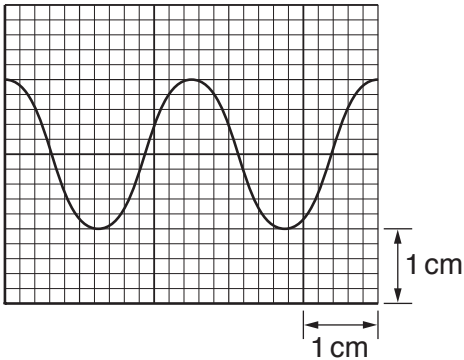


Fig. 4.1

Determine the time-base setting, in s cm^{-1} , of the c.r.o.

time-base setting = ... s cm^{-1} [3]

- (c) The intensity I of the sound at a distance r from the car horn in (b) is given by the expression

$$I = \frac{k}{r^2}$$

where k is a constant.

Fig. 4.2 shows the car in (b) on a road.

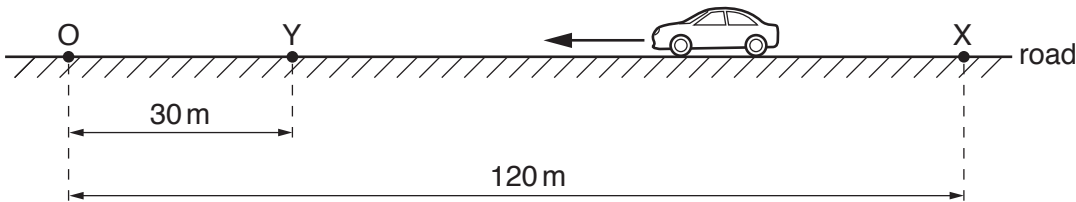


Fig. 4.2

An observer stands at point O. Initially the car is parked at point X which is 120 m away from point O. The car then moves directly towards the observer and stops at point Y, a distance of 30 m away from O.

The car horn continuously emits sound when the car is moving between points X and Y.

- (i) The sound wave at point O has amplitude A_X when the car is at X and has amplitude A_Y when the car is at Y.

Calculate the ratio $\frac{A_Y}{A_X}$.

ratio = ...[3]

- (ii) When the car is parked at X, the frequency of the sound from the horn that is detected by the observer is 800 Hz. As the car moves from X to Y, the maximum change in the detected frequency is 16 Hz. The speed of the sound in air is 330 m s^{-1} .

Determine, to two significant figures,

1. the minimum wavelength of the sound detected by the observer,

wavelength = ... m [2]

2. the maximum speed of the car.

speed = ... m s^{-1} [2]

[Total: 11]

- 4 (a) (i) Define the *wavelength* of a progressive wave.

.....
[1]

- (ii) State what is meant by an *antinode* of a stationary wave.

.....
[1]

- (b) A loudspeaker producing sound of constant frequency is placed near the open end of a pipe, as shown in Fig. 4.1.

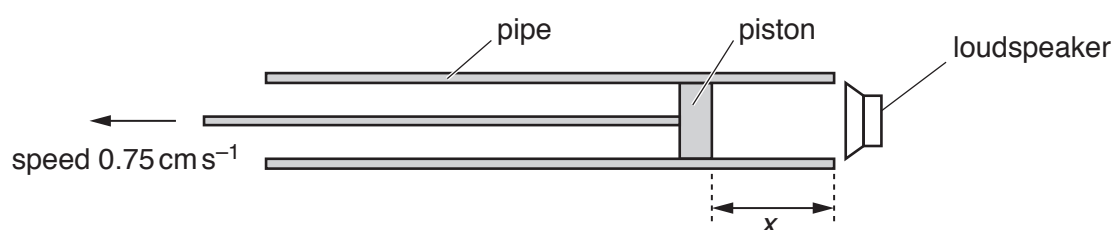


Fig. 4.1

A movable piston is at distance x from the open end of the pipe. Distance x is increased from $x = 0$ by moving the piston to the left with a constant speed of 0.75 cm s^{-1} .

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

- (i) A much louder sound is first heard when $x = 4.5 \text{ cm}$. Assume that there is an antinode of a stationary wave at the open end of the pipe.

Determine the frequency of the sound in the pipe.

frequency = ... Hz [3]

- (ii) After a time interval, a second much louder sound is heard. Calculate the time interval between the first louder sound and the second louder sound being heard.

time interval = ... s [2]

[Total: 7]

11. Question | 9702 Oct-Nov 2018 P2 V2 Q4

- 4 (a) Sound waves are longitudinal waves. By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

.....
[1]

- (b) A stationary sound wave in air has amplitude A . In an experiment, a detector is used to determine A^2 . The variation of A^2 with distance x along the wave is shown in Fig. 4.1.

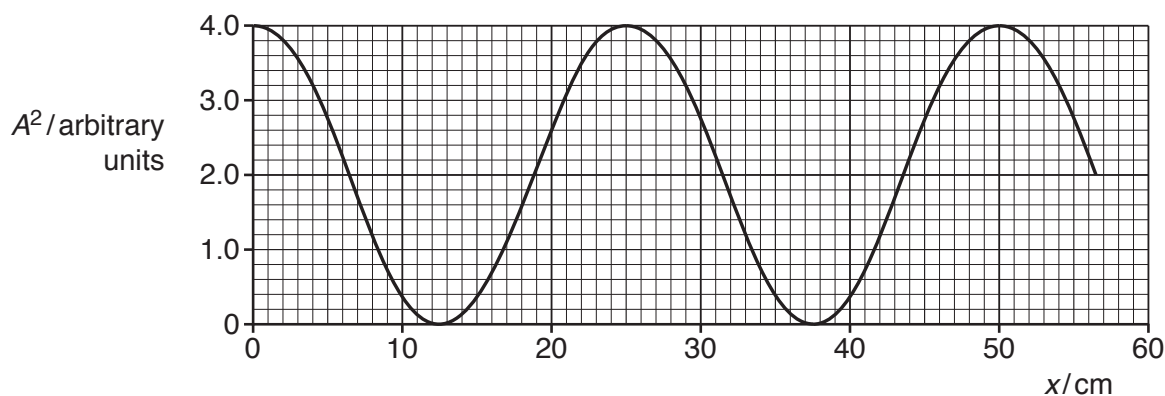


Fig. 4.1

- (i) State the phase difference between the vibrations of an air particle at $x = 25\text{ cm}$ and the vibrations of an air particle at $x = 50\text{ cm}$.

phase difference = ... ° [1]

- (ii) The speed of the sound in the air is 330 ms^{-1} . Determine the frequency of the sound wave.

frequency = ... Hz [3]

- (iii) Determine the ratio

$$\frac{\text{amplitude } A \text{ of wave at } x = 20\text{ cm}}{\text{amplitude } A \text{ of wave at } x = 25\text{ cm}}$$

ratio = ... [2]

12. Question part 1/2 | 9702 Oct-Nov 2018 P2 V3 Q4

- 4 (a) On Fig. 4.1, complete the two graphs to illustrate what is meant by the amplitude A , the wavelength λ and the period T of a progressive wave.

Ensure that you label the axes of each graph.

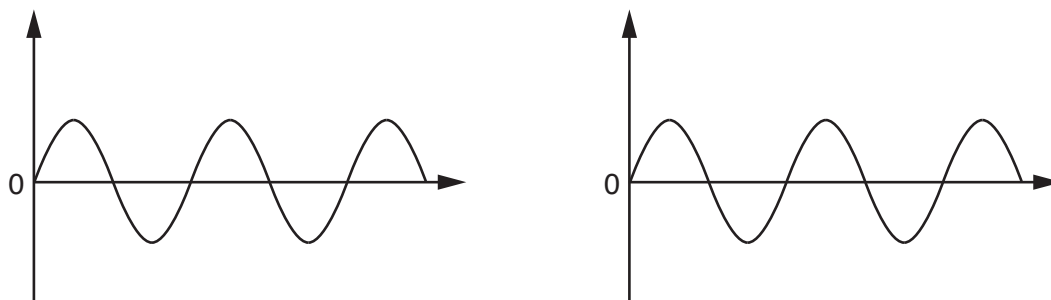


Fig. 4.1

[3]

- (b) A horizontal string is stretched between two fixed points X and Y. A vibrator is used to oscillate the string and produce a stationary wave. Fig. 4.2 shows the string at one instant in time.



Fig. 4.2

The speed of a progressive wave along the string is 30ms^{-1} . The stationary wave has a period of 40ms .

- (i) Explain how the stationary wave is formed on the string.

.....

.....

.....

.....[2]

9702 Physics Paper 2 - Waves

Topical questions | 41 questions

12. Question part 2/2 | 9702 Oct-Nov 2018 P2 V3 Q4

- (ii) A particle on the string oscillates with an amplitude of 13 mm. At time t , the particle has zero displacement.

Calculate

1. the displacement of the particle at time $(t + 100 \text{ ms})$,

displacement = ... mm

2. the total distance moved by the particle from time t to time $(t + 100 \text{ ms})$.

distance = ... mm
[3]

- (iii) Determine

1. the frequency of the wave,

frequency = ... Hz [1]

2. the horizontal distance from X to Y.

distance = ... m [3]

[Total: 12]

- 5 A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

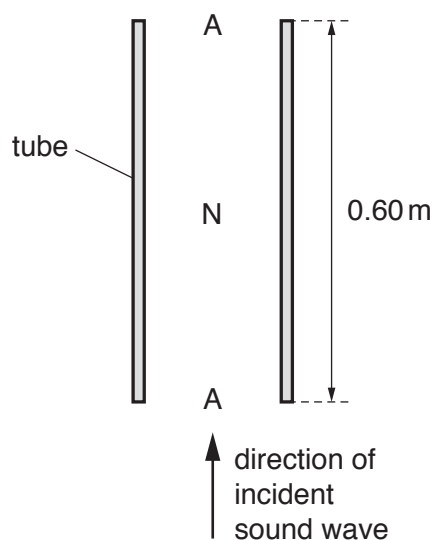


Fig. 5.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

- (a) Explain how the stationary wave is formed from the incident sound wave.

.....

.....

.....

.....[2]

- (b) On Fig. 5.2, sketch a graph to show the variation of the amplitude of the stationary wave with height h above the bottom of the tube.

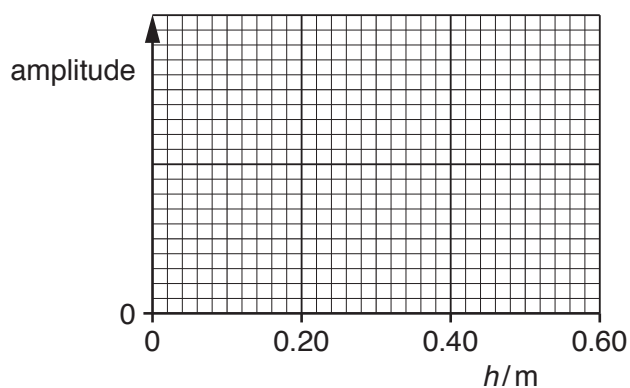


Fig. 5.2

[2]

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13. Question part 2/2 | 9702 May-June 2019 P2 V3 Q5

(c) For the stationary wave, state:

- (i)** the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

.....[1]

- (ii)** the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ... ° [1]

(d) The speed of the sound wave is 340 m s^{-1} .

Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(e) The frequency of the sound wave is gradually increased.

Determine the frequency of the wave when a stationary wave is next formed.

frequency = ... Hz [1]

[Total: 9]

14. Question part 1/2 | 9702 Feb-March 2020 P2 V2 Q4

4 (a) For a progressive wave, state what is meant by:

(i) the *wavelength*

.....
..... [1]

(ii) the *amplitude*.

.....
..... [1]

(b) A beam of red laser light is incident normally on a diffraction grating.

(i) Diffraction of the light waves occurs at each slit of the grating. The light waves emerging from the slits are coherent.

Explain what is meant by:

1. *diffraction*

.....
..... [1]

2. *coherent*.

.....
..... [1]

(ii) The wavelength of the laser light is 650 nm. The angle between the **third** order diffraction maxima is 68° , as illustrated in Fig. 4.1.

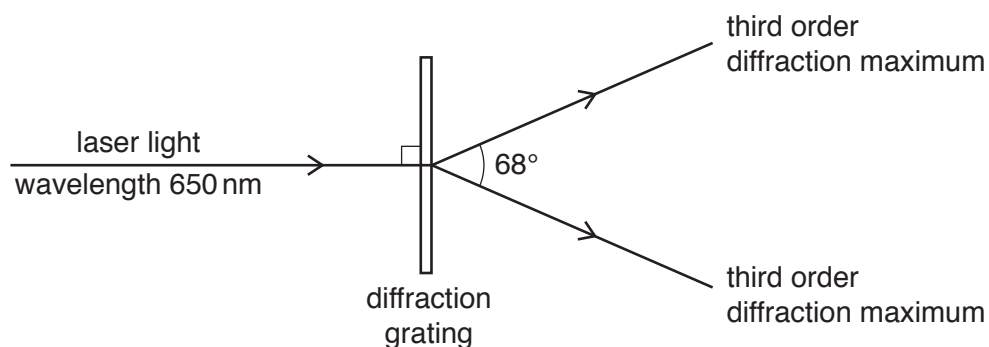


Fig. 4.1 (not to scale)

Calculate the separation d between the centres of adjacent slits of the grating.

$d =$ m [3]

(iii) The red laser light is replaced with blue laser light.

State and explain the change, if any, to the angle between the third order diffraction maxima.

.....

.....

..... [2]

[Total: 9]

15. Question part 1/2 | 9702 May-June 2020 P2 V2 Q4

- 4 (a) State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

.....
 [1]

- (b) A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

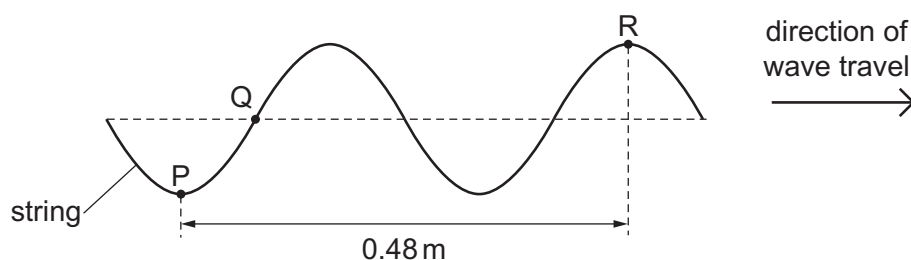


Fig. 4.1

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

- (i) Use Fig. 4.1 to determine the wavelength of the wave.

wavelength = ... m [1]

- (ii) Calculate the speed of the wave.

speed = ... ms^{-1} [2]

- (iii) Determine the phase difference between points Q and R.

phase difference = ... $^{\circ}$ [1]

- (iv) Fig. 4.1 shows the position of the string at time $t = 0$. Describe how the displacement of point Q on the string varies with time from $t = 0$ to $t = 0.010$ s.

.....

.....

.....

..... [2]

- (c) A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

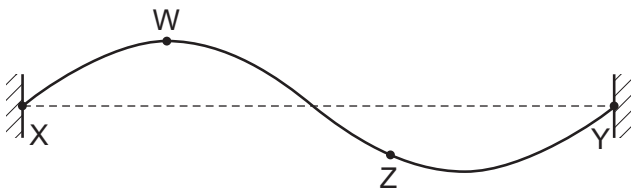


Fig. 4.2

- (i) Explain what is meant by a *node* of a stationary wave.
- [1]

- (ii) State the number of antinodes of the wave shown in Fig. 4.2.
- number = ... [1]

- (iii) State the phase difference between points W and Z on the string.
- phase difference = ...° [1]

- (iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

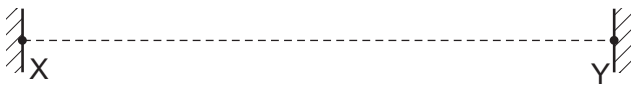


Fig. 4.3

[1]

16. Question part 1/2 | 9702 May-June 2020 P2 V3 Q4

- 4 Two progressive sound waves Y and Z meet at a fixed point P. The variation with time t of the displacement x of each wave at point P is shown in Fig. 4.1.

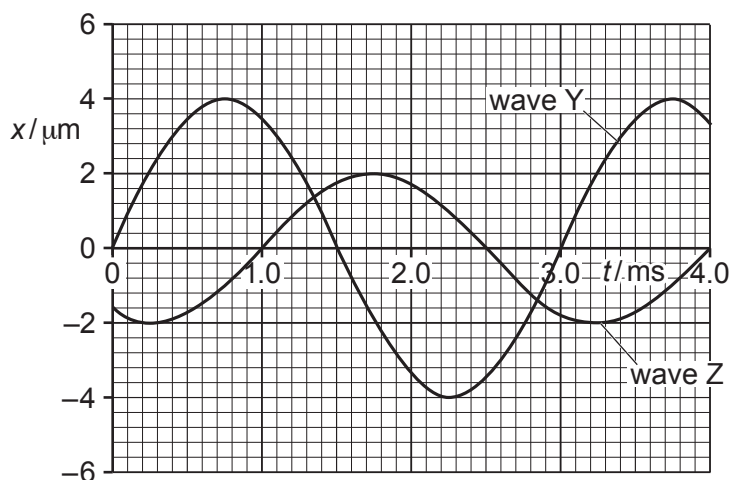


Fig. 4.1

- (a) Use Fig. 4.1 to state **one** quantity of waves Y and Z that is:

(i) the same

..... [1]

(ii) different.

..... [1]

- (b) State and explain whether waves Y and Z are coherent.

..... [1]

- (c) Determine the phase difference between the waves.

phase difference = ... ° [1]

- (d) The two waves superpose at P. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.75$ ms.

resultant displacement = ... μm [1]

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16. Question part 2/2 | 9702 May-June 2020 P2 V3 Q4

- (e) The intensity of wave Y at point P is I .

Determine, in terms of I , the intensity of wave Z.

intensity = ... [2]

- (f) The speed of wave Z is 330 m s^{-1} .

Determine the wavelength of wave Z.

wavelength = ... m [3]

[Total: 10]

- 5 A progressive wave Y passes a point P. The variation with time t of the displacement x for the wave at P is shown in Fig. 5.1.

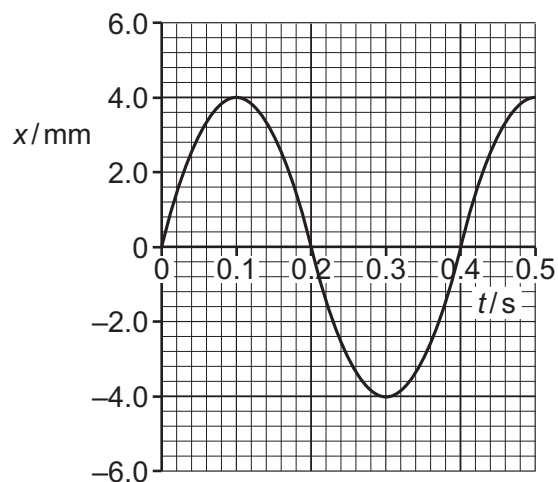


Fig. 5.1

The wave has a wavelength of 8.0 cm.

- (a) Determine the speed of the wave.

speed = ... ms^{-1} [2]

- (b) A second wave Z has wavelength 8.0 cm and amplitude 2.0 mm at point P. Waves Y and Z have the same speed.

For the waves at point P, calculate the ratio

$$\frac{\text{intensity of wave Z}}{\text{intensity of wave Y}}$$

ratio = ... [3]

[Total: 5]

- 5 A source of sound is attached to a rope and then swung at a constant speed in a horizontal circle, as illustrated in Fig. 5.1.

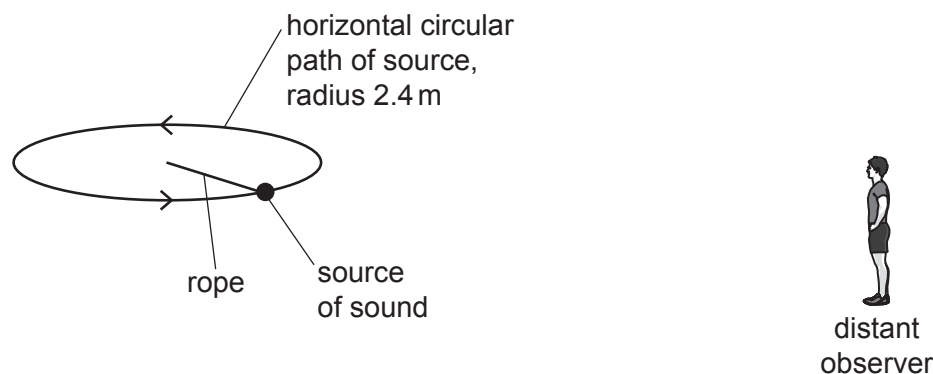


Fig. 5.1 (not to scale)

The source moves with a speed of 12.0 m s^{-1} and emits sound of frequency 951 Hz . The speed of the sound in the air is 330 m s^{-1} . An observer, standing a very long distance away from the source, hears the sound.

- (a) Calculate the minimum frequency, to three significant figures, of the sound heard by the observer.

minimum frequency = ... Hz [2]

- (b) The circular path of the source has a radius of 2.4 m .

Determine the shortest time interval between the observer hearing sound of minimum frequency and the observer hearing sound of maximum frequency.

time interval = ... s [2]

[Total: 4]

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19. Question part 1/2 | 9702 May-June 2021 P2 V1 Q4

4 (a) For a progressive wave, state what is meant by *wavelength*.

.....
..... [1]

(b) A light wave from a laser has a wavelength of 460 nm in a vacuum.

Calculate the period of the wave.

period = ... s [3]

(c) The light from the laser is incident normally on a diffraction grating.

Describe the diffraction of the light waves at the grating.

.....
.....
..... [2]

(d) A diffraction grating is used with different wavelengths of visible light. The angle θ of the **fourth**-order maximum from the zero-order (central) maximum is measured for each wavelength. The variation with wavelength λ of $\sin \theta$ is shown in Fig. 4.1.

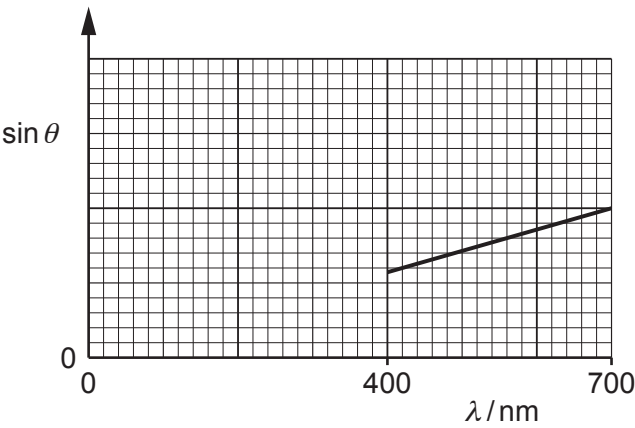


Fig. 4.1

19. Question part 2/2 | 9702 May-June 2021 P2 V1 Q4

- (i) The gradient of the graph is G .

Determine an expression, in terms of G , for the distance d between the centres of two adjacent slits in the diffraction grating.

$$d = \dots\dots\dots [2]$$

- (ii) On Fig. 4.1, sketch a graph to show the results that would be obtained for the **second-order** maxima. [2]

[Total: 10]

- 4 (a) By reference to the direction of transfer of energy, state what is meant by a *longitudinal* wave.

.....
..... [1]

- (b) A vehicle travels at constant speed around a wide circular track. It continuously sounds its horn, which emits a single note of frequency 1.2 kHz. An observer is a large distance away from the track, as shown in the view from above in Fig. 4.1.

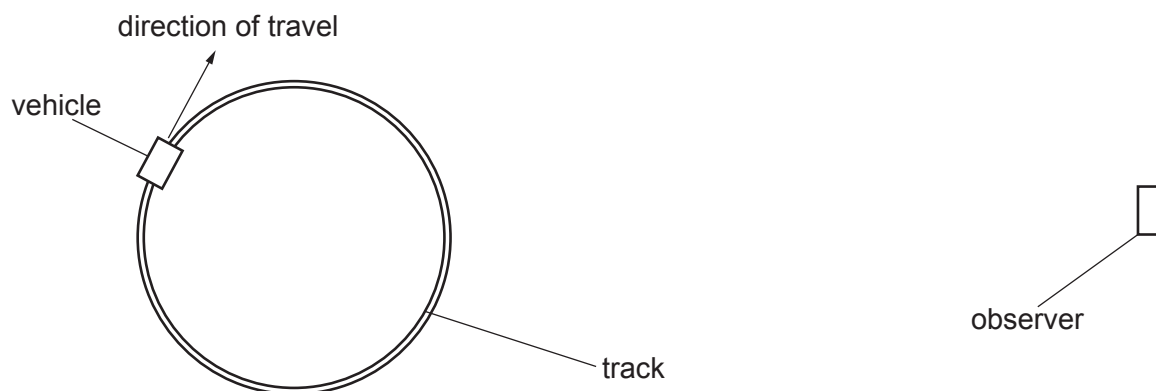


Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with time of the frequency f of the sound of the horn that is detected by the observer. The time taken for the vehicle to travel once around the track is T .

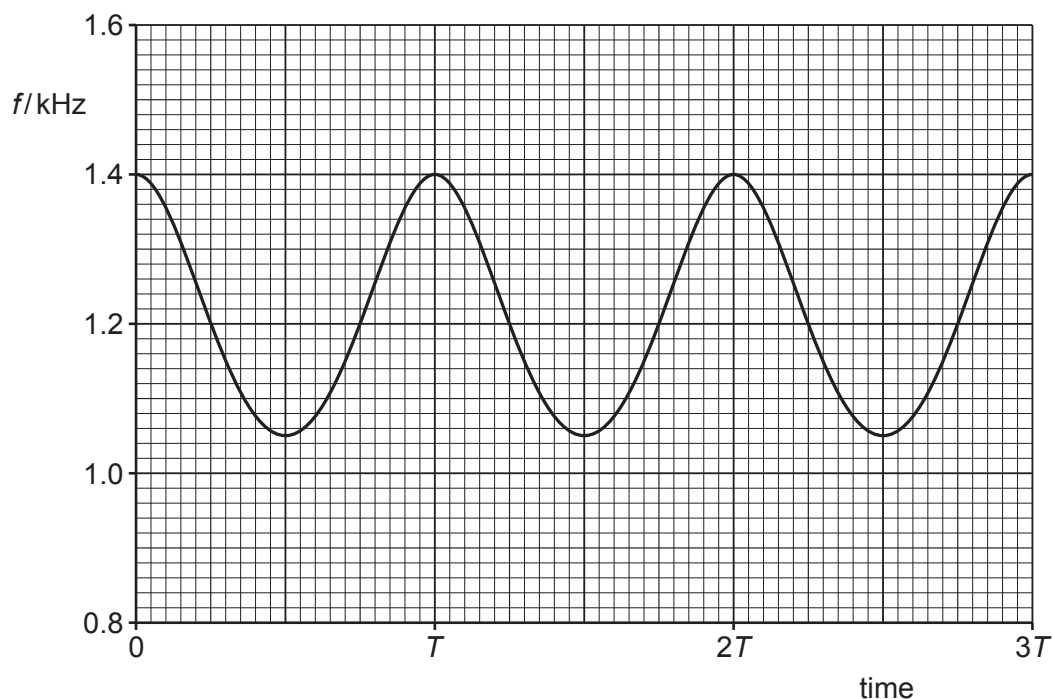


Fig. 4.2

(i) Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.

.....

.....

.....

..... [2]

(ii) State the name of the phenomenon in (b)(i).

..... [1]

(iii) On Fig. 4.1, mark with a letter X the position of the vehicle when it emitted the sound that is detected at time T . [1]

(iv) On Fig. 4.1, mark with a letter Y the position of the vehicle when it emitted the sound that is detected at time $\frac{9T}{4}$. [1]

(c) The speed of the sound in the air is 320 ms^{-1} .

Use Fig. 4.2 to determine the speed of the vehicle in (b).

speed = ... ms^{-1} [3]

[Total: 9]

21. Question part 1/2 | 9702 Oct-Nov 2021 P2 V2 Q4

- 4 A child sits on the ground next to a remote-controlled toy car. At time $t = 0$, the car begins to move in a straight line directly away from the child. The variation with time t of the velocity of the car along this line is shown in Fig. 4.1.

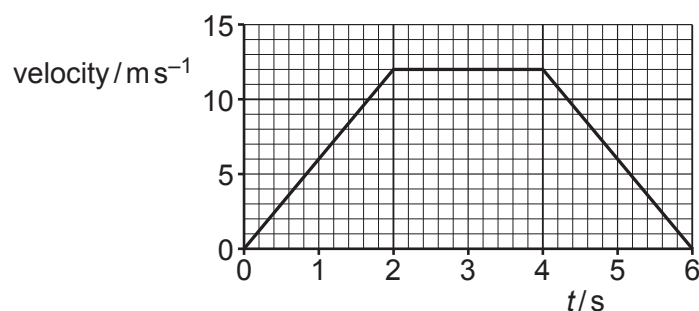


Fig. 4.1

The car's horn continually emits sound of frequency 925 Hz between time $t = 0$ and time $t = 6.0$ s. The speed of the sound in the air is 338 m s^{-1} .

- (a) Describe qualitatively the variation, if any, in the frequency of the sound heard, by the child, that was emitted from the car horn:

- (i) from time $t = 0$ to time $t = 2.0$ s

..... [1]

- (ii) from time $t = 4.0$ s to time $t = 6.0$ s.

..... [1]

- (b) Determine the frequency, to three significant figures, of the sound heard, by the child, that was emitted from the car horn at time $t = 3.0$ s.

frequency = ... Hz [2]

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21. Question part 2/2 | 9702 Oct-Nov 2021 P2 V2 Q4

(c) Determine the time taken for the sound emitted at time $t = 4.0$ s to travel to the child.

time taken = ... s [2]

[Total: 6]

- 5 A tube is initially fully submerged in water. The axis of the tube is kept vertical as the tube is slowly raised out of the water, as shown in Fig. 5.1.

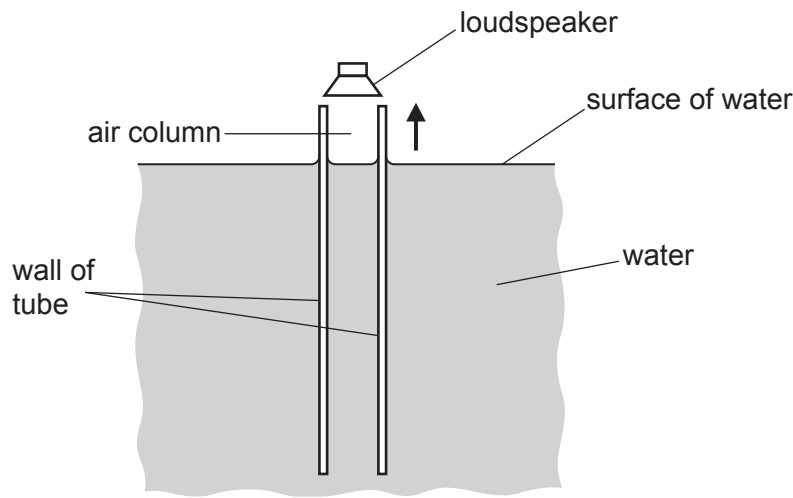


Fig. 5.1

A loudspeaker producing sound of frequency 530 Hz is positioned at the open top end of the tube as it is raised. The water surface inside the tube is always level with the water surface outside the tube. The speed of the sound in the air column in the tube is 340 m s^{-1} .

- (a) Describe a simple way that a student, without requiring any additional equipment, can detect when a stationary wave is formed in the air column as the tube is being raised.

.....
 [1]

- (b) Determine the height of the top end of the tube above the surface of the water when a stationary wave is first produced in the tube. Assume that an antinode is formed level with the top of the tube.

height = ... m [3]

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22. Question part 2/2 | 9702 Oct-Nov 2021 P2 V2 Q5

- (c) Determine the distance moved by the tube between the positions at which the first and second stationary waves are formed.

distance = ... m [1]

[Total: 5]

- 5 (a) (i)** State the conditions required for the formation of a stationary wave.

.....
.....
.....
..... [2]

- (ii)** State the phase difference between any two vibrating particles in a stationary wave between two adjacent nodes.

phase difference = ...° [1]

- (b)** A motorcycle is travelling at 13.0 m s^{-1} along a straight road. The rider of the motorcycle sees a pedestrian standing in the road directly ahead and operates a horn to emit a warning sound. The pedestrian hears the warning sound from the horn at a frequency of 543 Hz . The speed of the sound in the air is 334 m s^{-1} .

- (i)** Calculate the frequency, to three significant figures, of the sound emitted by the horn.

frequency = ... Hz [2]

- (ii)** The motorcycle rider passes the stationary pedestrian and then moves directly away from her. As the rider moves away, he operates the horn for a second time. The pedestrian now hears sound that is increasing in frequency.

State the variation, if any, in the speed of the motorcycle when the rider operates the horn for the second time.

..... [1]

- (c) A beam of vertically polarised monochromatic light is incident normally on a polarising filter, as shown in Fig. 5.1.

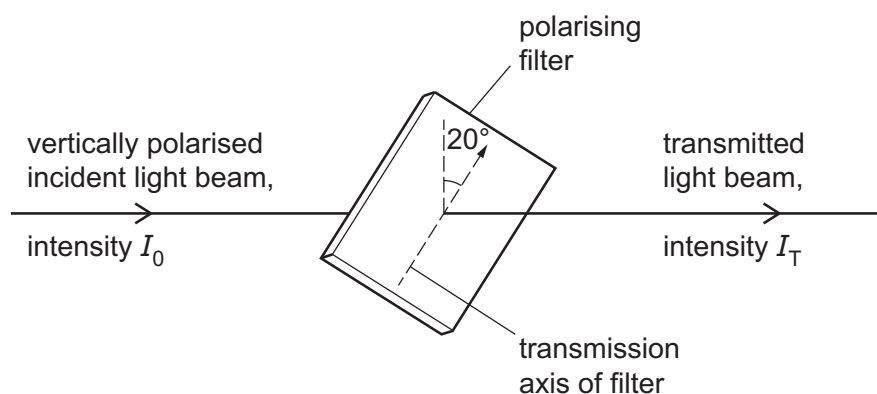


Fig. 5.1

The filter is positioned with its transmission axis at an angle of 20° to the vertical. The incident light has intensity I_0 and the transmitted light has intensity I_T .

- (i) By considering the ratio $\frac{I_T}{I_0}$, calculate the ratio

$$\frac{\text{amplitude of transmitted light}}{\text{amplitude of incident light}}.$$

Show your working.

ratio = ... [3]

- (ii) The filter is now rotated, about the direction of the light beam, from its starting position shown in Fig. 5.1. The direction of rotation is such that the angle of the transmission axis to the vertical initially increases.

Calculate the minimum angle through which the filter must be rotated so that the intensity of the transmitted light returns to the value that it had when the filter was at its starting position.

angle = ... $^\circ$ [1]

[Total: 10]

- 5 A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

At one instant, the moving string is straight, as shown in Fig. 5.1.



Fig. 5.1

The dots in the diagram represent the positions of the nodes on the string. Point P on the string is moving downwards.

The wave on the string has a speed of 35 ms^{-1} and a period of 0.040 s .

- (a) Explain how the stationary wave is formed on the string.

.....

.....

.....

..... [2]

- (b) On Fig. 5.1, sketch a line to show a possible position of the string a quarter of a cycle later than the position shown in the diagram. [1]

- (c) Determine the horizontal distance from A to B.

distance = ... m [3]

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24. Question part 2/2 | 9702 May-June 2022 P2 V1 Q5

- (d) A particle on the string has zero displacement at time $t = 0$. From time $t = 0$ to time $t = 0.060\text{ s}$, the particle moves through a total distance of 72 mm .

Calculate the amplitude of oscillation of the particle.

amplitude = ... mm [2]

[Total: 8]

25. Question part 1/2 | 9702 Oct-Nov 2022 P2 V2 Q5

- 5 (a) Two progressive sound waves meet to form a stationary wave. The two waves have the same amplitude, wavelength, frequency and speed.

State the other condition that must be fulfilled by the two waves in order for them to produce the stationary wave.

..... [1]

- (b) A stationary wave is formed on a string that is stretched between two fixed points A and B. Fig. 5.1 shows the string at time $t = 0$ when each point is at its maximum displacement.

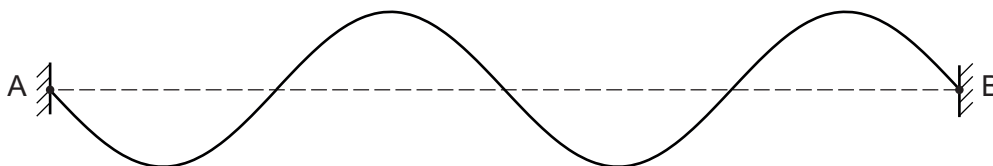


Fig. 5.1

Distance AB is 0.80 m. The period of the stationary wave is 0.016 s.

- (i) On Fig. 5.1, sketch a solid line to show the position of the string:

- at time $t = 0.004$ s (label this line P)
- at time $t = 0.024$ s (label this line Q).

[2]

- (ii) Determine the speed of a progressive wave along the string.

speed = ... ms^{-1} [3]

- (c) A beam of vertically polarised light of intensity I_0 is incident normally on a polarising filter that has its transmission axis at 30° to the vertical, as shown in Fig. 5.2.

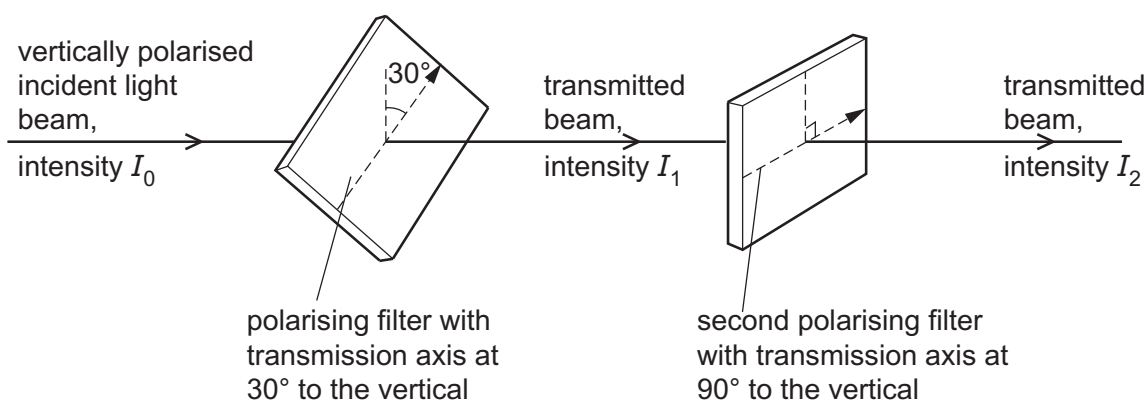


Fig. 5.2

The transmitted light from the first polarising filter has intensity I_1 . This light is then incident normally on a second polarising filter that has its transmission axis at 90° to the vertical. The transmitted light from the second filter has intensity I_2 .

Calculate:

- (i) the ratio $\frac{I_1}{I_0}$

$$\frac{I_1}{I_0} = \dots\dots\dots [2]$$

- (ii) the ratio $\frac{I_2}{I_0}$.

$$\frac{I_2}{I_0} = \dots\dots\dots [2]$$

[Total: 10]

- 4 (a) A progressive longitudinal wave travels through a medium from left to right. Fig. 4.1 shows the positions of some of the particles of the medium at time t_0 and a graph showing the particle displacements at the same time t_0 .

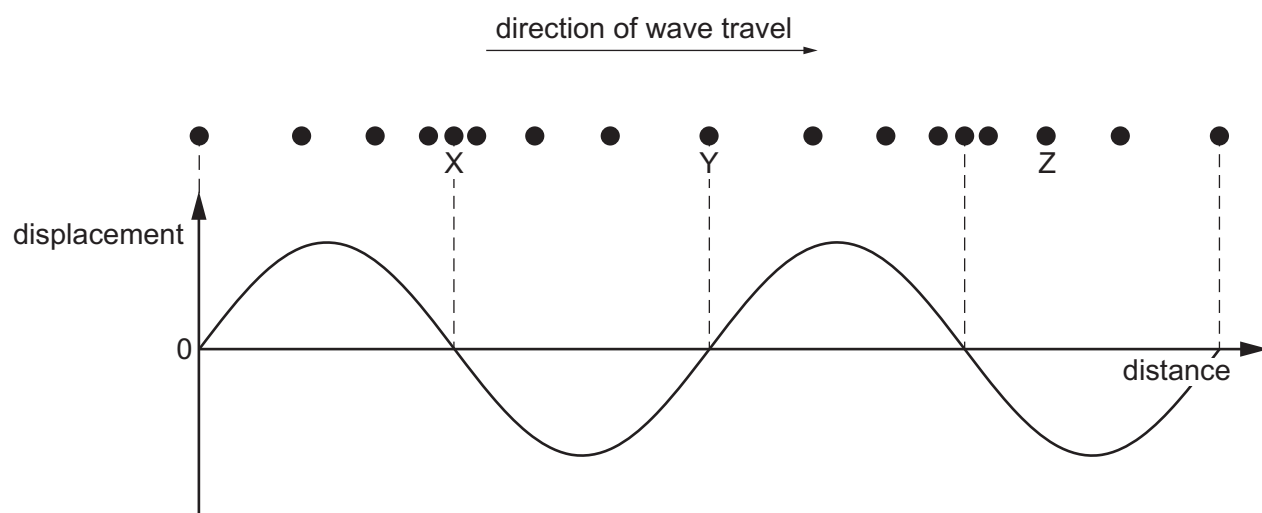


Fig. 4.1

Particle displacements to the right of their equilibrium positions are shown as positive on the graph and particle displacements to the left are shown as negative on the graph.

The period of the wave is T .

- (i) On Fig. 4.1, draw circles around two particles which are exactly one wavelength apart. [1]

- (ii) On Fig. 4.1, sketch a line on the graph to represent the displacements of the particles for the longitudinal wave at time $t_0 + \frac{T}{4}$. [3]

- (iii) State the direction of motion of particle Z at time $t_0 + \frac{T}{4}$. [1]
-

- (b) The frequency of the wave in (a) is 16 kHz. The distance between particles X and Y is 0.19 m.

Calculate the speed of the wave as it travels through the medium.

speed = ... ms^{-1} [3]

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26. Question part 2/2 | 9702 Oct-Nov 2022 P2 V3 Q4

- (c) A longitudinal sound wave is travelling through a solid. The initial intensity of the wave is I_0 . The frequency of the wave remains constant and the amplitude falls to half of its original value.

Determine, in terms of I_0 , the final intensity of the wave.

intensity = ... I_0 [2]

- (d) The sound wave in (c) now meets another sound wave travelling in the opposite direction.

- (i) State a condition necessary for these two waves to form a stationary wave.

..... [1]

- (ii) State **two** ways in which a stationary wave differs from a progressive wave.

1

.....

2

.....

[2]

[Total: 13]

1 The speed v of a transverse wave on a uniform string is given by the expression

$$v = \sqrt{\frac{Tl}{m}}$$

where T is the tension in the string, l is its length and m is its mass.

An experiment is performed to determine the speed v of the wave. The measurements are shown in Table 1.1.

Table 1.1

quantity	measurement	uncertainty
T	1.8 N	$\pm 5\%$
l	126 cm	$\pm 1\%$
m	5.1 g	$\pm 2\%$

(a) Use the data in Table 1.1 to calculate the speed v .

$v = \dots\dots\dots \text{m s}^{-1}$ [2]

(b) Use your answer in (a) and the data in Table 1.1 to calculate the absolute uncertainty in the value of v .

absolute uncertainty = $\dots\dots\dots \text{m s}^{-1}$ [2]

[Total: 4]

- 5 A beam of vertically polarised monochromatic light is incident on a polarising filter, as shown in Fig. 5.1.

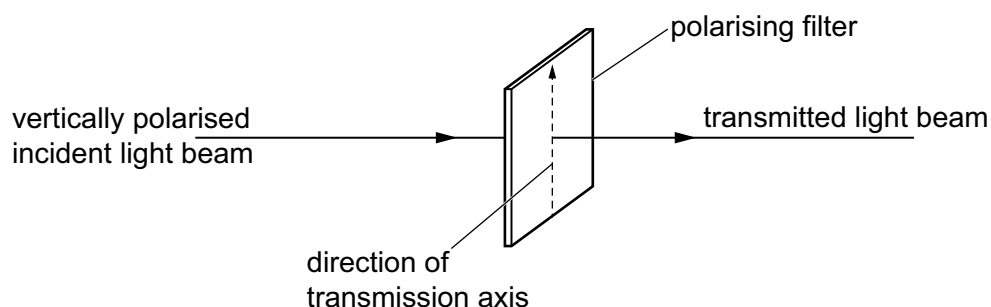


Fig. 5.1

The transmission axis of the filter is initially vertical and the transmitted light beam has the same intensity as the incident light beam.

The filter may be rotated about the direction of the light beam to change the angle of the transmission axis to the vertical.

- (a) State one angle of the transmission axis to the vertical that results in no transmitted light beam.

angle = ... ° [1]

- (b) The filter is now positioned with its transmission axis at angle θ to the vertical, as shown in Fig. 5.2.

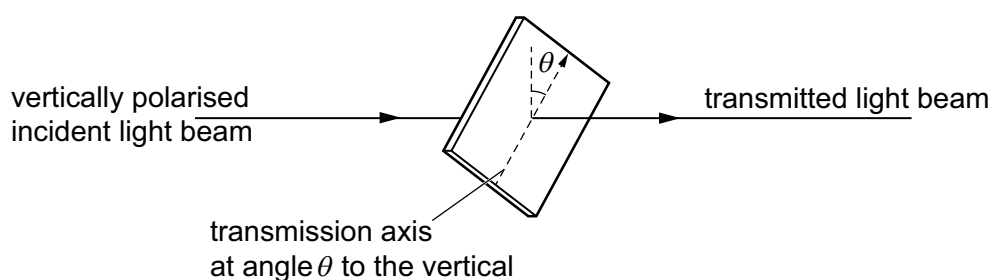


Fig. 5.2

The ratio $\frac{\text{intensity of transmitted light}}{\text{intensity of incident light}}$ is equal to 0.75.

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28. Question part 2/2 | 9702 Specimen 2022 P2 Q5

(i) Calculate angle θ .

$\theta = \dots\dots\dots^\circ$ [2]

(ii) Calculate the ratio

$$\frac{\text{amplitude of transmitted light}}{\text{amplitude of incident light}}.$$

ratio = $\dots\dots\dots$ [2]

[Total: 5]

29. Question part 1/3 | 9702 May-June 2023 P2 V2 Q5

- 5 (a) A progressive wave travels through a medium. The wave causes a particle of the medium to vibrate along a line P. The energy of the wave propagates along a line Q.

Compare the directions of lines P and Q if the wave is:

(i) a transverse wave
..... [1]

(ii) a longitudinal wave.
..... [1]

- (b) A tube is closed at one end. A loudspeaker is placed near the other end of the tube, as shown in Fig. 5.1.

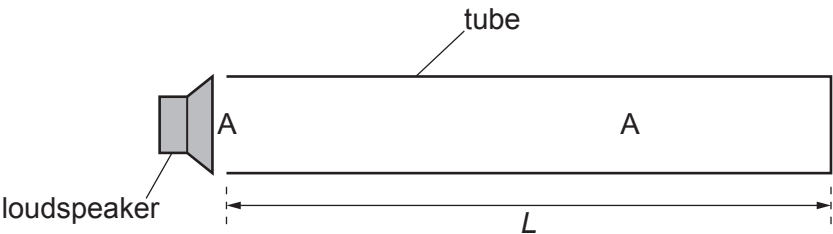


Fig. 5.1 (not to scale)

The loudspeaker emits sound of frequency 1.7 kHz . The speed of sound in the air in the tube is 340 m s^{-1} . A stationary wave is formed with an antinode A at the open end of the tube. There is only one other antinode A inside the tube, as shown in Fig. 5.1.

Determine:

- (i) the wavelength of the sound

wavelength = ... m [2]

- (ii) the length L of the tube

$L =$ m [1]

- (iii) the maximum wavelength of the sound from the loudspeaker that can produce a stationary wave in the tube.

maximum wavelength = ...m [1]

- (c) Two polarising filters are arranged so that their planes are vertical and parallel. The first filter has its transmission axis at an angle of 35° to the vertical and the second filter has its transmission axis at angle α to the vertical, as shown in Fig. 5.2.

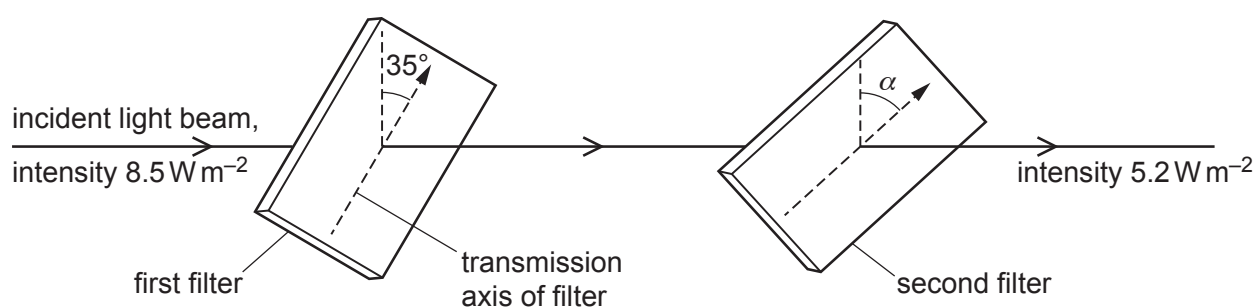


Fig. 5.2

Angle α is greater than 35° and less than 90° . A beam of vertically polarised light of intensity 8.5 W m^{-2} is incident normally on the first filter.

- (i) Show that the intensity of the light transmitted by the first filter is 5.7 W m^{-2} .

[1]

- (ii) The intensity of the light transmitted by the second filter is 5.2 W m^{-2} .

Calculate angle α .

$\alpha = \dots\dots\dots^\circ$ [2]

[Total: 9]

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30. Question part 1/4 | 9702 May-June 2023 P2 V3 Q4

- 4 (a) For a progressive wave, state what is meant by the frequency.

.....
..... [1]

- (b) A loudspeaker, microphone and cathode-ray oscilloscope (CRO) are arranged as shown in Fig. 4.1.

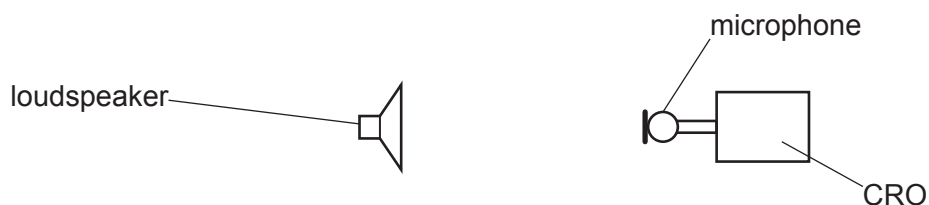


Fig. 4.1

The loudspeaker is emitting a sound wave which is detected by the microphone and displayed on the screen of the CRO as shown in Fig. 4.2.

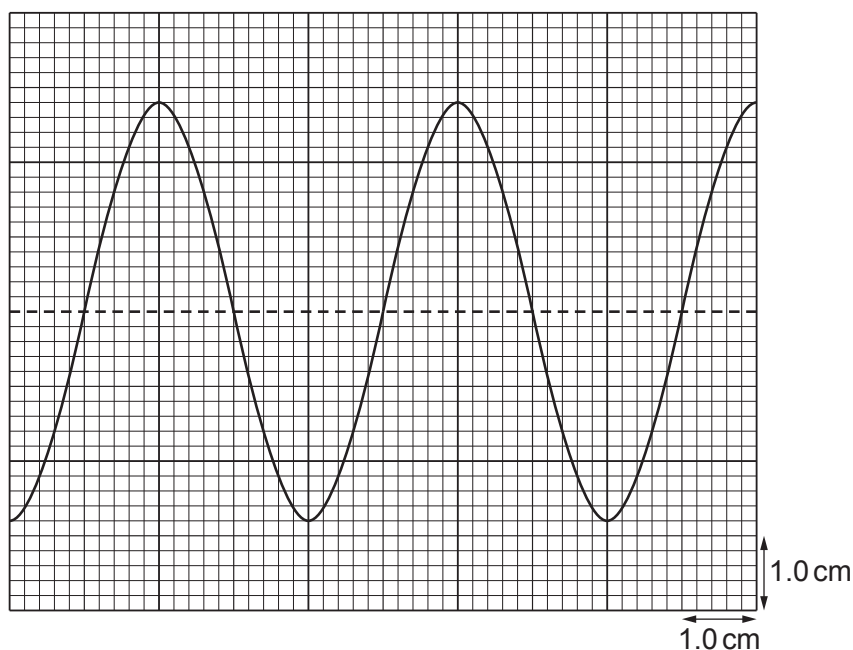


Fig. 4.2

The time-base on the CRO is set to 0.50 ms cm^{-1} and the y-gain is set to 0.20 V cm^{-1} .

Calculate:

(i) the frequency of the sound wave

frequency = ... Hz [2]

(ii) the amplitude of the signal received by the CRO.

amplitude = ... V [1]

(c) The intensity of the sound wave in (b) is reduced to a quarter of its original intensity without a change in frequency. Assume that the amplitude of the signal received by the CRO is proportional to the amplitude of the sound wave.

On Fig. 4.2, sketch the trace that is now seen on the screen of the CRO. [3]

(d) A metal sheet is now placed in front of the loudspeaker in (b), as shown in Fig. 4.3.

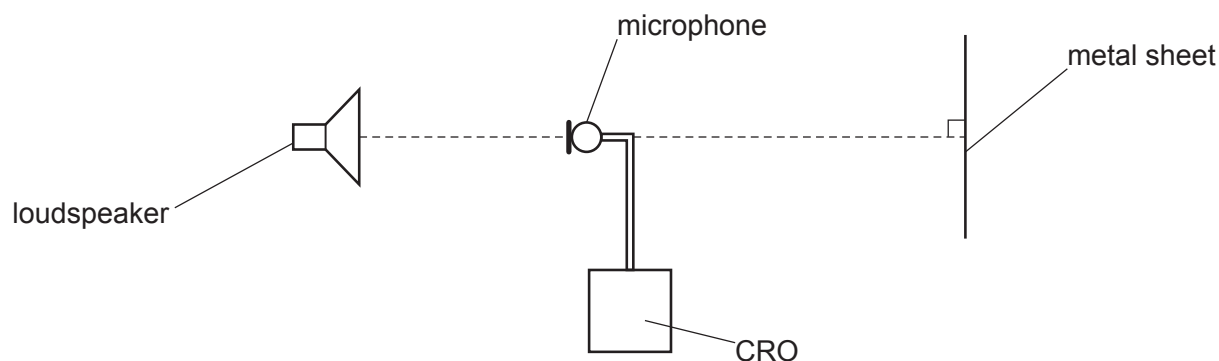


Fig. 4.3

A stationary wave is formed between the loudspeaker and the metal sheet.

(i) State the principle of superposition.

.....

 [2]

(ii) The initial position of the microphone is such that the trace on the CRO has an amplitude minimum. It is now moved a distance of 1.05 m away from the loudspeaker along the line joining the loudspeaker and metal sheet.

As the microphone moves, it passes through three positions where the trace has an amplitude maximum before ending at a position where the trace has an amplitude minimum.

Determine the wavelength of the sound wave.

wavelength = ... m [2]

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30. Question part 4/4 | 9702 May-June 2023 P2 V3 Q4

(iii) Use your answers in **(b)(i)** and **(d)(ii)** to determine the speed of the sound in the air.

speed = ... ms^{-1} [2]

[Total: 13]

31. Question | 9702 Oct-Nov 2023 P2 V1 Q5

- 5 A train travels at a constant high speed along a straight horizontal track towards an observer standing adjacent to the track, as shown in Fig. 5.1.

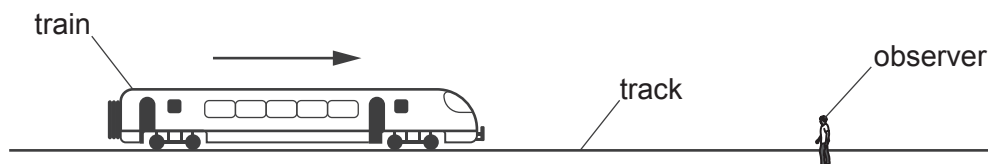


Fig. 5.1

The train sounds its horn continuously as it approaches the observer, from time $t = 0$ until it is well past the observer at time $t = t_2$. The train passes the observer at time $t = t_1$. The horn emits a sound wave of constant frequency f_S .

- (a) On Fig. 5.2, sketch the variation of the frequency of sound heard by the observer with time t , from time $t = 0$ to $t = t_2$.

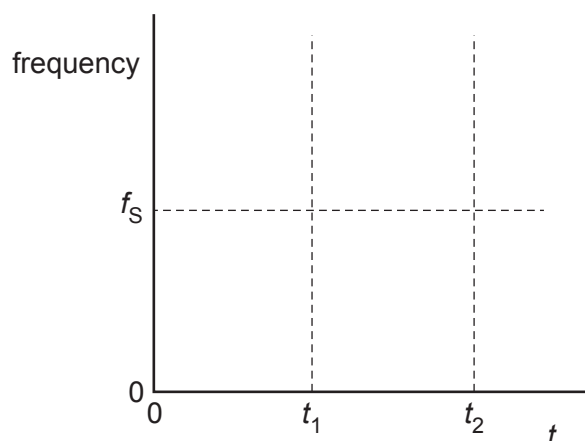


Fig. 5.2

[1]

- (b) At a particular time, the sound waves at the observer have an intensity of $4.7 \times 10^{-3} \text{ W m}^{-2}$. The waves at the observer are incident at right angles on a circular detector of radius 2.8 cm.

Calculate the power P of the waves incident on the detector.

$P = \dots\dots\dots \text{ W}$ [3]

[Total: 4]

- 5 (a) A beam of vertically polarised light is incident normally on a polarising filter, as shown in Fig. 5.1.

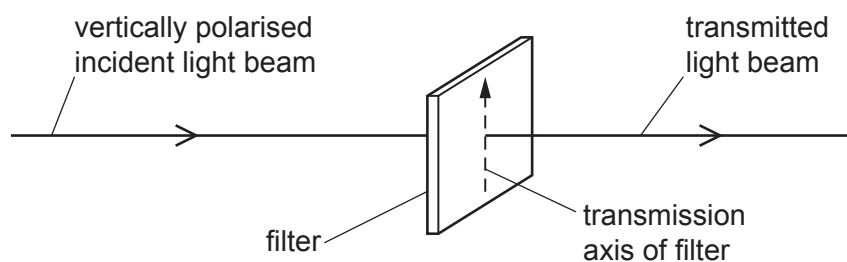


Fig. 5.1

- (i) The transmission axis of the filter is initially vertical. The filter is then rotated through an angle of 360° while the plane of the filter remains perpendicular to the beam.

On Fig. 5.2, sketch a graph to show the variation of the intensity of the light in the transmitted beam with the angle through which the transmission axis is rotated.

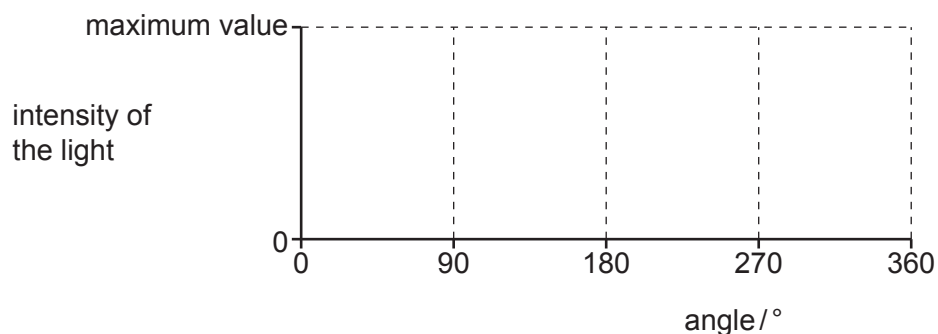


Fig. 5.2

[2]

- (ii) The intensity of the light in the incident beam is 7.6 W m^{-2} . When the transmission axis of the filter is at angle θ to the vertical, the light intensity of the transmitted beam is 4.2 W m^{-2} .

Calculate angle θ .

$\theta = \dots\dots\dots^\circ$ [2]

- (b) State what is meant by the diffraction of a wave.

.....

 [2]

- (c) A beam of light of wavelength $4.3 \times 10^{-7} \text{ m}$ is incident normally on a diffraction grating in air, as shown in Fig. 5.3.

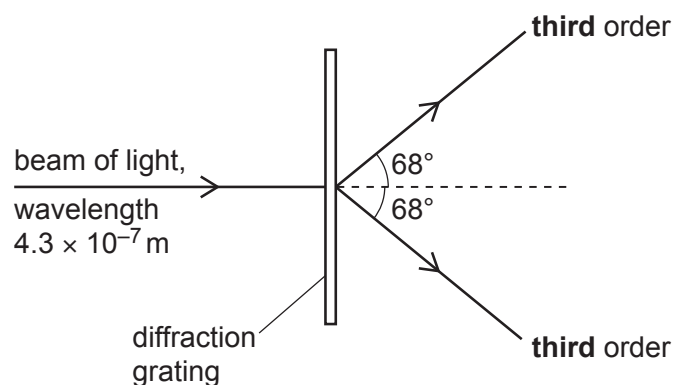


Fig. 5.3 (not to scale)

The **third**-order diffraction maximum of the light is at an angle of 68° to the direction of the incident light beam.

- (i) Calculate the line spacing d of the diffraction grating.

$d = \dots\dots\dots \text{m}$ [2]

- (ii) Determine a different wavelength of **visible** light that will also produce a diffraction maximum at an angle of 68° .

wavelength = $\dots\dots\dots \text{m}$ [2]

[Total: 10]

- 6 A train travels at constant speed along a straight horizontal track towards an observer standing adjacent to the track, as shown in Fig. 6.1.

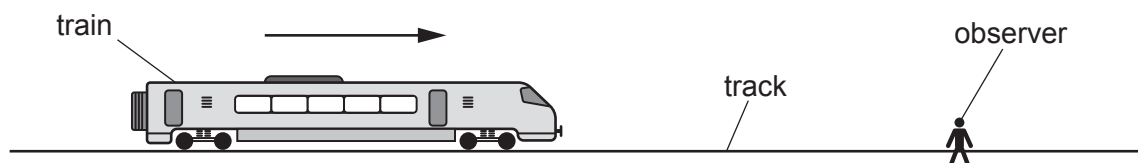


Fig. 6.1

The train sounds its horn continuously as it approaches the observer. The horn emits a sound of constant frequency 251 Hz. The frequency of sound heard by the observer is 291 Hz. The speed of sound in air is 340 m s^{-1} .

- (a) Calculate the speed of the train.

speed = ... m s^{-1} [2]

- (b) The train approaches and then passes the observer. The intensity I of the sound heard by the observer varies with the distance d of the horn from the observer.

When the horn is at a distance x_0 from the observer, the intensity I of the sound heard is I_0 and the amplitude A of the sound wave at the observer is A_0 .

Fig. 6.2 shows the variation with d/x_0 of I/I_0 as the train moves away from the observer.

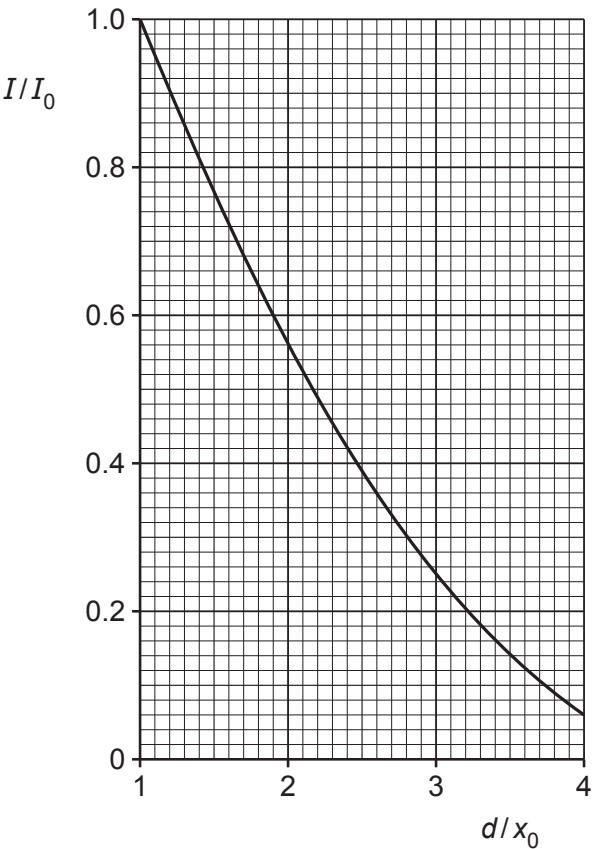


Fig. 6.2

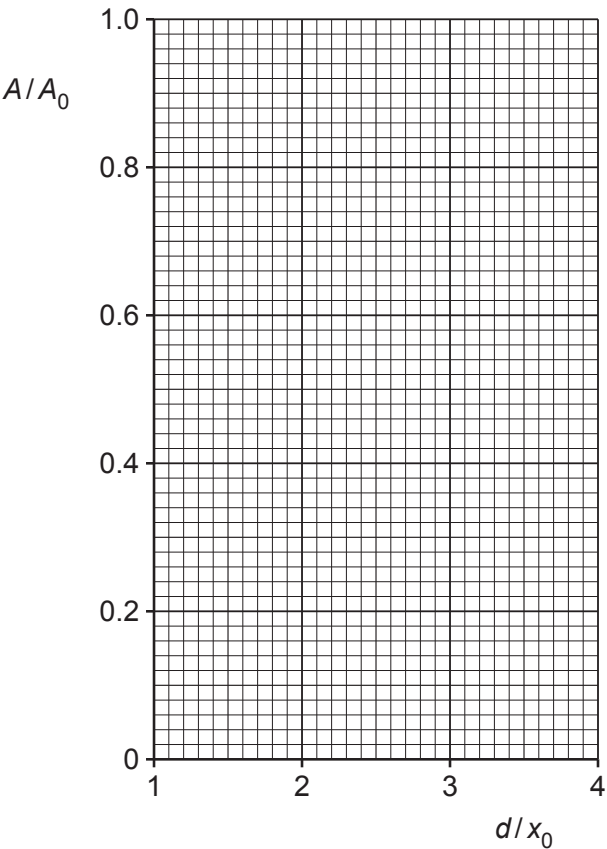


Fig. 6.3

- (i) State the relationship between amplitude A and intensity I for a progressive wave.
..... [1]
- (ii) On Fig. 6.3, sketch the variation with d/x_0 of A/A_0 . [2]

[Total: 5]

34. Question | 9702 Feb-March 2024 P2 V2 Q5

5 (a) By reference to the direction of propagation of energy, state what is meant by a transverse wave.

..... [1]

(b) A space telescope is designed to detect electromagnetic radiation with wavelengths in the range 12 μm to 28 μm.

State the region of the electromagnetic spectrum for this radiation.

..... [1]

(c) A detector on another space telescope detects an electromagnetic wave. The signal from the detector is transmitted to Earth and displayed on an oscilloscope as shown in Fig. 5.1. The frequency of the signal displayed on the oscilloscope is equal to the frequency of the detected electromagnetic wave.

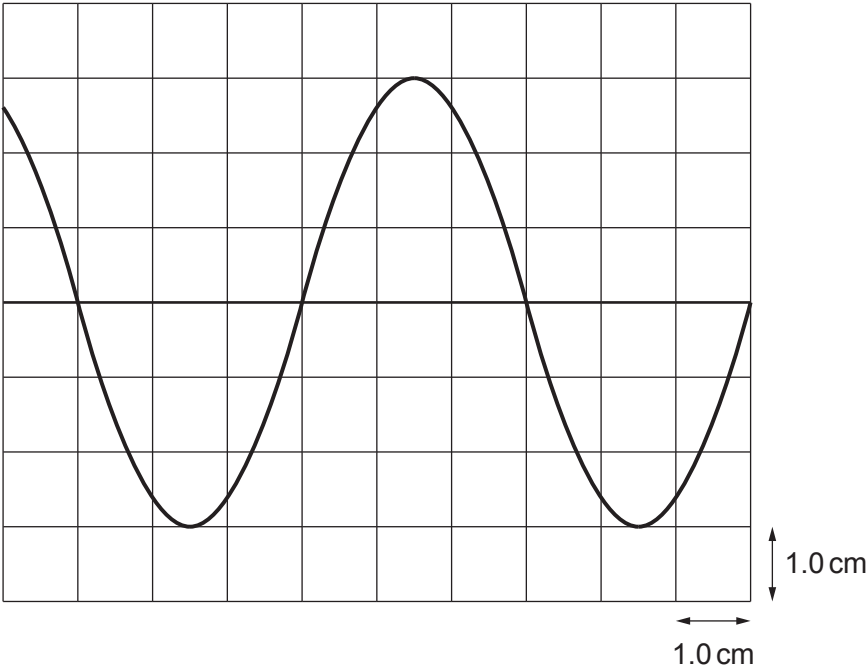


Fig. 5.1

The time-base setting on the oscilloscope is $5.0 \times 10^{-15} \text{ s cm}^{-1}$.

Calculate the wavelength of the detected electromagnetic wave.

wavelength = ... m [3]

[Total: 5]

35. Question part 1/2 | 9702 Oct-Nov 2024 P2 V2 Q4

- 4 (a) With reference to the direction of transfer of energy, compare the oscillations of transverse and longitudinal progressive waves.

.....

.....

.....

..... [2]

- (b) A pipe is open at one end and closed at the other with a piston. The piston can slide freely and is at a distance of $4.5 \times 10^{-2}\text{ m}$ from the open end of the pipe.

A loudspeaker is positioned near the open end of the pipe and emits a sound wave of a single constant frequency. A stationary wave is formed in the pipe, as illustrated in Fig. 4.1.

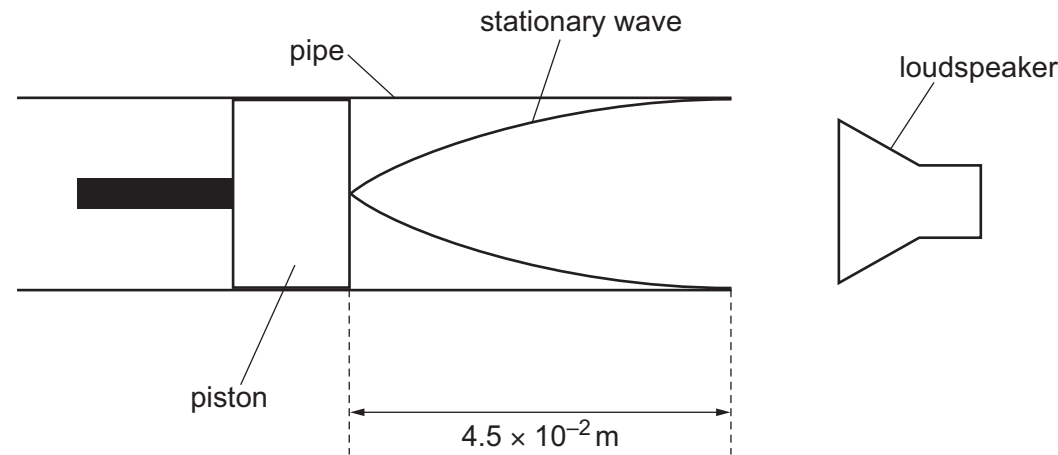


Fig. 4.1

- (i) On Fig. 4.1, draw a letter A at the position of an antinode. [1]

- (ii) The speed of sound in air is 340 ms^{-1} .

Determine the frequency of the sound wave.

frequency = ... Hz [3]

35. Question part 2/2 | 9702 Oct-Nov 2024 P2 V2 Q4



(iii) The piston is moved to the left. The frequency of the sound wave emitted by the loudspeaker is then changed so that a stationary wave is formed with same number of antinodes as in Fig. 4.1.

State and explain the change that is made to the frequency of the sound wave.

.....

.....

.....

..... [2]

[Total: 8]

36. Question part 1/2 | 9702 Oct-Nov 2024 P2 V3 Q5

- 5 (a) A stationary wave is formed on a string XY that has a length of 0.48 m. Fig. 5.1 shows the string at one instant in time.

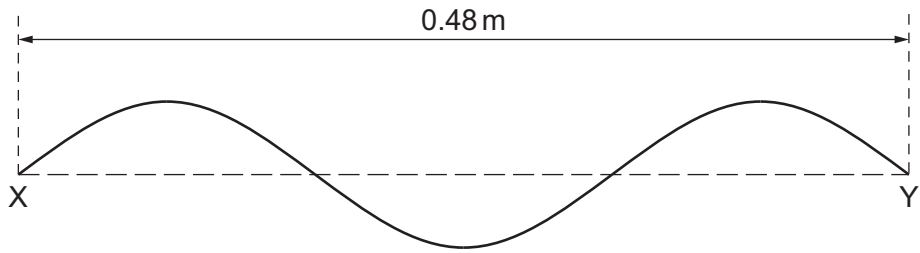


Fig. 5.1

The speed of the wave on the string is 1400 ms^{-1} .

- (i) On Fig. 5.1, draw a cross (×) at **one** position that is a node and another cross at **one** position that is an antinode. Label the node N and the antinode A. [1]
- (ii) Show that the wavelength of the wave produced is 0.32 m. Explain your reasoning.

[1]

- (iii) Calculate the frequency of the wave.

frequency = ... Hz [2]

36. Question part 2/2 | 9702 Oct-Nov 2024 P2 V3 Q5



- (b) A source of sound waves of frequency 780 Hz is on a rotating platform. The speed of the source is 39 m s^{-1} .

The sound is detected by an observer that is a large distance from the rotating platform, as shown in Fig. 5.2.

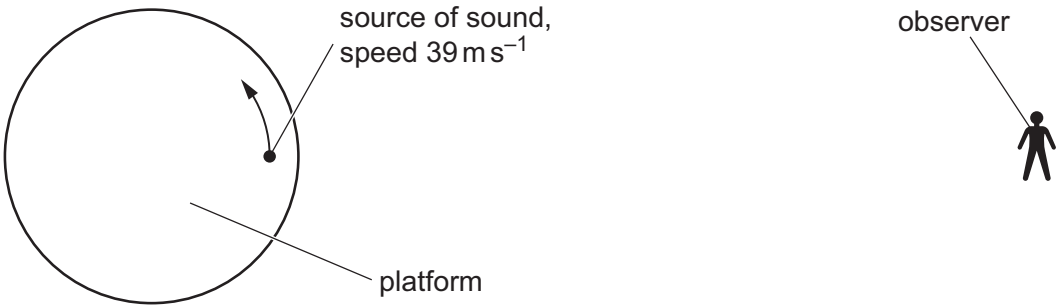


Fig. 5.2 (not to scale)

- (i) The speed of sound in air is 320 m s^{-1} .

Calculate the maximum frequency of the sound detected by the observer.

maximum frequency = ... Hz [2]

- (ii) At time $t = 0$, the observer detects the sound emitted by the source when it was in the position shown in Fig. 5.2.

On Fig. 5.3, sketch the variation with t of the frequency f of the sound detected by the observer for one complete rotation of the platform. Calculations are not required.

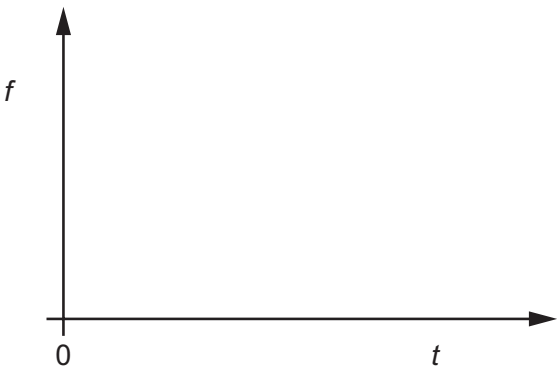


Fig. 5.3

[2]

[Total: 8]

37. Question part 1/2 | 9702 Feb-March 2025 P2 V2 Q4

- 4 A device containing a microwave emitter and receiver is placed in front of a large metal sheet in a vacuum as shown in Fig. 4.1.

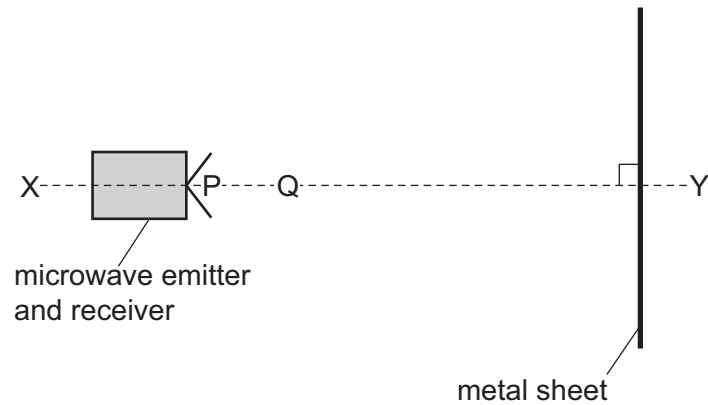


Fig. 4.1 (not to scale)

The line XY is perpendicular to the metal sheet. The device emits microwaves of frequency 6.3GHz.

- (a) When the device is at position P, a stationary wave is formed between the device and the sheet.

Explain how the stationary wave, including the nodes and the antinodes, is formed.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (b) (i) Calculate the wavelength of the microwaves.

wavelength = ...m [2]

37. Question part 2/2 | 9702 Feb-March 2025 P2 V2 Q4



(ii) At point P the receiver detects a maximum amplitude of the stationary wave.

The device is moved slowly from point P along the line XY and the receiver detects a series of minimum and maximum amplitudes. The first time a minimum amplitude is detected by the receiver is when the device is at point Q.

Determine the distance between P and Q.

distance = ... m [1]

(iii) The intensity of the microwaves emitted by the device is increased. The frequency of the microwaves is unchanged. The device is moved slowly along the line XY from point Q until the next maximum amplitude is detected at point R.

State and explain whether the distance QR is greater than, less than or the same as distance PQ.

.....
.....
..... [1]

[Total: 8]

38. Question | 9702 Feb-March 2025 P2 V2 Q5

- 5 A stationary loudspeaker emits sound of constant frequency. A microphone is placed near to the loudspeaker and connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

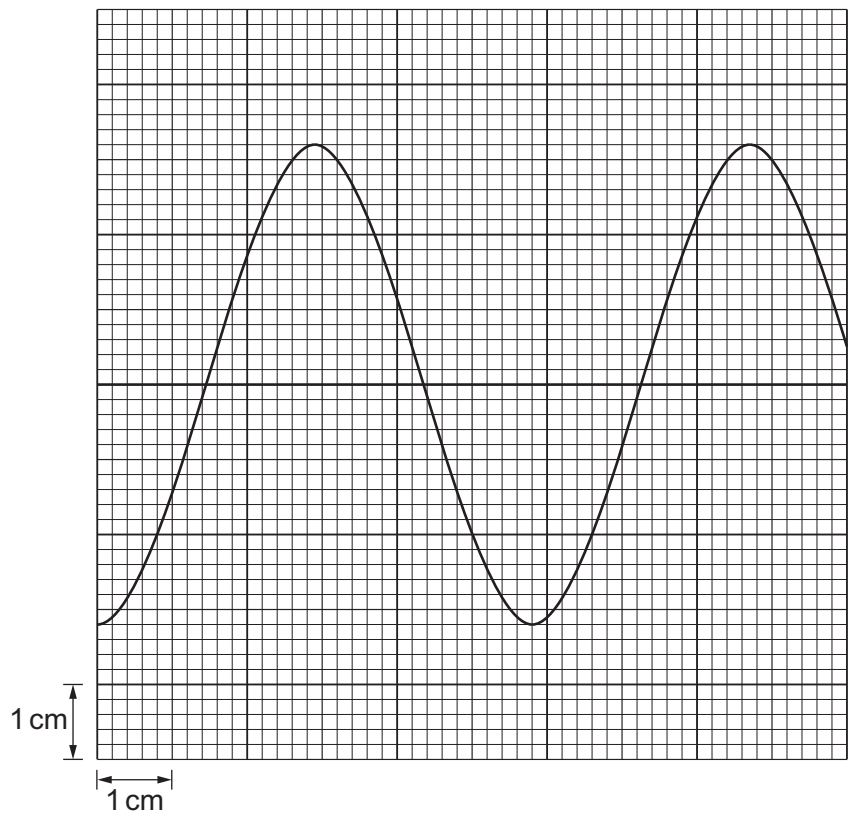


Fig. 5.1

The time-base of the CRO is set to $5.0 \times 10^{-4} \text{ s cm}^{-1}$.

- (a) The speed of the sound emitted by the loudspeaker is 330 m s^{-1} .

Determine the wavelength of the sound.

wavelength = ...m [3]

- (b) The loudspeaker now moves in a straight line while emitting the same sound of constant frequency. The period of the trace on the CRO increases continuously.

Describe the motion of the loudspeaker.

.....
.....
..... [2]

[Total: 5]

39. Question part 1/2 | 9702 May-June 2025 P2 V1 Q5

- 5 (a) Use the definitions of speed v , frequency f and wavelength λ to derive the wave equation

$$v = f\lambda.$$

[2]

- (b) A source of sound waves of frequency 236 Hz is travelling at a constant velocity of 20 m s^{-1} .

A stationary observer has a microphone connected to a cathode-ray oscilloscope (CRO). The microphone detects the sound waves as the source moves directly towards the observer.

The resulting trace on the CRO is shown in Fig. 5.1.

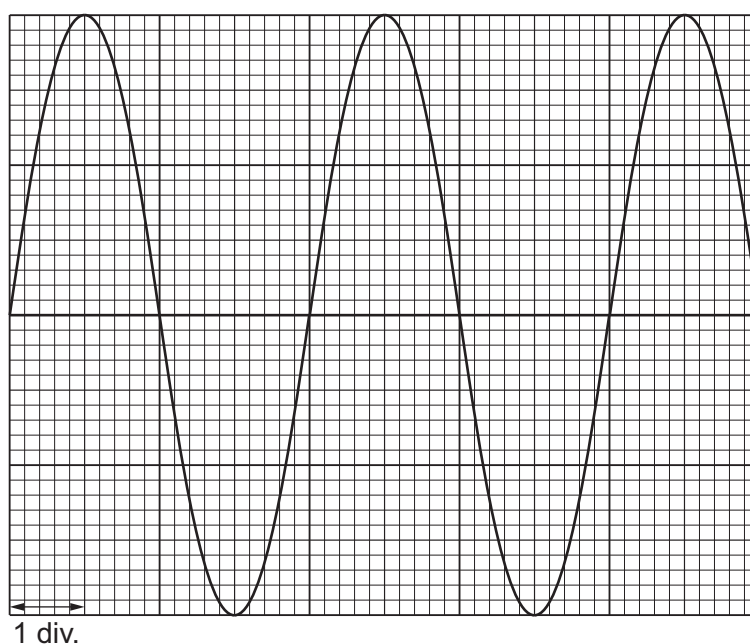


Fig. 5.1

The time-base on the CRO is set to 1.0 ms div^{-1} .

39. Question part 2/2 | 9702 May-June 2025 P2 V1 Q5



(i) Calculate the frequency of the sound waves detected by the microphone.

frequency = ... Hz [2]

(ii) Determine the speed of the sound in air.

speed of sound = ... ms^{-1} [2]

[Total: 6]

40. Question part 1/2 | 9702 May-June 2025 P2 V3 Q5

- 5 (a) State why sound waves **cannot** be polarised.

.....
 [1]

- (b) A plane-polarised light wave is incident on a polarising filter as shown in Fig. 5.1.

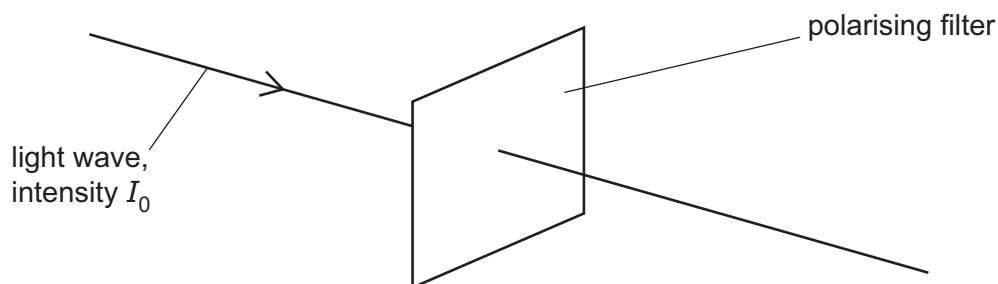


Fig. 5.1

The intensity of the light incident on the filter is I_0 .

The light is incident normally on the filter and the transmission axis of the filter is initially perpendicular to the plane of polarisation of the light.

The filter is now rotated through 360° about the direction of travel of the light wave.

- (i) On Fig. 5.2, sketch the variation of the intensity I of the transmitted light with the angle of rotation α as the filter is rotated through 360° from its initial position.

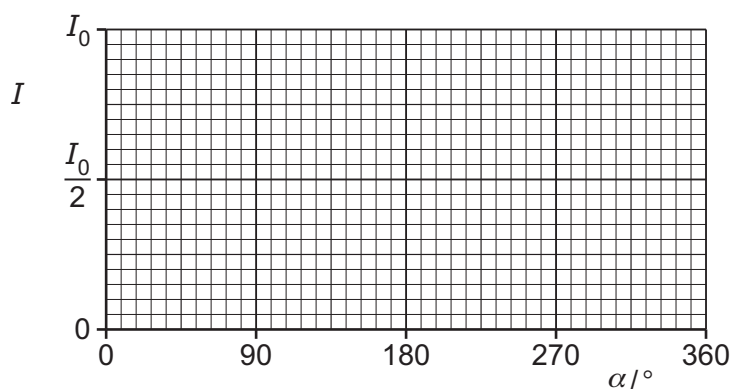


Fig. 5.2

[3]

40. Question part 2/2 | 9702 May-June 2025 P2 V3 Q5



(ii) The amplitude of the incident light wave is A_0 when the intensity of the wave is I_0 .

Use Malus’s law to determine, in terms of A_0 , the amplitude of the transmitted wave when $\alpha = 20^\circ$.

amplitude = ... A_0 [4]

[Total: 8]

41. Question part 1/2 | 9702 Oct-Nov 2025 P2 V3 Q4

- 4 (a) State what is meant by diffraction of a wave.

.....

.....

..... [2]

- (b) A beam of vertically polarised light of wavelength 540 nm is incident normally on a diffraction grating, as shown in Fig. 4.1.

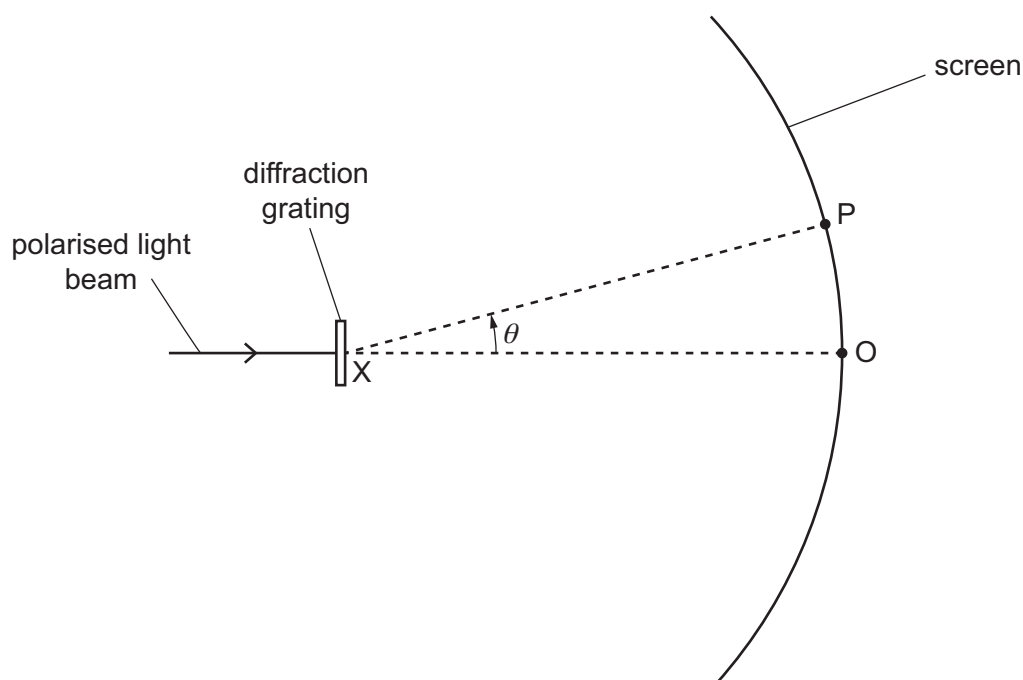


Fig. 4.1 (not to scale)

The diffraction grating has a line spacing of 5.0×10^{-6} m.

The light transmitted by the diffraction grating illuminates a circular screen. The diffraction grating is at the centre X of the circle.

The central bright fringe is formed at point O on the screen and has intensity I_0 .

P is a point on the screen where the line XP is at a variable angle θ to the line XO. The intensity I of light on the screen at P varies with θ .

- (i) Show that the angle θ at which the first-order bright fringe is formed is 6.2° .

41. Question part 2/2 | 9702 Oct-Nov 2025 P2 V3 Q4



(ii) Determine the value of θ at which the second-order bright fringe is formed.

$\theta = \dots\dots\dots^\circ$ [1]

(iii) On Fig. 4.2, sketch the variation of the intensity I with θ for values of θ from -15° to $+15^\circ$.

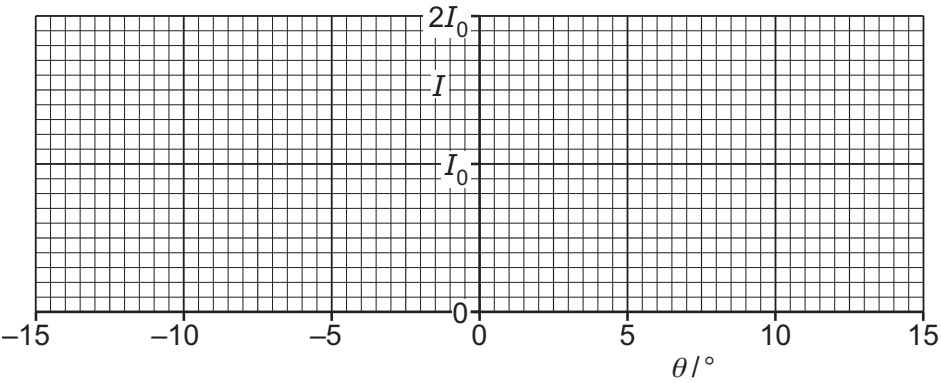


Fig. 4.2

[3]

(c) A polarising filter is placed in the path of the light beam that is incident on the diffraction grating in Fig. 4.1. The transmission axis of the filter is at 45° to the vertical.

Suggest how the variation of intensity with θ for the light on the screen compares with the answer in (b)(iii).

.....
.....
..... [2]

[Total: 10]