WAVES WORKSHEET
AS-Level Physics 9702

MJ25/21/Q5

1 **(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 $20\,\text{m}\,\text{s}^{-1}$.

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.

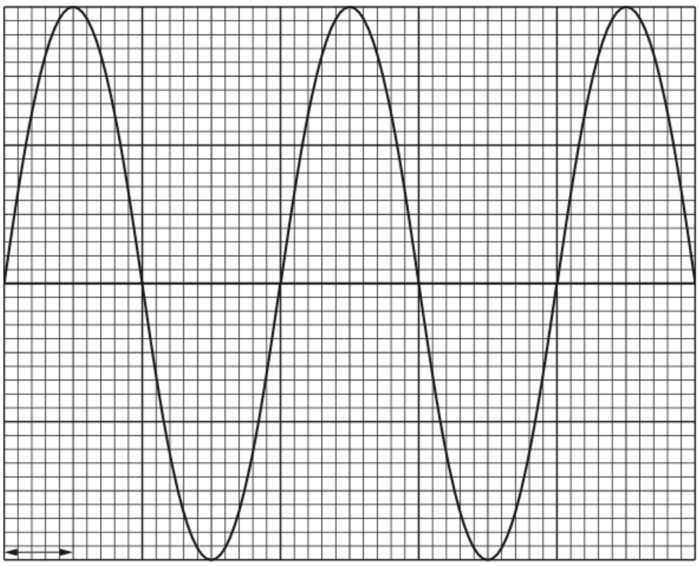

Fig. 5.1

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

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(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 = ... $m\,s^{-1}$ [2]

[Total: 6]

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

MJ25/23/Q5

....

.... [1]

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

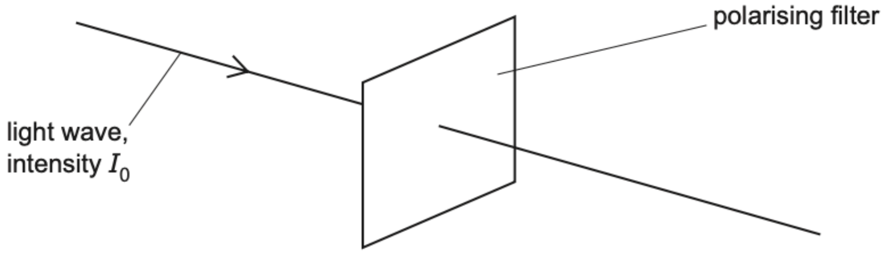

Fig. 5.1

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.

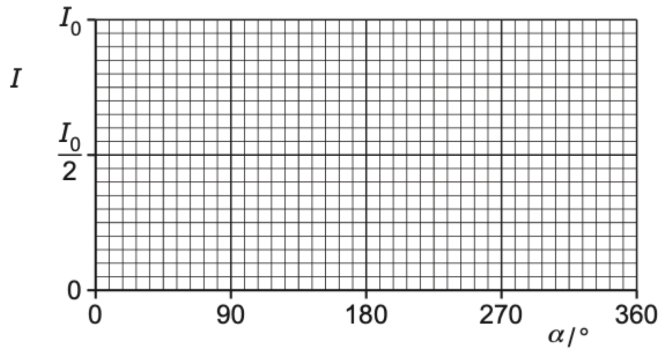

Fig. 5.2

[3]

(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 $\alpha = 20°$.

amplitude = ... A_0 [4]

[Total: 8]

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3 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.

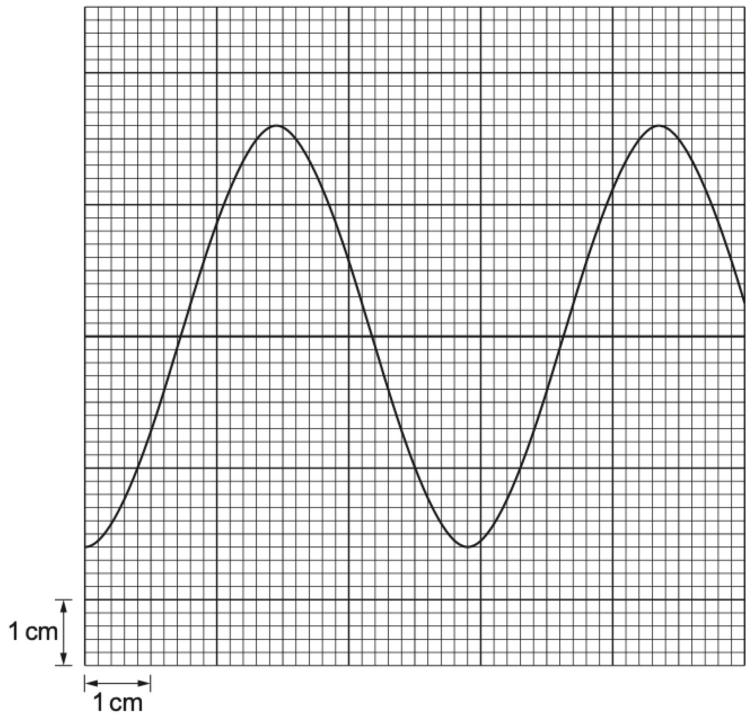

Fig. 5.1

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

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

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]

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4 **(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.

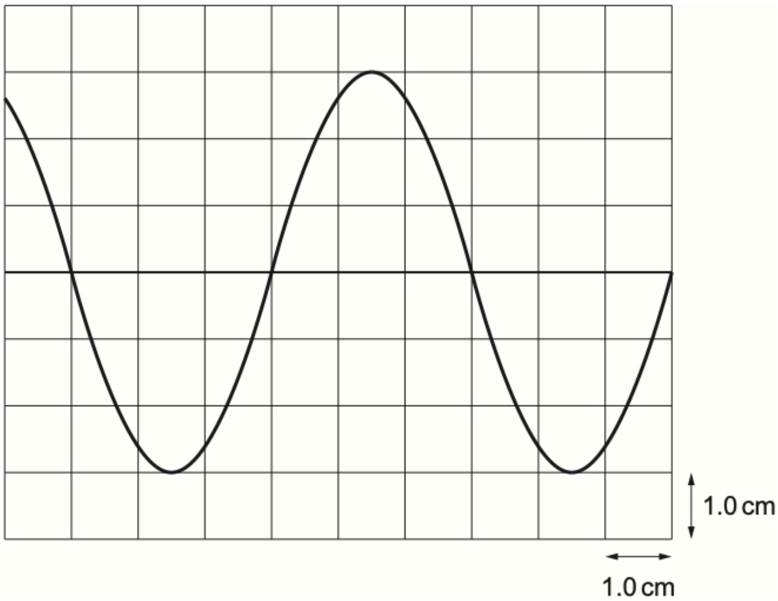

Fig. 5.1

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

Calculate the wavelength of the detected electromagnetic wave.

wavelength = ... m [3]

[Total: 5]

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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.

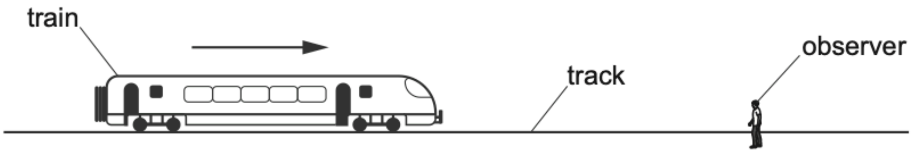

Fig. 5.1

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 $t = t_2$.

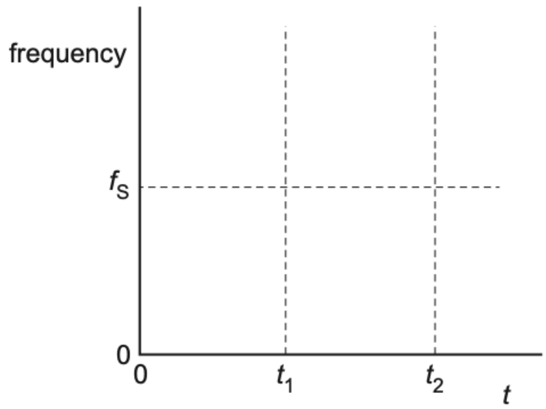

Fig. 5.2

[1]

(b) At a particular time, the sound waves at the observer have an intensity of $4.7 \times 10^{-3}\,\mathrm{W\,m^{-2}}$. 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 = ... W [3]

[Total: 4]

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

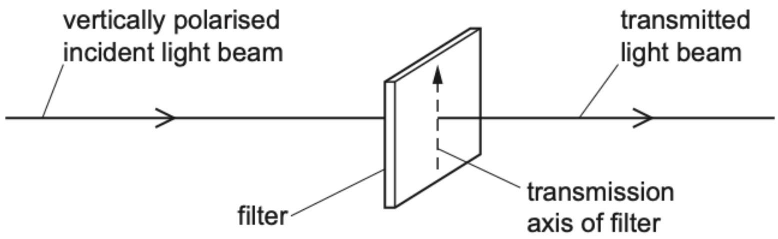

Fig. 5.1

(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.

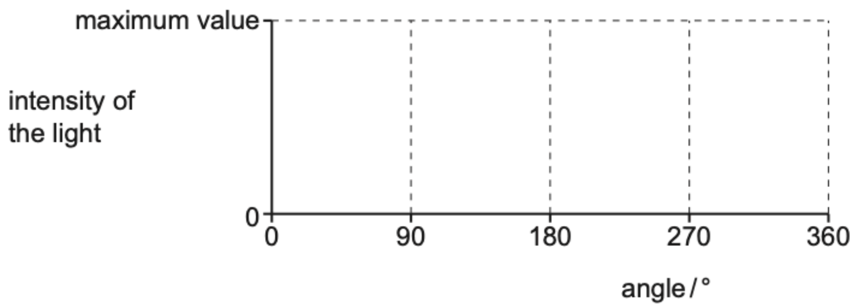

Fig. 5.2

[2]

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

Calculate angle θ.

θ = ...° [2]

7 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.

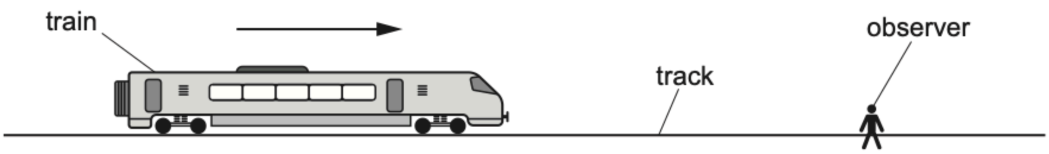

Fig. 6.1

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.

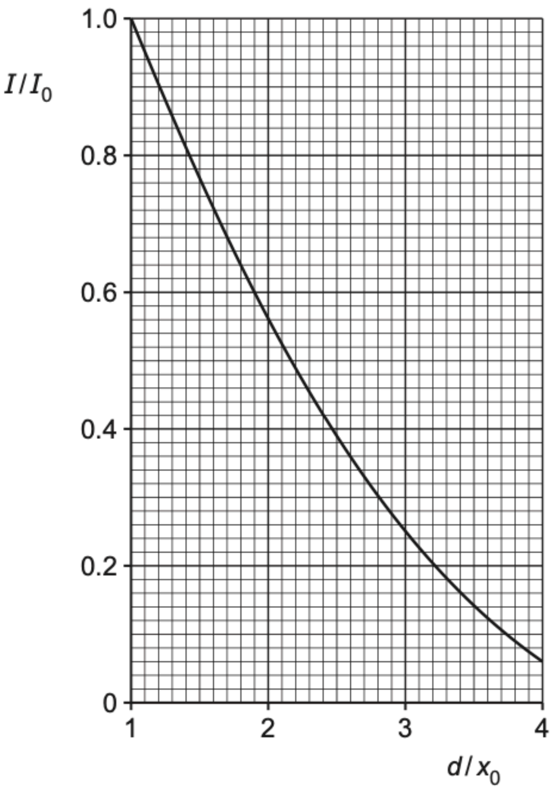

Fig. 6.2

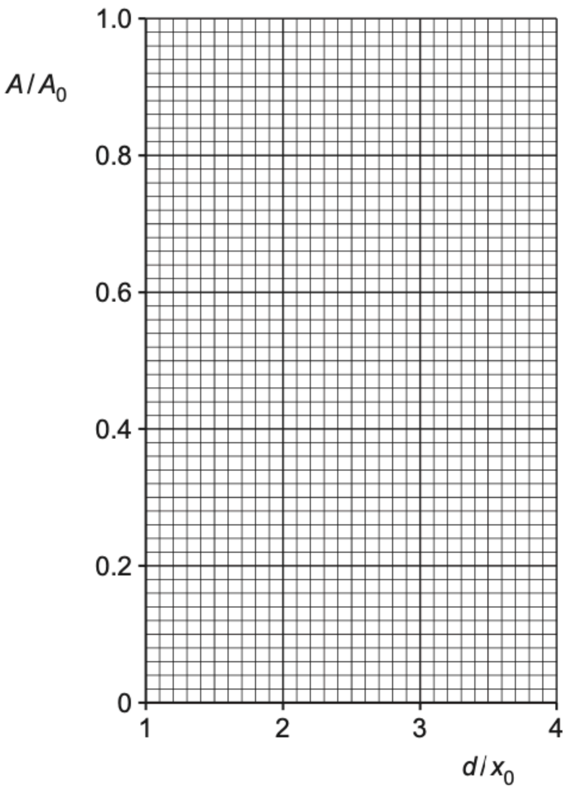

Fig. 6.3

(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]

8 **(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]

(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.

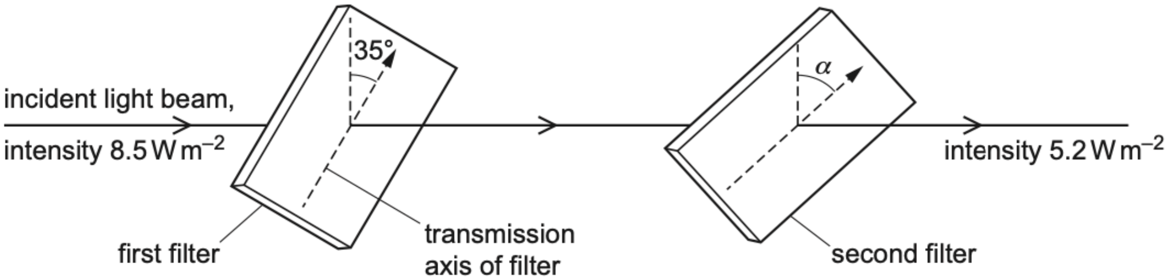

Fig. 5.2

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.

α = ... ° [2]

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9 **(a)** For a progressive wave, state what is meant by the frequency. **MJ23/23/Q4**

....

.... [1]

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

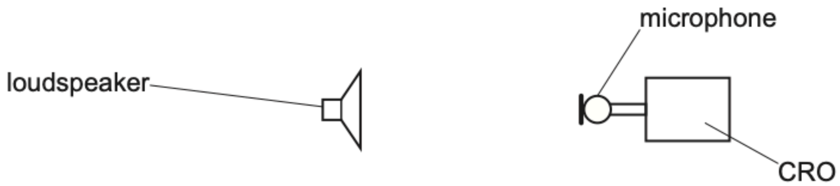

Fig. 4.1

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.

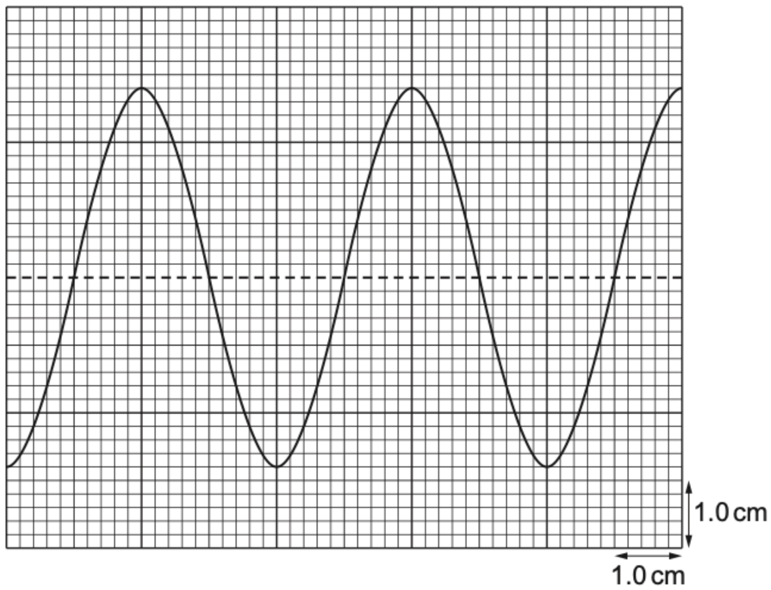

Fig. 4.2

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

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]

ON22/21/Q4

10 **(a)** Polarisation is a phenomenon associated with light waves but not with sound waves.

(i) State the meaning of polarisation.

....

....

.... [1]

(ii) State why light waves can be plane polarised but sound waves cannot.

....

....

.... [1]

(b) Two polarising filters A and B are positioned so that their planes are parallel to each other and perpendicular to a central axis line XY, as shown in Fig. 4.1.

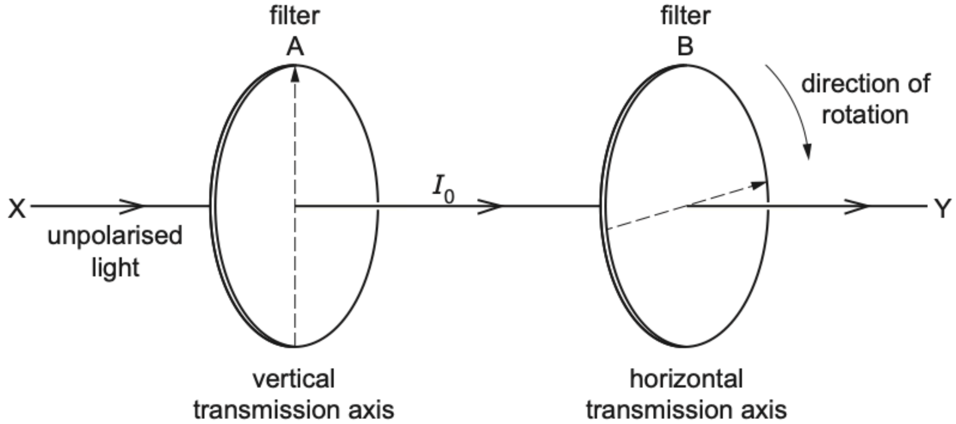

Fig. 4.1

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The transmission axis of filter A is vertical and the transmission axis of filter B is horizontal.

Unpolarised light of a single frequency is directed along the line XY from a source positioned at X. The light emerging from filter A is vertically plane polarised and has intensity I_0.

Filter B is rotated from its starting position about the line XY, as shown in Fig. 4.1.

After rotation, the intensity of the light emerging from filter B is $\frac{1}{4} I_0$.

Calculate the angle of rotation of filter B from its starting position.

angle of rotation = ... ° [3]

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11 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.

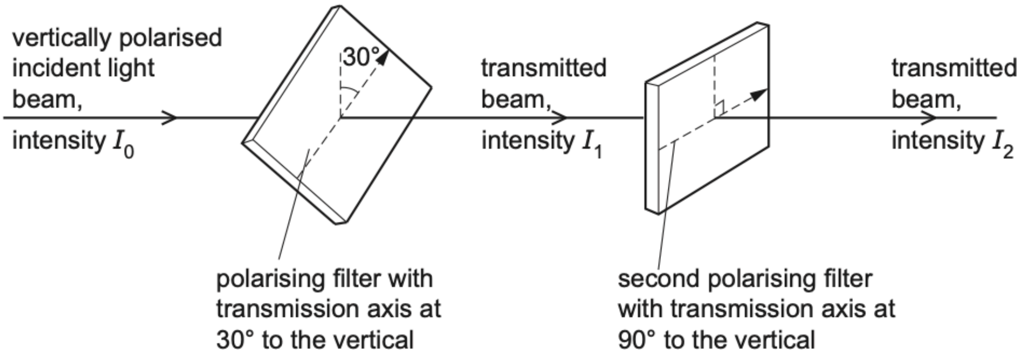

Fig. 5.2

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 $\frac{I_1}{I_0}$

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

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

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

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12 **(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.

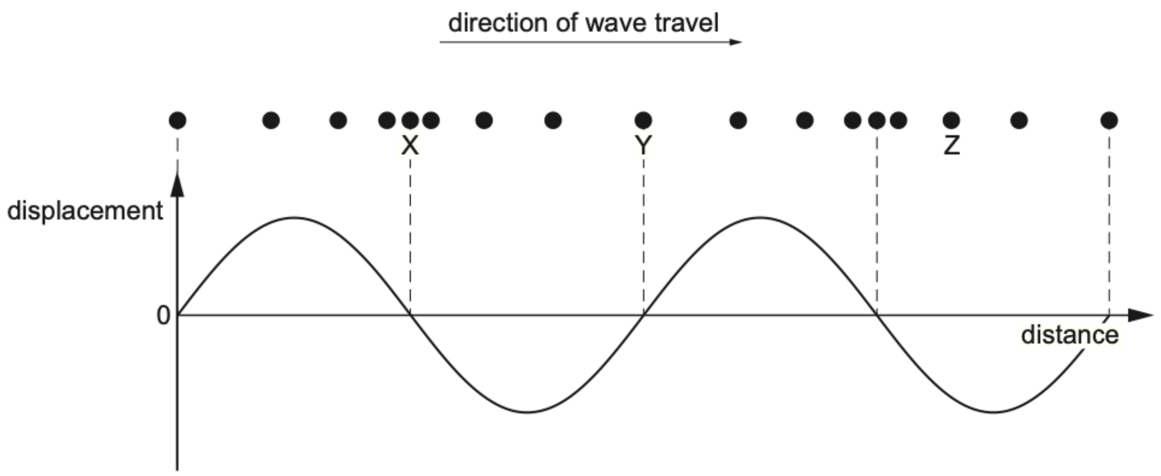

Fig. 4.1

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

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(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]

MJ22/23/Q5

13 (a) Parallel light rays from the Sun are incident normally on a magnifying glass. The magnifying glass directs the light to an area A of radius r, as shown in Fig. 5.1.

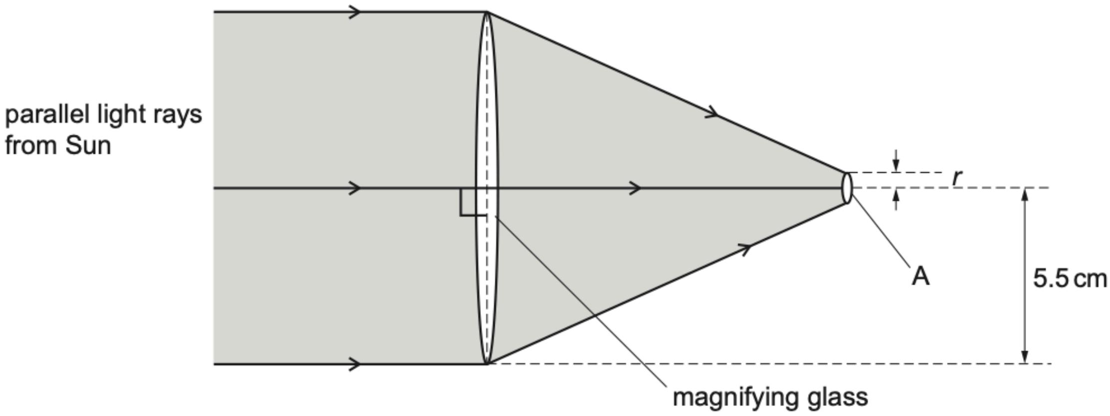

Fig. 5.1 (not to scale)

The magnifying glass is circular in cross-section with a radius of 5.5 cm. The intensity of the light from the Sun incident on the magnifying glass is 1.3 kW m^{-2}.

Assume that all of the light incident on the magnifying glass is transmitted through it.

(i) Calculate the power of the light from the Sun incident on the magnifying glass.

power = ... W [2]

(ii) The value of r is 1.5 mm.

Calculate the intensity of the light on area A.

intensity = ... W m^{-2} [1]

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(b) A laser emits a beam of electromagnetic waves of frequency 3.7×10^{15} Hz in a vacuum.

(i) Show that the wavelength of the waves is 8.1×10^{-8} m.

[2]

(ii) State the region of the electromagnetic spectrum to which these waves belong.

.... [1]

March22/22/Q5

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

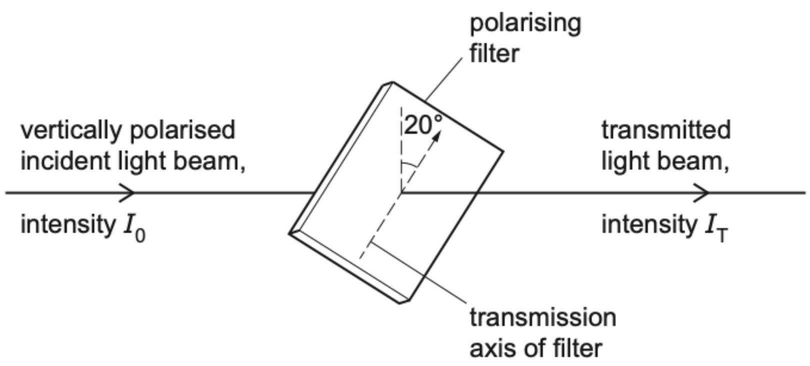

Fig. 5.1

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 $\dfrac{I_T}{I_0}$, calculate the ratio

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

Show your working.

ratio = ... [3]

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(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 = ... ° [1]

ON21/21/Q4

15 **(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.

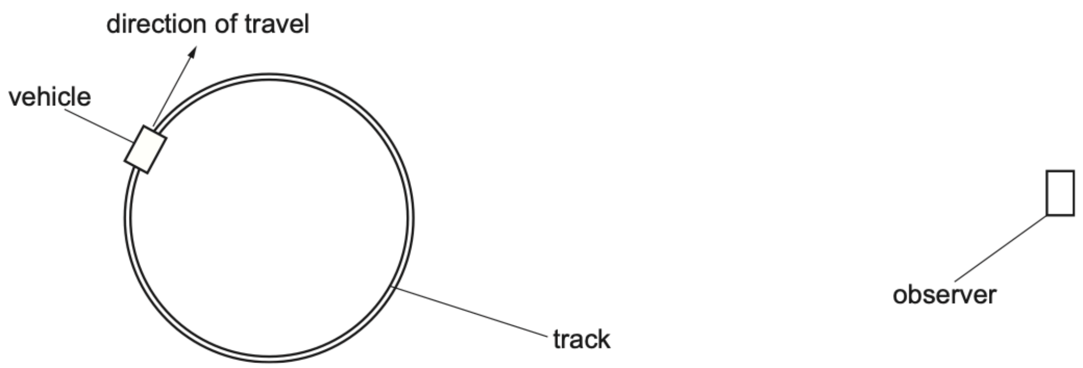
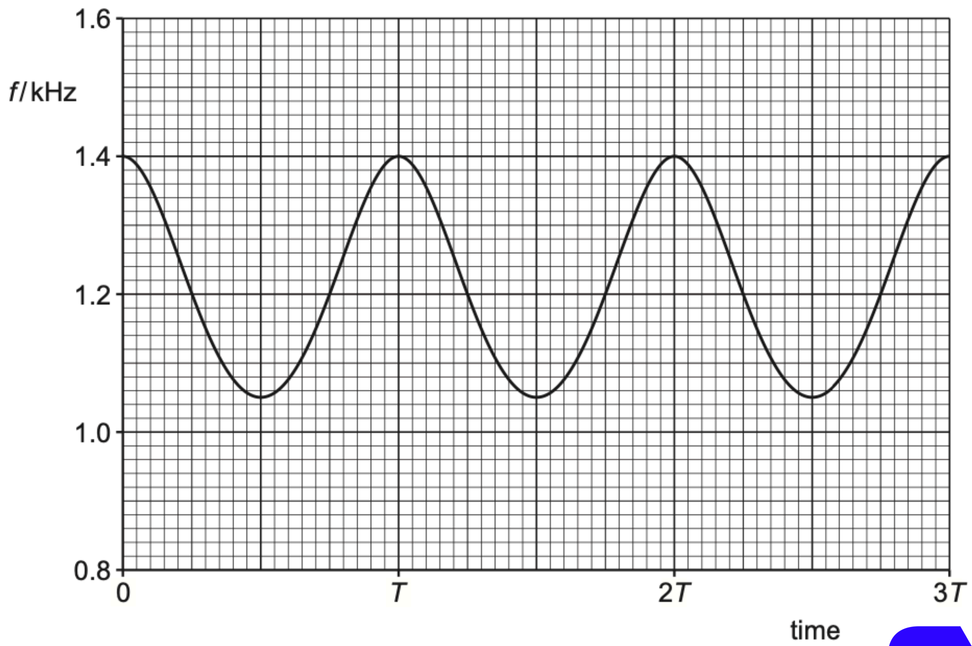


Fig. 4.1 (not to scale)

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.



(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 $320\,\mathrm{m\,s^{-1}}$.

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

speed = ... $\mathrm{m\,s^{-1}}$ [3]

[Total: 9]

ON21/22/Q4

16 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.

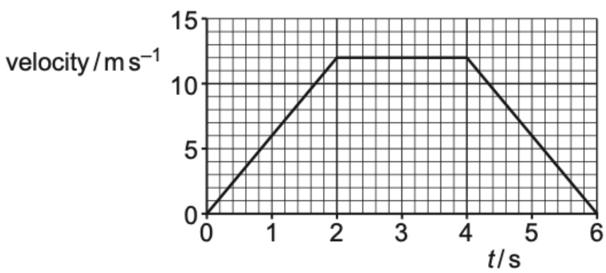


Fig. 4.1

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

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(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]

(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]

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17 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.

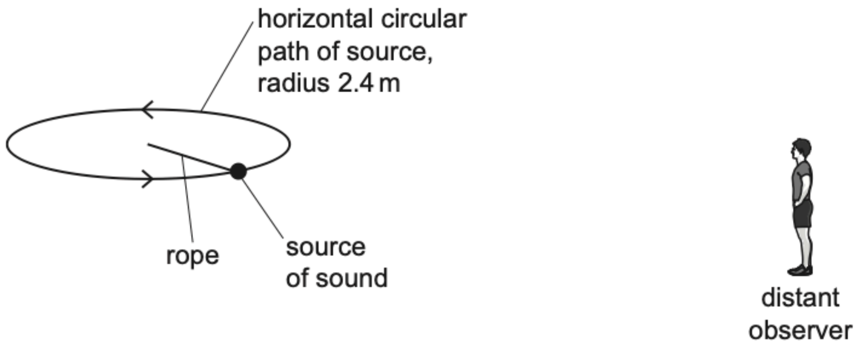

Fig. 5.1 (not to scale)

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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18 **(a)** A sound wave is detected by a microphone that is connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

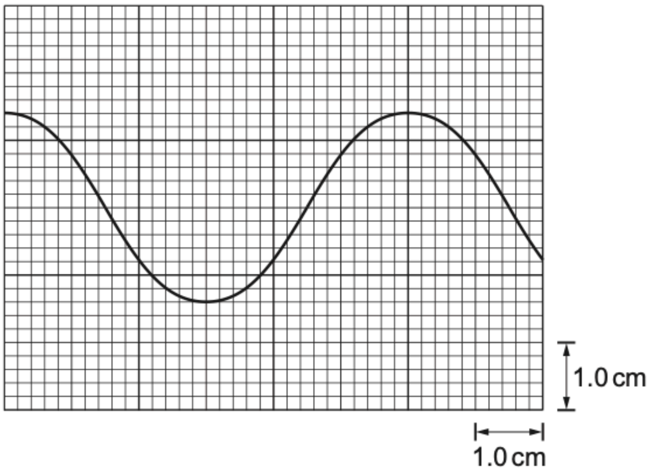

Fig. 5.1

The time-base setting of the CRO is $2.0 \times 10^{-5}\,\text{s cm}^{-1}$.

(i) Determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The intensity of the sound wave is now doubled. The frequency is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

On Fig. 5.1, sketch the new trace shown on the screen. [2]

(iii) The time-base is now switched off.

Describe the trace seen on the screen.

....

.... [1]

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19 **(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.

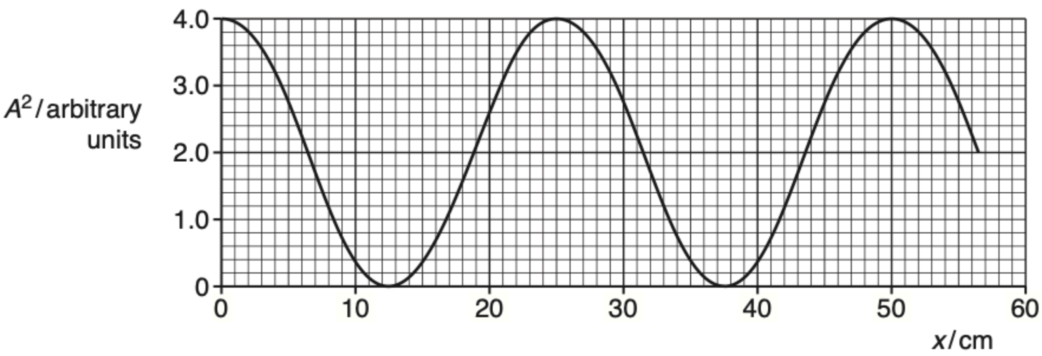

Fig. 4.1

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

phase difference = ... ° [1]

(ii) The speed of the sound in the air is $330\,\text{m}\,\text{s}^{-1}$. 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]

[Total: 7]

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20 **(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.

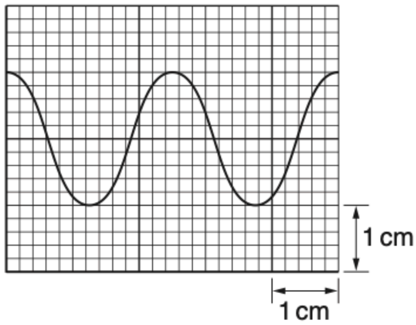

Fig. 4.1

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.

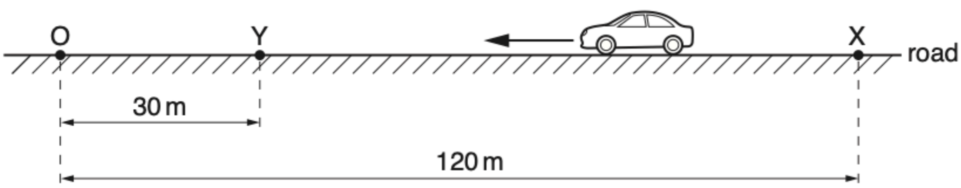

Fig. 4.2

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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]

MJ17/21/Q5

21 **(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 $340\,\mathrm{m\,s^{-1}}$.

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

v = ... $\mathrm{m\,s^{-1}}$

direction ....
[3]

[Total: 4]

MJ17/22/Q5

22 **(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.

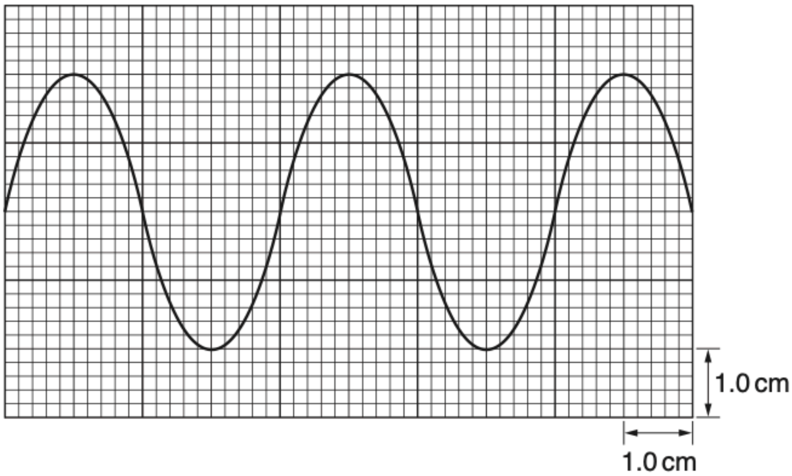

Fig. 5.1

The *y*-axis setting is $5.0\,\text{mV}\,\text{cm}^{-1}$.
The time-base setting is $0.50\,\text{ms}\,\text{cm}^{-1}$.

(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]

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1 a	• speed = distance / time • wavelength = distance between successive crests/troughs/in phase points • frequency = number of crests/troughs/oscillations per unit time so wavelength × frequency (= distance per unit time) = velocity	**B2**	Allow 's' or 'v' for speed, 'd' or 'x' for distance and 't' or 'T' for time Allow 'λ' for wavelength Allow 'distance per oscillation/ crest/ trough' Allow 'f' for frequency Any two of the bulleted statements for 1 mark. All three bulleted statements and final conclusion for 2 marks.
5bi	T = 4×10^{-3} (s) $f = 1 / T = 1 / 0.004$ f = 250 Hz	**C1** **A1**	Allow T = 4 (ms)
5bii	$f_o = f_s / (v - v_s)$ 250 = 236 (v – 20) v = (250 × 20) / (250 – 236) = 360 m s^{-1}	 **C1** **A1**	No mark for symbol formula as given in formula sheet Any subject ecf f_o from (b)(i) 357 m s^{-1}
6ai	I = 1.3 / 1.1 = 1.2 A	**A1**	1.18

2 a	sound waves are longitudinal/not transverse (and only transverse waves can be polarised)	**B1**	**Allow** a full description of the oscillations in a sound wave compared to the direction of propagation.
5bi	A periodic curve of at least one period with minimum 0 and maximum I_0 Smooth continuous sin^2 curve Peaks at 90° and 270° **and** troughs at 0, 180° and 360°	**B1** **B1** **B1**	 **Allow** a cos^2 curve
5bii	$I \propto$ amplitude^2 $I = I_0 \cos^2 \theta$ At α = 20° the angle between the planes of polarisation of light and filter is 70° (or 110°) $I = I_0 \cos^2 70$ **or** $I = I_0 \cos^2 110$ ($I = 0.12\, I_0$) amplitude = 0.34 A_0	**C1** **C1** **C1** **C1** **A1**	This first two C1 marks are scored independently of each other $A = A_0 \cos\theta$ scores the first 2 C1 marks **Allow** $I = I_0 \sin^2 20$ **or** $I = I_0 \sin^2 160$ The third C1 mark implies the second C1 mark, but not the first. Allow $A = A_0 \cos 70$ or $A = A_0 \cos 110$ (0.342) **Special case:** use of α = 20° cannot scored the third mark, but allow ECF for the 4th mark. This gives I = 0.88 I_0 and A = 0.94 A_0

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3 (a)	$T = 5.8 \times 5.0 \times 10^{-4}$ $= 2.9 \times 10^{-3}$	**C1**
	$\lambda = vT$ or $v = f\lambda$ <u>and</u> $f = 1 / T$	**C1**
	$\lambda = 330 \times 2.9 \times 10^{-3}$ or $\lambda = 330 / 345$ $= 0.96$ m	**A1**
5(b)	(loudspeaker) moves away (from the microphone)	**B1**
	at an increasing speed / whilst accelerating	**B1**

4 (a)	vibrations / oscillations (of the particles / wave) are perpendicular to the direction (of the propagation of energy)	**B1**
5(b)	infrared	**B1**
5(c)	$T = 6 \times 5.0 \times 10^{-15}$ $T = 3.0 \times 10^{-14}$	**C1**
	$\lambda = c\,T$ **or** $\lambda = c / f$ **and** $f = 1 / T$	**C1**
	$\lambda = 3.0 \times 10^{8} \times 3.0 \times 10^{-14}$ **or** $\lambda = 3.0 \times 10^{8} / 3.33 \times 10^{13}$ $= 9.0 \times 10^{-6}$ m	**A1**

5 (a)	sketch: approximately horizontal line above horizontal dashed line from $t = 0$ to $t = t_1$ **and** approximately horizontal line below horizontal dashed line from $t = t_1$ to $t = t_2$	**A1**
5(b)	$I = P / A$	**C1**
	$A = \pi \times 0.028^2$ **or** $\pi \times 2.8^2$ ($= 2.46 \times 10^{-3}$ **or** 24.6)	**C1**
	$P = 4.7 \times 10^{-3} \times 2.46 \times 10^{-3}$ $= 1.2 \times 10^{-5}$ W	**A1**

6 a)(i)	light intensity has maximum value at 0°, 180°, 360° and zero intensity at 90°, 270°	**M1**
	'sinusoidally-shaped' curve	**A1**
5(a)(ii)	$4.2 = 7.6 \cos^2\theta$	**C1**
	$\theta = 42°$	**A1**

7 (a)	$291 = 251 \times 340 / (340 - v_{(s)})$	**C1**
	$v_s = 47$ m s^{-1}	**A1**
6(b)(i)	$I \propto A^2$	**B1**
6(b)(ii)	sketch: line starts at (1.0, 1.0)	**B1**
	approximately straight line drawn with negative gradient and line ends at (4.0, 0.25)	**B1**

8 a)(i)	(they are) perpendicular	**B1**
5(a)(ii)	(they are) parallel	**B1**
5(c)(i)	$(I =)\ 8.5 \times \cos^2 35° = 5.7$ (W m^{-2})	**A1**
5(c)(ii)	$5.2 = 5.7 \cos^2\theta$ $(\theta = 17°)$	**C1**
	$\alpha = 35° + 17°$ $= 52°$	**A1**

9)	the number of wavefronts/crests/troughs passing a fixed point per unit time **or** the number of oscillations per unit time (of source / point on wave / particle of medium)	**B1**
4(b)(i)	$T = 4 \times 0.50 \times 10^{-3}$ $(= 2.0 \times 10^{-3}$ s)	**C1**
	$f = 1 / 2.0 \times 10^{-3}$ = 500 Hz	**A1**
4(b)(ii)	amplitude = 2.8×0.20 = 0.56 V	**A1**
4(c)	period same as original trace	**B1**
	sinusoidal wave of constant amplitude less than 2.8 cm throughout	**M1**
	amplitude 1.4 cm	**A1**

10 'a)(i)	oscillations are in a single direction, which is perpendicular to the direction of propagation (of the wave) **or** oscillations are in a single plane, which contains the direction of propagation (of the wave)	**B1**
4(a)(ii)	light waves are transverse **and** sound waves are longitudinal	**B1**
4(b)	$I = I_0 \cos^2\theta$	**C1**
	$\cos^2\theta = 1/4$ so $\cos\theta = 1/2$ $\theta = 60°$ or $120°$ or $240°$ or $300°$	**C1**
	angle of rotation = (120° – 90°) or (240° – 90°) or (300° – 90°) = 30° or 150° or 210° or 330°	**A1**

11 (c)(i)	$I_1 / I_0 = \cos^2 30°$	**C1**
	= 0.75	**A1**
5(c)(ii)	$I_2 / I_1 = \cos^2 60°$ $I_2 / I_0 = \cos^2 30° \times \cos^2 60°$ **or** $0.75 \times \cos^2 60°$	**C1**
	= 0.19	**A1**

12 (a)(i)	circles drawn around any two particles with seven (uncircled) particles in between	**A1**
4(a)(ii)	curve has an initial negative displacement and initial amplitude same as original curve	**B1**
	curve has same amplitude as original curve throughout	**B1**
	curve has same wavelength as original curve throughout, with constant (non-zero) phase difference	**B1**
4(a)(iii)	(to the) right / rightwards	**A1**
4(b)	$\lambda = 2 \times 0.19$ = 0.38 m	**C1**
	$v = f\lambda$	**C1**
	$v = (16 \times 10^3) \times 0.38$ $v = 6100$ m s^{-1}	**A1**
4(c)	$I \propto A^2$	**C1**
	$I = (1/2)^2 I_0$ intensity = $0.25\, I_0$	**A1**

13

5(a)(i)	power = intensity × area	**C1**
	= $1.3 \times 10^3 \times (\pi \times 0.055^2)$ = 12 W	**A1**
5(a)(ii)	intensity = power / area = $12 / (\pi \times 0.0015^2)$ = $1.7 \times 10^6\ \text{W m}^{-2}$	**A1**
5(b)(i)	(λ =) v / f **or** c / f	**C1**
	(λ =) $3.0 \times 10^8 / 3.7 \times 10^{15} = 8.1 \times 10^{-8}$ (m)	**A1**
5(b)(ii)	ultraviolet	**A1**

14

5(c)(i)	$I \propto A^2$	**B1**
	$I_T / I_0 = \cos^2 20°$ or $A_T / A_0 = \cos 20°$	**C1**
	ratio = 0.94	**A1**
5(c)(ii)	angle = 140°	**A1**

15

4(a)	oscillations (of particles) are parallel to (the direction of) energy transfer	**B1**
4(b)(i)	(frequency varies as) vehicle moves relative to (stationary) observer	**C1**
	(vehicle) moving towards (observer) gives higher (observed) frequency (than 1.2 kHz) <u>and</u> (vehicle) moving away (from observer) gives lower (observed) frequency (than 1.2 kHz)	**A1**
4(b)(ii)	Doppler effect	**B1**
4(b)(iii)	position of vehicle labelled 'X' at top (12 o'clock) position on track	**B1**
4(b)(iv)	position of vehicle labelled 'Y' at right-hand edge (3 o'clock) position on track	**B1**
4(c)	maximum frequency = 1.40 (kHz) **or** 1.40×10^3 (Hz)	**C1**
	$1.40 = (1.2 \times 320) / (320 - v)$	**C1**
	$v = 46\ \text{m s}^{-1}$	**A1**
	or	
	minimum frequency = 1.05 (kHz) **or** 1.05×10^3 (Hz)	**(C1)**
	$1.05 = (1.2 \times 320) / (320 + v)$	**(C1)**
	$v = 46\ \text{m s}^{-1}$	**(A1)**

16

4(a)(i)	decrease(s)	**B1**
4(a)(ii)	increase(s)	**B1**
4(b)	$f_o = f_s v / (v + v_s)$ = $925 \times 338 / (338 + 12)$	**C1**
	= 893 Hz	**A1**
4(c)	distance = $(½ \times 2 \times 12) + (2 \times 12)$ (= 36 m)	**C1**
	time taken = 36 / 338 = 0.11 s	**A1**

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17 5(a)	$f_o = f_s v / (v + v_s)$		C1
	$f_o = 951 \times 330 / (330 + 12)$		
	$= 918$ Hz		A1
5(b)	$t = d / 12$		C1
	$= (\pi \times 2.4) / 12$		
	$= 0.63$ s		A1

18 5(a)(i)	$T = 2.0 \times 10^{-5} \times 6.0$ $(= 1.2 \times 10^{-4}$ s)
	$f = 1 / (2.0 \times 10^{-5} \times 6.0)$
	$= 8300$ Hz
5(a)(ii)	new trace shows the same period
	new trace shows amplitude of 10 small squares
5(a)(iii)	(trace is a) vertical line

19 (a)	vibration(s)/oscillation(s) (of particles) parallel to direction of propagation of energy	B1
4(b)(i)	phase difference = 180°	A1
4(b)(ii)	$v = f\lambda$	C1
	$\lambda/2 = 25$ (cm) or 0.25 (m)	C1
	$f = 330/0.50$	A1
	$= 660$ Hz	
4(b)(iii)	(readings from graph =) 2.6 <u>and</u> 4.0	C1
	ratio $= (2.6/4.0)^{1/2}$	A1
	$= 0.81$	

20 (a)	displacement of particles/vibration(s)/oscillation(s) is parallel to/along the direction of energy/propagation	B1
4(b)	period = 1 / 800 (= 1.25×10^{-3} s)	C1
	time-base setting $= 1.25 \times 10^{-3} / 2.5$	C1
	$= 5.0 \times 10^{-4}$ s cm^{-1}	A1
4(c)(i)	$I \propto A^2$	C1
	$(I_X / I_Y =)$ $[r_Y / r_X]^2 = [A_X / A_Y]^2$	C1
	ratio $A_Y / A_X = 120 / 30$	A1
	$= 4.0$	
4(c)(ii)	**1.** $v = f\lambda$	C1
	minimum $\lambda = 330 / (800 + 16) = 0.40$ m	A1
	2. $f_o / f_s = v / (v - v_s)$	C1
	$816 / 800 = 330 / (330 - v_s)$	
	$v_s = 6.5$ m s^{-1}	A1

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21	5(a)	observed frequency is different to source frequency when source moves relative to observer	**B1**
	5(b)	360 = (400 × 340) / (340 ± v)	**C1**
		v = 38 (37.8) m s^{-1}	**A1**
		away (from the observer)	**B1**

22	5(a)	frequency is the number of vibrations/oscillations per unit time **or** the number of wavefronts passing a point per unit time	**B1**
	5(b)	vibrations/oscillation of the air particles are parallel to the direction of it (the direction of travel of the sound wave)	**B1**
	5(c)(i)	T = 2(.0) (ms)	**C1**
		f = 500 Hz	**A1**
	5(c)(ii)	**1.** amplitude increases (time) period decreases **2.** amplitude decreases (time) period increases *any 3 points*	**B3**