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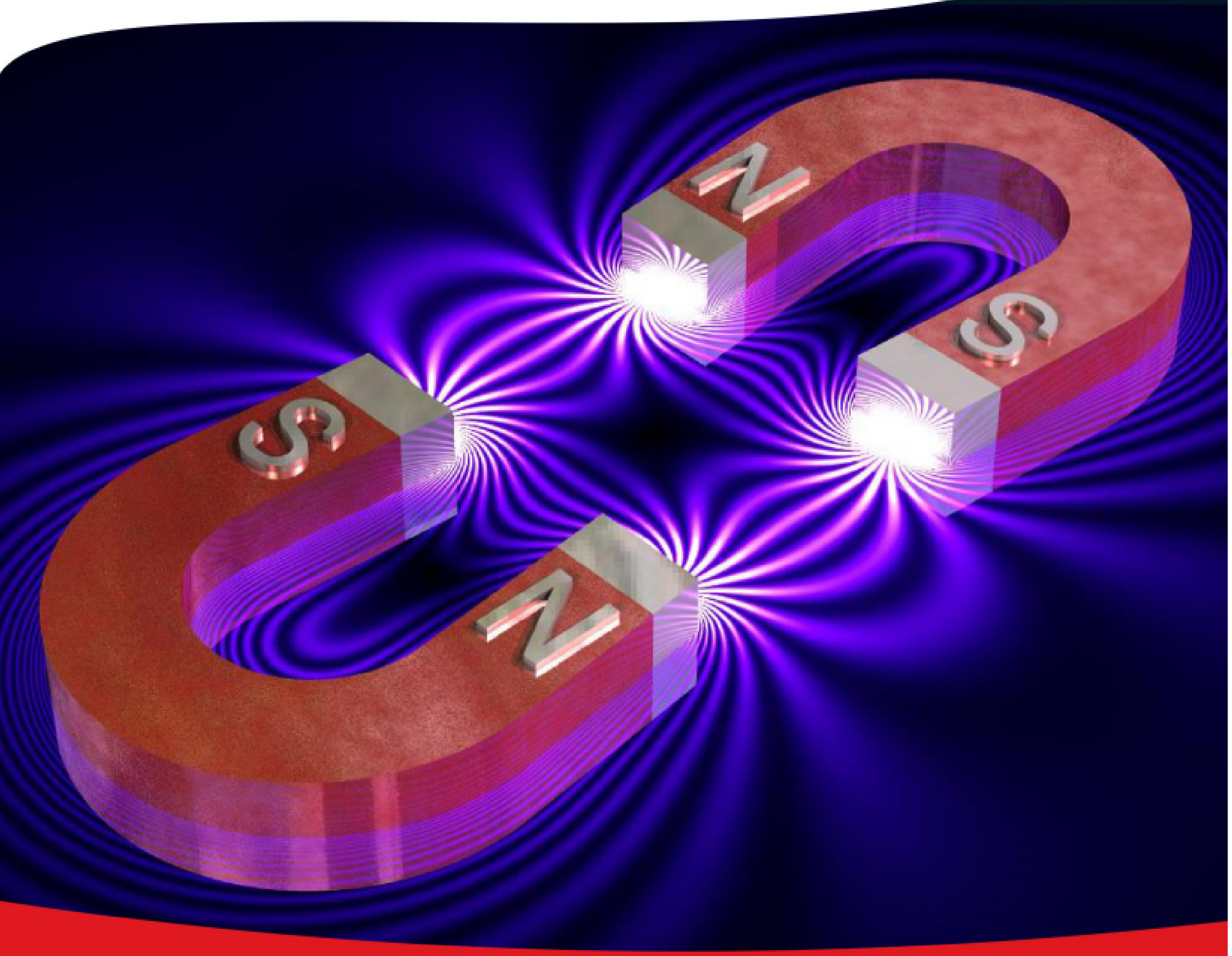
# PHYSICS (9702) P2

TOPIC WISE QUESTIONS + ANSWERS | COMPLETE SYLLABUS

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Chapter 9

# Superposition

## 9.1 Stationary waves

147. 9702_s20_qp_22 Q: 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.

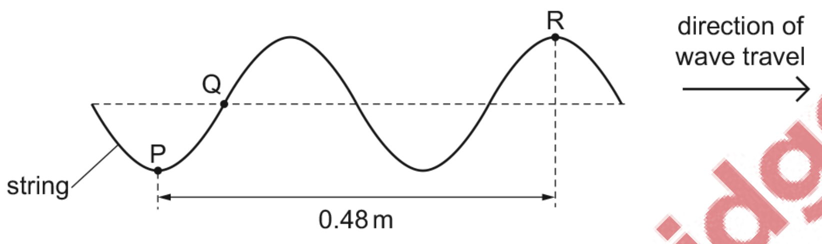


**Fig. 4.1**

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

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

phase difference = ........................................................ ° [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.

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.......................................................................................................................... [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.

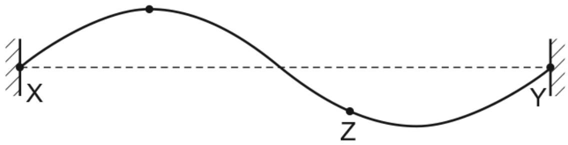


**Fig. 4.2**

**(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.

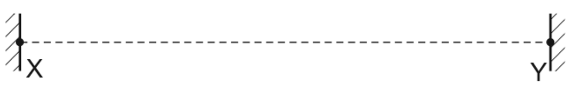


**Fig. 4.3**

[1]

[Total: 11]

148. 9702_w20_qp_21 Q: 6

**(a)** Describe the conditions required for two waves to be able to form a stationary wave.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** A stationary wave on a string has nodes and antinodes. The distance between a node and an adjacent antinode is 6.0 cm.

**(i)** State what is meant by a *node*.

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

**(ii)** Calculate the wavelength of the two waves forming the stationary wave.

wavelength = ...................................................... cm [1]

**(iii)** State the phase difference between the particles at two adjacent antinodes of the stationary wave.

phase difference = ...................................................... ° [1]

[Total: 5]

149. 9702_m18_qp_22 Q: 4

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

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

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

**(b)** The sound from a loudspeaker is detected by a microphone that is connected to a cathode-ray oscilloscope (c.r.o.). Fig. 4.1 shows the trace on the screen of the c.r.o.

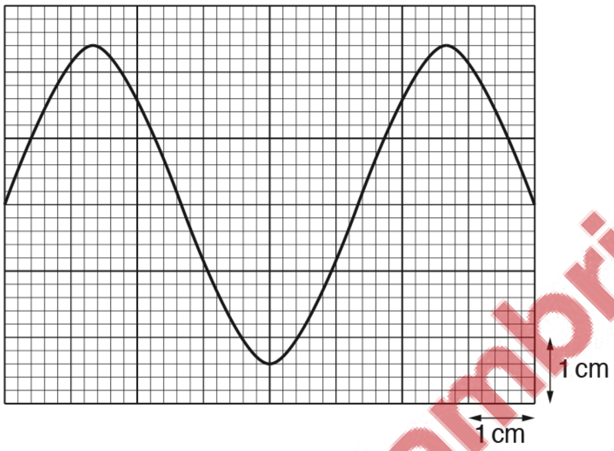


**Fig. 4.1**

In air, the sound wave has a speed of $330\,m\,s^{-1}$ and a wavelength of 0.18 m.

**(i)** Calculate the frequency of the sound wave.

frequency = ..................................................... Hz [2]

**(ii)** Determine the time-base setting, in $s\,cm^{-1}$, of the c.r.o.

time-base setting = ............................................... $s\,cm^{-1}$ [2]

**(iii)** The intensity of the sound from the loudspeaker is now halved. The wavelength of the sound is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

**On Fig. 4.1**, sketch the new trace shown on the screen of the c.r.o. [2]

**(c)** The loudspeaker in **(b)** is held above a vertical tube of liquid, as shown in Fig. 4.2.

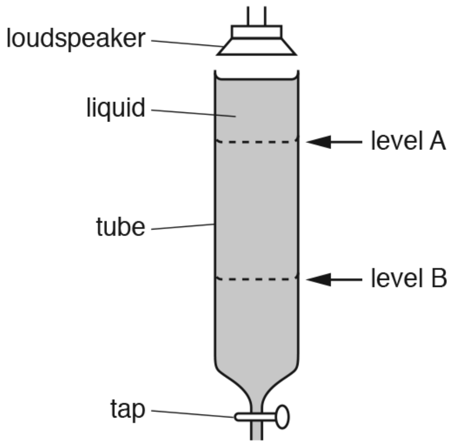


**Fig. 4.2**

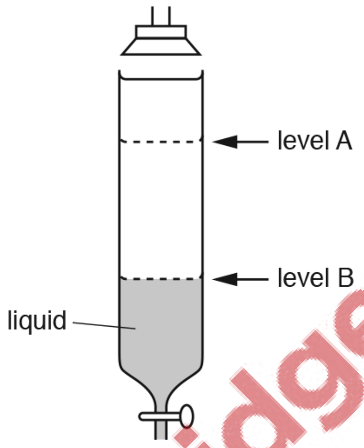


**Fig. 4.3**

A tap at the bottom of the tube is opened so that liquid drains out at a constant rate. The wavelength of the sound from the loudspeaker is 0.18 m. The sound that is heard first becomes much louder when the liquid surface reaches level A. The next time that the sound becomes much louder is when the liquid surface reaches level B, as shown in Fig. 4.3.

**(i)** Calculate the vertical distance between level A and level B.

distance = ..................................................... m [1]

**(ii)** **On Fig. 4.3**, label with the letter N the positions of the nodes of the stationary wave that is formed in the air column when the liquid surface is at level B. [1]

**(iii)** The mass of liquid leaving the tube per unit time is 6.7 g $s^{-1}$. The tube has an internal cross-sectional area of 13 $cm^2$. The density of the liquid is 0.79 g $cm^{-3}$.

Calculate the time taken for the liquid to move from level A to level B.

time = ..................................................... s [2]

[Total: 12]

150. 9702_s18_qp_22 Q: 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.

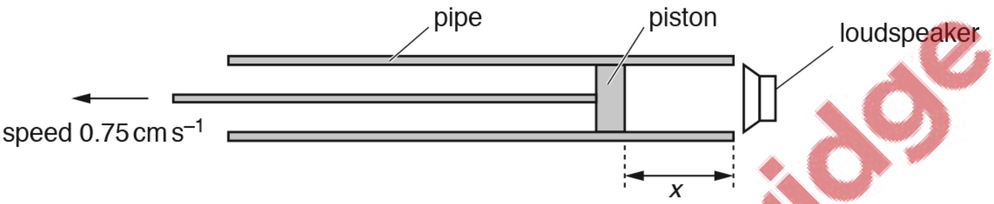


**Fig. 4.1**

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 $0.75\,\text{cm}\,\text{s}^{-1}$.

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

**(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]

151. 9702_w18_qp_23 Q: 4

**(a)** On Fig. 4.1, complete the two graphs to illustrate what is meant by the amplitude *A*, the wavelength $\lambda$ and the period *T* of a progressive wave.

Ensure that you label the axes of each graph.

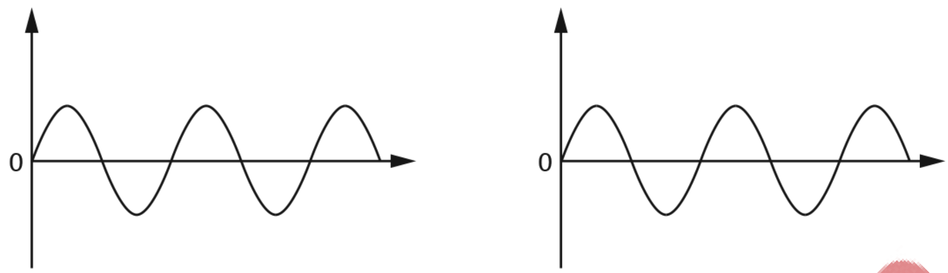


**Fig. 4.1**

[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.

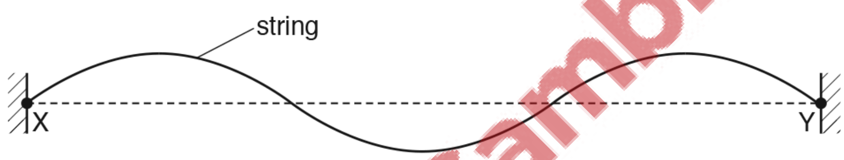


**Fig. 4.2**

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

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

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

**(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 ms),

displacement = .................................................... mm

**2.** the total distance moved by the particle from time *t* to time (*t* + 100 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]

152. 9702_s17_qp_21 Q: 4

**(a)** State the conditions required for the formation of stationary waves.

...................................................................................................................................

...................................................................................................................................

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

**(b)** One end of a string is attached to a vibrator. The string is stretched by passing the other end over a pulley and attaching a load, as illustrated in Fig. 4.1.

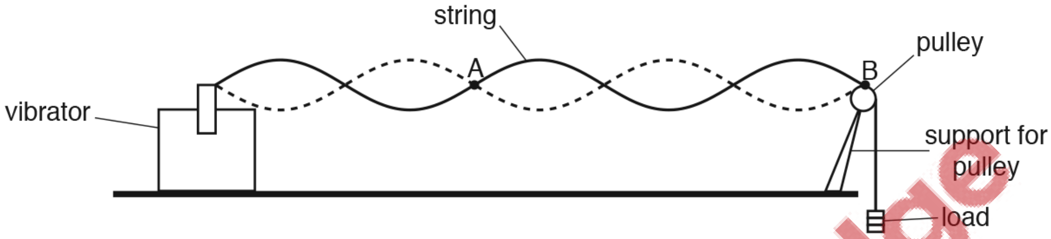


**Fig. 4.1**

The frequency of vibration of the vibrator is adjusted to 250 Hz and a transverse wave travels along the string with a speed of $12\,m\,s^{-1}$. The wave is reflected at the pulley and a stationary wave forms on the string.

Fig. 4.2 shows the string between points A and B at time $t = t_1$.

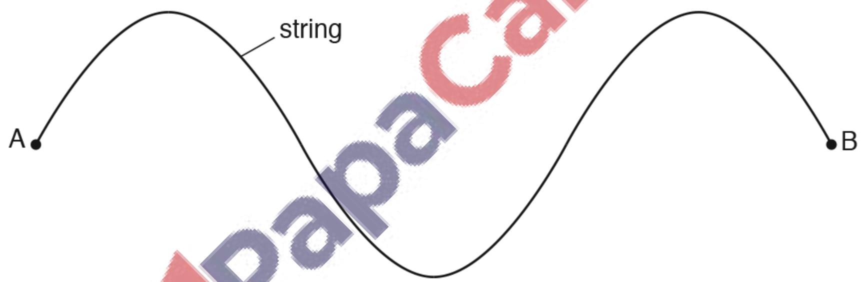


**Fig. 4.2**

At time $t = t_1$ the string has maximum displacement.

**(i)** Calculate the distance AB.

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

**(ii)** On Fig. 4.2, sketch the position of the string between A and B at times

**1.** $t = t_1 + 2.0\,\text{ms}$ (label this line P),

**2.** $t = t_1 + 5.0\,\text{ms}$ (label this line Q).

[3]

[Total: 7]

153. 9702_w17_qp_21 Q: 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.

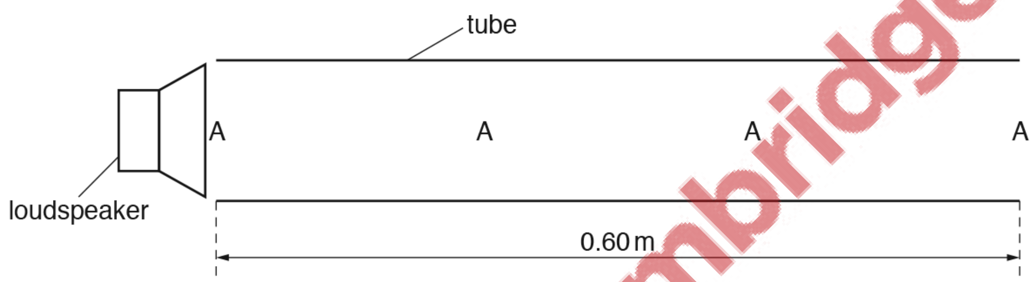


**Fig. 3.1**

The speed of the sound in the tube is $340\,m\,s^{-1}$. 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]

154. 9702_w17_qp_22 Q: 4

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

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

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

**(b)** A horizontal string is stretched between two fixed points X and Y. The string is made to vibrate vertically so that a stationary wave is formed. At one instant, each particle of the string is at its maximum displacement, as shown in Fig. 4.1.

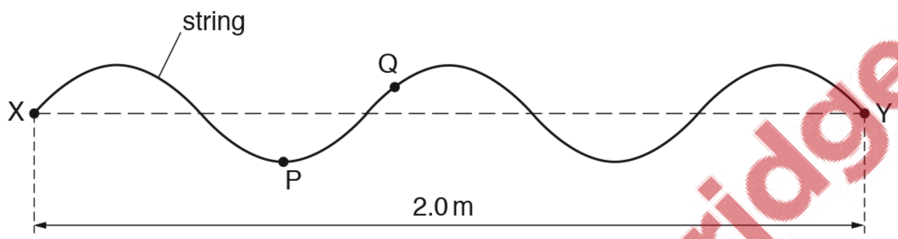


**Fig. 4.1**

P and Q are two particles of the string. The string vibrates with a frequency of 40 Hz. Distance XY is 2.0 m.

**(i)** State the number of antinodes in the stationary wave.

number = ..........................................................[1]

**(ii)** Determine the minimum time taken for the particle P to travel from its lowest point to its highest point.

time taken = ....................................................... s [2]

**(iii)** State the phase difference, with its unit, between the vibrations of particle P and of particle Q.

phase difference = ..........................................................[1]

**(iv)** Determine the speed of a progressive wave along the string.

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

[Total: 8]

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155. 9702_s16_qp_23 Q: 7

**(a)** Apparatus used to produce stationary waves on a stretched string is shown in Fig. 7.1.

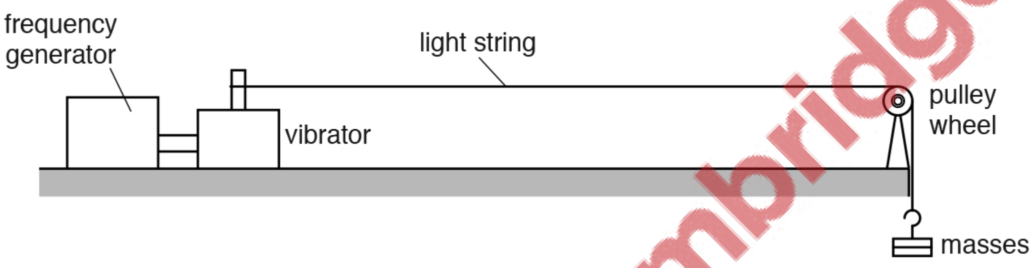


**Fig. 7.1**

The frequency generator is switched on.

**(i)** Describe two adjustments that can be made to the apparatus to produce stationary waves on the string.

1. ..............................................................................................................

..............................................................................................................

2. ..............................................................................................................

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

**(ii)** Describe the features that are seen on the stretched string that indicate stationary waves have been produced.

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

**(b)** The variation with time *t* of the displacement *x* of a particle caused by a progressive wave R is shown in Fig. 7.2. For the same particle, the variation with time *t* of the displacement *x* caused by a second wave S is also shown in Fig. 7.2.

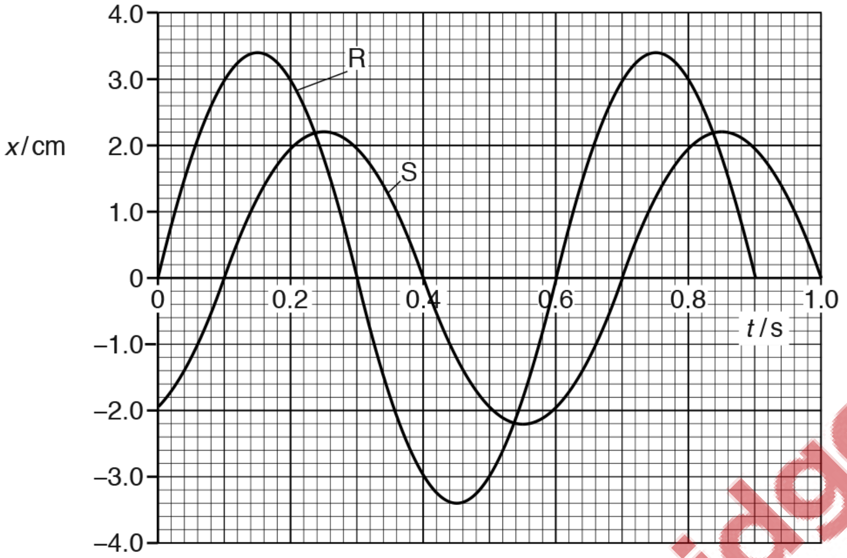


**Fig. 7.2**

**(i)** Determine the phase difference between wave R and wave S. Include an appropriate unit.

phase difference = ........................................................ [1]

**(ii)** Calculate the ratio

$$\frac{\text{intensity of wave R}}{\text{intensity of wave S}}.$$

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

[Total: 6]

156. 9702_s15_qp_22 Q: 6

**(a)** State two differences between progressive waves and stationary waves.

1. ..........................................................................................................................

..........................................................................................................................

2. ..........................................................................................................................

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

**(b)** A source S of microwaves is placed in front of a metal reflector R, as shown in Fig. 6.1.

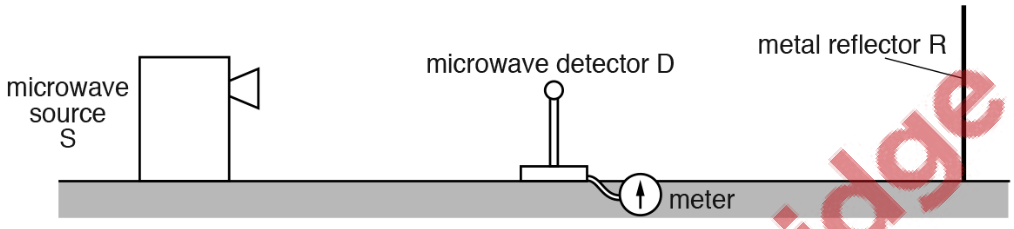


**Fig. 6.1**

A microwave detector D is placed between R and S.

Describe

**(i)** how stationary waves are formed between R and S,

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

.......................................................................................................................... [3]

**(ii)** how D is used to show that stationary waves are formed between R and S,

..........................................................................................................................

..........................................................................................................................

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

**(iii)** how the wavelength of the microwaves may be determined using the apparatus in Fig. 6.1.

..........................................................................................................................

..........................................................................................................................

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

**(c)** The wavelength of the microwaves in **(b)** is 2.8 cm. Calculate the frequency, in GHz, of the microwaves.

frequency = ................................................ GHz [3]

157. 9702_w15_qp_21 Q: 5

**(a)** A progressive wave transfers energy. A stationary wave does not transfer energy. State two other differences between progressive waves and stationary waves.

1. ..........................................................................................................................

..........................................................................................................................

2. ..........................................................................................................................

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

**(b)** A stationary wave is formed on a stretched string between two fixed points A and B. The variation of the displacement $y$ of particles of the string with distance $x$ along the string for the wave at time $t = 0$ is shown on Fig. 5.1.

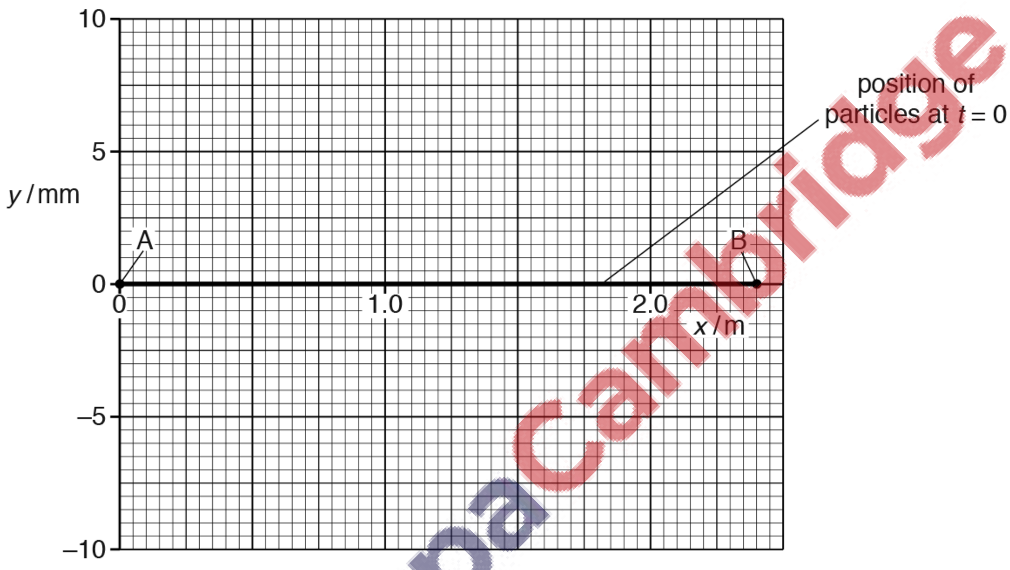


**Fig. 5.1**

The wave has a period of 20 ms and a wavelength of 1.2 m. The maximum amplitude of the particles of the string is 5.0 mm.

**(i)** On Fig. 5.1, draw a line to represent the position of the string at $t = 5.0$ ms. [2]

**(ii)** State the phase difference between the particles of the string at $x = 0.40$ m and at $x = 0.80$ m.

phase difference = ......................... unit .................... [1]

**(iii)** State and explain the change in the kinetic energy of a particle at an antinode between $t = 0$ and $t = 5.0$ ms. A numerical value is not required.

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

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

158. 9702_w15_qp_23 Q: 6

An arrangement for producing stationary waves in air in a tube that is closed at one end is shown in Fig. 6.1.

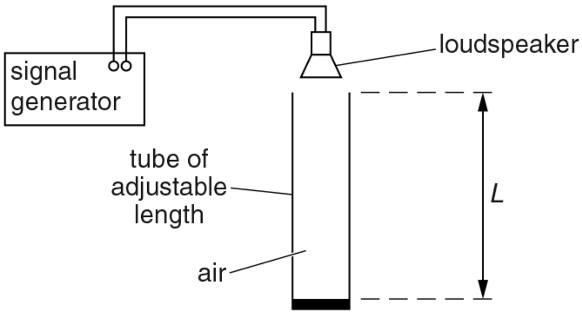


**Fig. 6.1**

A loudspeaker produces sound waves of wavelength 0.680 m in the tube.
For some values of the length $L$ of the tube, stationary waves are formed.

**(a)** Explain how stationary waves are formed in the tube.

..............................................................................................................................................

..............................................................................................................................................

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

**(b)** The length $L$ is adjusted between 0.200 m and 1.00 m.

**(i)** Calculate two values of $L$ for which stationary waves are formed.

$L$ = ................................ m and $L$ = ............................ m [2]

**(ii)** On Fig. 6.2, label the positions of the antinodes with an **A** and the nodes with an **N** for the least value of $L$ for which a stationary wave is formed.

**Fig. 6.2**

[1]

## 9.2 Interference, twosource interference

159. 9702_s20_qp_21 Q: 4

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

.......................................................................................................................................

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

**(ii)** State the principle of superposition.

.......................................................................................................................................

.......................................................................................................................................

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

**(b)** The wavelength of light from a laser is determined using the apparatus shown in Fig. 4.1.

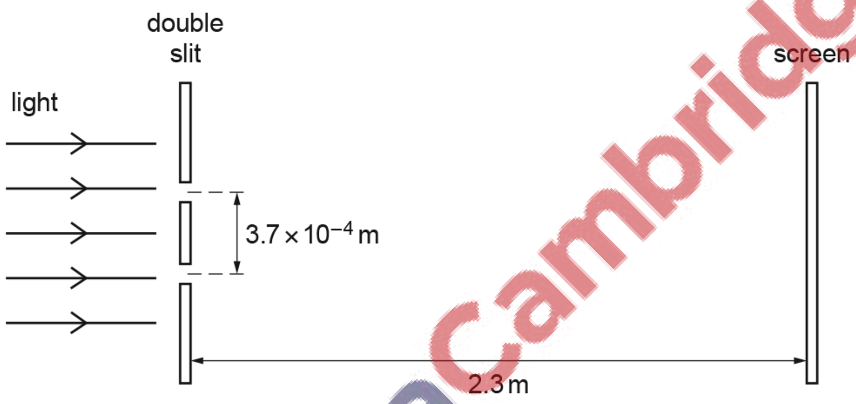


**Fig. 4.1** (not to scale)

The light from the laser is incident normally on the plane of the double slit.
The separation of the two slits is $3.7 \times 10^{-4}$ m. The screen is parallel to the plane of the double slit. The distance between the screen and the double slit is 2.3 m.

A pattern of bright fringes and dark fringes is seen on the screen. The separation of adjacent bright fringes on the screen is $4.3 \times 10^{-3}$ m.

**(i)** Calculate the wavelength, in nm, of the light.

wavelength = ................................................... nm [3]

**(ii)** The intensity of the light passing through each slit was initially the same. The intensity of the light through **one** of the slits is now reduced.

Compare the appearance of the fringes before and after the change of intensity.

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

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

[Total: 8]

160. 9702_s20_qp_23 Q: 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.

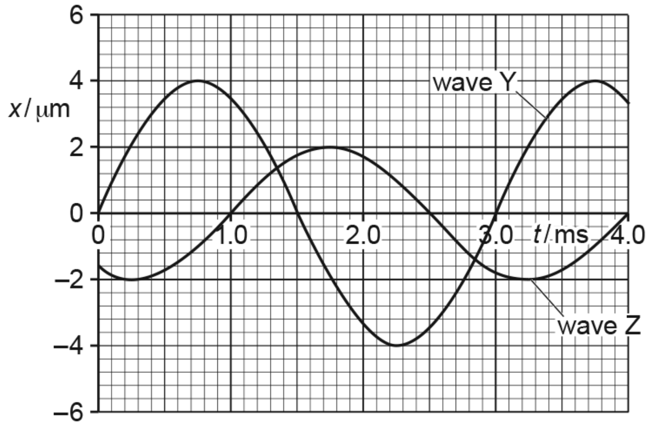


**Fig. 4.1**

**(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]

**(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]

161. 9702_w20_qp_22 Q: 5

Microwaves with the same wavelength and amplitude are emitted in phase from two sources X and Y, as shown in Fig. 5.1.

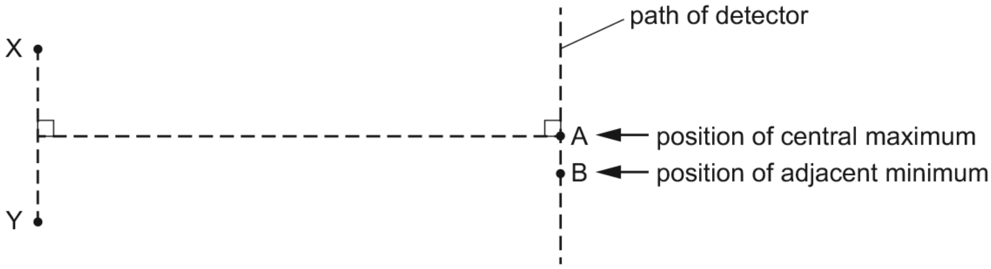


**Fig. 5.1** (not to scale)

A microwave detector is moved along a path parallel to the line joining X and Y. An interference pattern is detected. A central intensity maximum is located at point A and there is an adjacent intensity minimum at point B. The microwaves have a wavelength of 0.040 m.

**(a)** Calculate the frequency, in GHz, of the microwaves.

frequency = ................................................ GHz [3]

**(b)** For the waves arriving at point B, determine:

**(i)** the path difference

path difference = .................................................... m [1]

**(ii)** the phase difference.

phase difference = .......................................................° [1]

**(c)** The amplitudes of the waves from the sources are changed. This causes a change in the amplitude of the waves arriving at point A. At this point, the amplitude of the wave arriving from source X is doubled and the amplitude of the wave arriving from source Y is also doubled.

Describe the effect, if any, on the intensity of the central maximum at point A.

..........................................................................................................................................

..........................................................................................................................................

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

**(d)** Describe the effect, if any, on the positions of the central intensity maximum and the adjacent intensity minimum due to the following separate changes.

**(i)** The separation of the sources X and Y is increased.

..........................................................................................................................................

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

**(ii)** The phase difference between the microwaves emitted by the sources X and Y changes to 180°.

..........................................................................................................................................

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

[Total: 9]

162. 9702_m19_qp_22 Q: 5

**(a)** By reference to two waves, state:

**(i)** the principle of superposition

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

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

**(ii)** what is meant by *coherence*.

..........................................................................................................................

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

**(b)** Two coherent waves P and Q meet at a point in phase and superpose. Wave P has an amplitude of 1.5 cm and intensity $I$. The resultant intensity at the point where the waves meet is $3I$.

Calculate the amplitude of wave Q.

amplitude = .................................................. cm [2]

**(c)** The apparatus shown in Fig. 5.1 is used to produce an interference pattern on a screen.

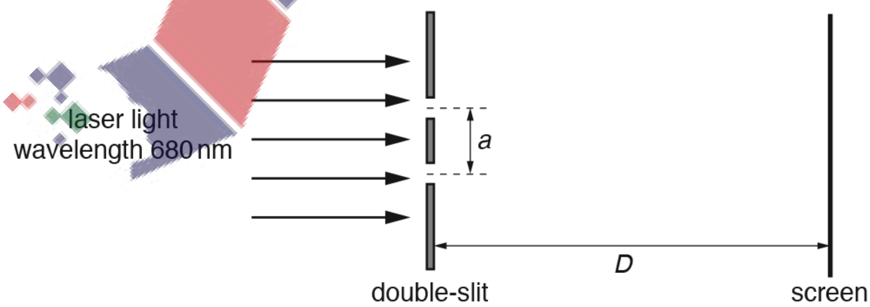


**Fig. 5.1** (not to scale)

Light of wavelength 680 nm is incident on a double-slit. The slit separation is *a*. The separation between adjacent fringes is *x*. Fringes are viewed on a screen at distance *D* from the double-slit.

Distance $D$ is varied from 2.0 m to 3.5 m. The variation with $D$ of $x$ is shown in Fig. 5.2.

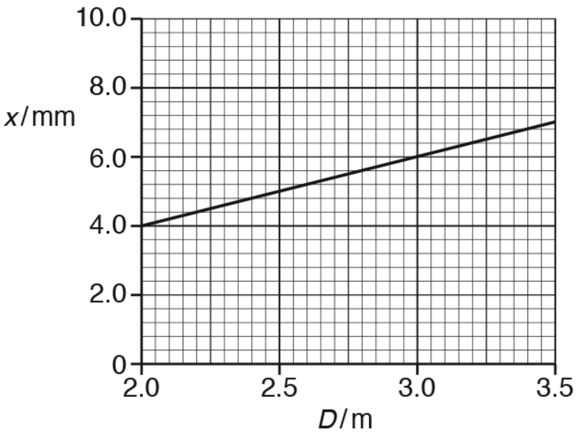


**Fig. 5.2**

**(i)** Use Fig. 5.2 to determine the slit separation $a$.

$a$ = ...................................................... m [3]

**(ii)** The laser is now replaced by another laser that emits light of a shorter wavelength.

On Fig. 5.2, sketch a possible line to show the variation with $D$ of $x$ for the fringes that are now produced. [2]

[Total: 10]

163. 9702_s19_qp_21 Q: 5

**(a)** A loudspeaker oscillates with frequency $f$ to produce sound waves of wavelength $\lambda$. The loudspeaker makes $N$ oscillations in time $t$.

**(i)** State expressions, in terms of some or all of the symbols $f$, $\lambda$ and $N$, for:

**1.** the distance moved by a wavefront in time $t$

distance = ..............................................................

**2.** time $t$.

time $t$ = ..............................................................
[2]

**(ii)** Use your answers in **(i)** to deduce the equation relating the speed $v$ of the sound wave to $f$ and $\lambda$.

[1]

**(b)** The waveform of a sound wave is displayed on the screen of a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

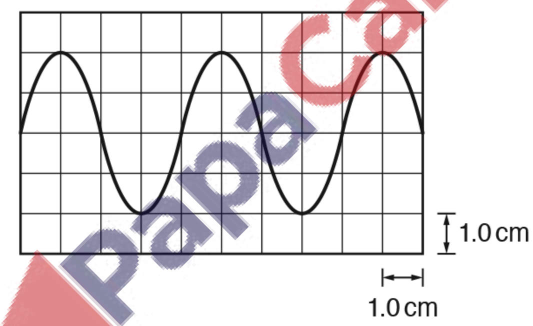


**Fig. 5.1**

The time-base setting is 0.20 ms cm$^{-1}$.

Determine the frequency of the sound wave.

frequency = .................................................... Hz [2]

**(c)** Two sources $S_1$ and $S_2$ of sound waves are positioned as shown in Fig. 5.2.

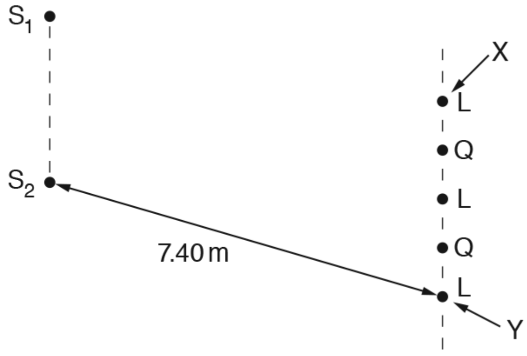


**Fig. 5.2** (not to scale)

The sources emit coherent sound waves of wavelength 0.85 m. A sound detector is moved parallel to the line $S_1S_2$ from a point X to a point Y. Alternate positions of maximum loudness L and minimum loudness Q are detected, as illustrated in Fig. 5.2.

Distance $S_1X$ is equal to distance $S_2X$. Distance $S_2Y$ is 7.40 m.

**(i)** Explain what is meant by *coherent* waves.

..........................................................................................................................................

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

**(ii)** State the phase difference between the two waves arriving at the position of minimum loudness Q that is closest to point X.

phase difference = ...................................................... ° [1]

**(iii)** Determine the distance $S_1Y$.

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

[Total: 9]

164. 9702_w19_qp_21 Q: 5

A ripple tank is used to demonstrate the interference of water waves.
Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 5.1.

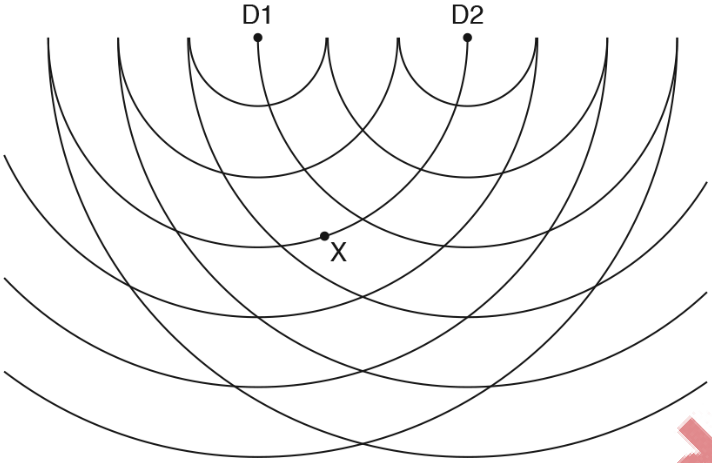


**Fig. 5.1**

The lines in the diagram represent crests. The waves have a wavelength of 6.0 cm.

**(a)** One condition that is required for an observable interference pattern is that the waves must be coherent.

**(i)** Describe how the apparatus is arranged to ensure that the waves from the dippers are coherent.

..........................................................................................................................

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

**(ii)** State one other condition that must be satisfied by the waves in order for the interference pattern to be observable.

..........................................................................................................................

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

**(b)** Light from a lamp above the ripple tank shines through the water onto a screen below the tank. Describe one way of seeing the illuminated pattern more clearly.

..........................................................................................................................

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

**(c)** The speed of the waves is $0.40\,\mathrm{m\,s^{-1}}$. Calculate the period of the waves.

period = ...................................................... s [2]

**(d)** Fig. 5.1 shows a point X that lies on a crest of the wave from D1 and midway between two adjacent crests of the wave from D2.

For the waves at point X, state:

**(i)** the path difference, in cm

path difference = ...................................................... cm [1]

**(ii)** the phase difference.

phase difference = ...................................................... ° [1]

**(e)** On Fig. 5.1, draw **one** line, at least 4 cm long, which joins points where only maxima of the interference pattern are observed. [1]

[Total: 8]

165. 9702_s18_qp_21 Q: 4

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

**(i)** the *period*,

..........................................................................................................................

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

**(ii)** the *wavelength*.

..........................................................................................................................

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

**(b)** Fig. 4.1 shows the variation with time *t* of the displacement *x* of two progressive waves P and Q passing the same point.

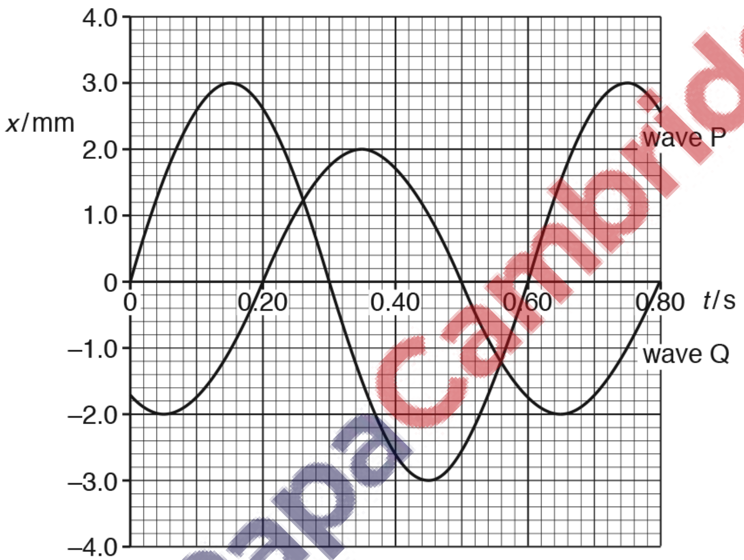


**Fig. 4.1**

The speed of the waves is $20\,cm\,s^{-1}$.

**(i)** Calculate the wavelength of the waves.

wavelength = ........................................................ cm [2]

**(ii)** Determine the phase difference between the two waves.

phase difference = ........................................................ ° [1]

**(iii)** Calculate the ratio

$$\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}.$$

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

**(iv)** The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45$ s.

displacement = .................................................. mm [1]

[Total: 8]

166. 9702_s18_qp_23 Q: 5

**(a)** State the relationship between the intensity and the amplitude of a wave.

..............................................................................................................................

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

**(b)** Microwaves of the same amplitude and wavelength are emitted in phase from two sources P and Q. The sources are arranged as shown in Fig. 5.1.

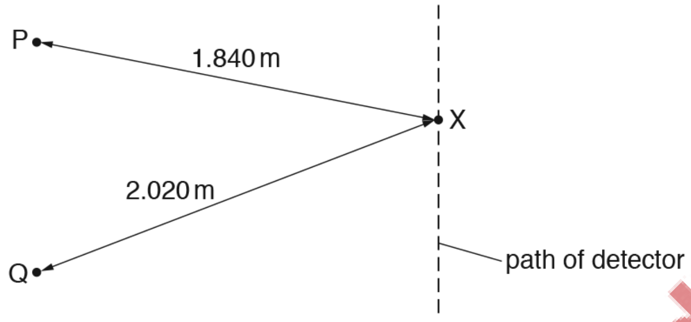


**Fig. 5.1**

A microwave detector is moved along a path that is parallel to the line joining P and Q. A series of intensity maxima and intensity minima are detected.

When the detector is at a point X, the distance PX is 1.840 m and the distance QX is 2.020 m. The microwaves have a wavelength of 6.0 cm.

**(i)** Calculate the frequency of the microwaves.

frequency = ................................................... Hz [2]

**(ii)** Describe and explain the intensity of the microwaves detected at X.

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................[3]

**(iii)** Describe the effect on the interference pattern along the path of the detector due to each of the following separate changes.

**1.** The wavelength of the microwaves decreases.

...................................................................................................................................

...................................................................................................................................

**2.** The phase difference between the microwaves emitted from the sources changes to 180°.

...................................................................................................................................

...................................................................................................................................

[2]

[Total: 8]

167. 9702_w18_qp_21 Q: 4

**(a)** State the principle of superposition.

.......................................................................................................................................

.......................................................................................................................................

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

**(b)** An arrangement for demonstrating the interference of light is shown in Fig. 4.1.

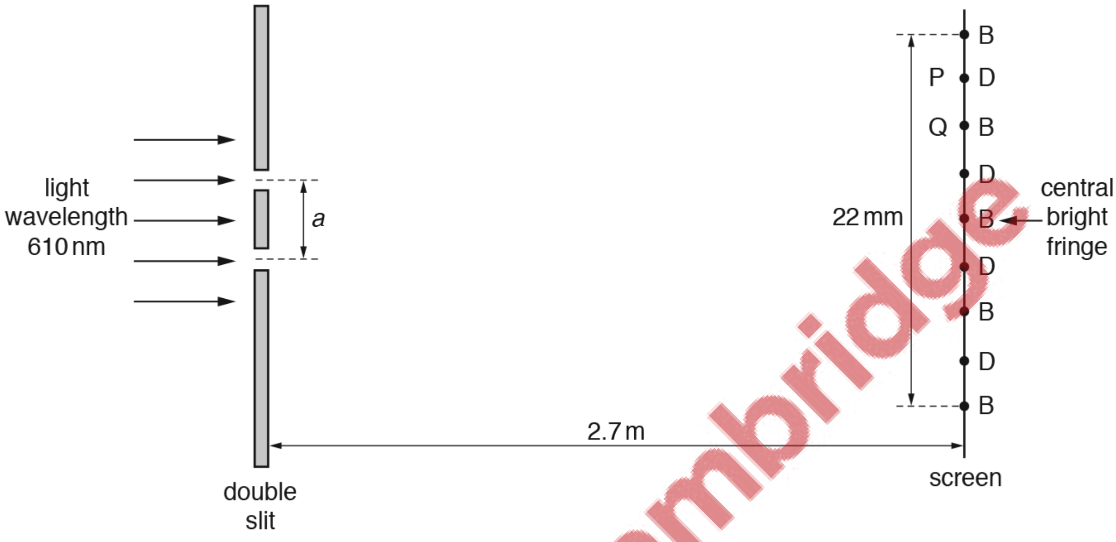


**Fig. 4.1** (not to scale)

The wavelength of the light is 610 nm. The distance between the double slit and the screen is 2.7 m.

An interference pattern of bright fringes and dark fringes is observed on the screen. The centres of the bright fringes are labelled B and centres of the dark fringes are labelled D. Point P is the centre of a particular dark fringe and point Q is the centre of a particular bright fringe, as shown in Fig. 4.1. The distance across five bright fringes is 22 mm.

**(i)** The light waves leaving the two slits are coherent.

State what is meant by *coherent*.

.......................................................................................................................................

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

**(ii)** **1.** State the phase difference between the waves meeting at Q.

phase difference = ........................................................... °

**2.** Calculate the path difference, in nm, of the waves meeting at P.

path difference = ........................................................ nm
[2]

**(iii)** Determine the distance *a* between the two slits.

*a* = ................................................... m [3]

**(iv)** A higher frequency of visible light is now used. State and explain the change to the separation of the fringes.

..........................................................................................................................

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

**(v)** The intensity of the light incident on the double slit is now increased without altering its frequency. Compare the appearance of the fringes after this change with their appearance before this change.

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..........................................................................................................................

..........................................................................................................................

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

[Total: 11]

168. 9702_s17_qp_22 Q: 6

**(a)** Interference fringes may be observed using a light-emitting laser to illuminate a double slit. The double slit acts as two sources of light.

Explain

**(i)** the part played by diffraction in the production of the fringes,

..........................................................................................................................................

..........................................................................................................................................

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

**(ii)** the reason why a double slit is used rather than two separate sources of light.

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** A laser emitting light of a single wavelength is used to illuminate slits $S_1$ and $S_2$, as shown in Fig. 6.1.

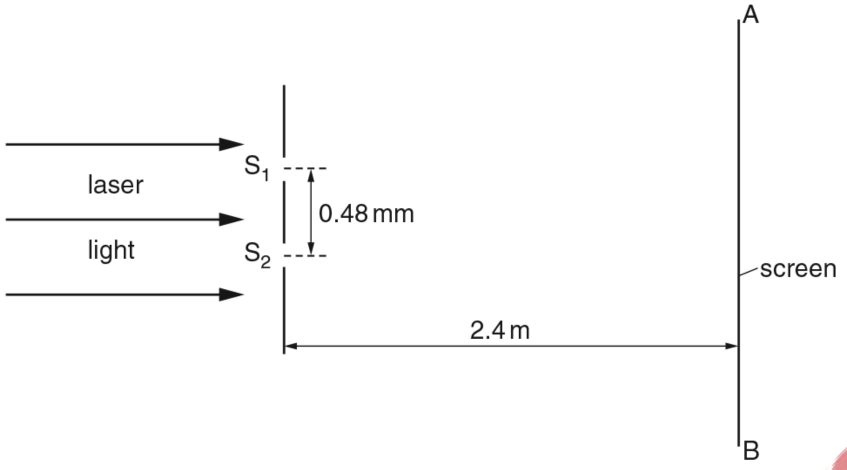


**Fig. 6.1** (not to scale)

An interference pattern is observed on the screen AB. The separation of the slits is 0.48 mm. The slits are 2.4 m from AB. The distance on the screen across 16 fringes is 36 mm, as illustrated in Fig. 6.2.

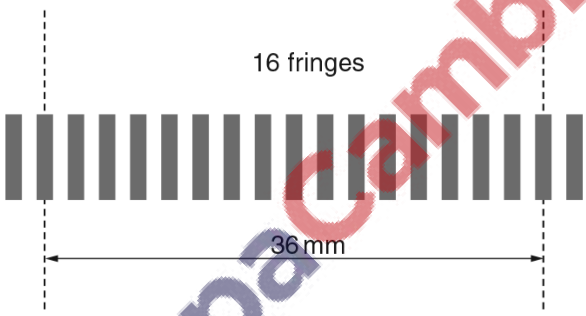


**Fig. 6.2**

Calculate the wavelength of the light emitted by the laser.

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

**(c)** Two dippers $D_1$ and $D_2$ are used to produce identical waves on the surface of water, as illustrated in Fig. 6.3.

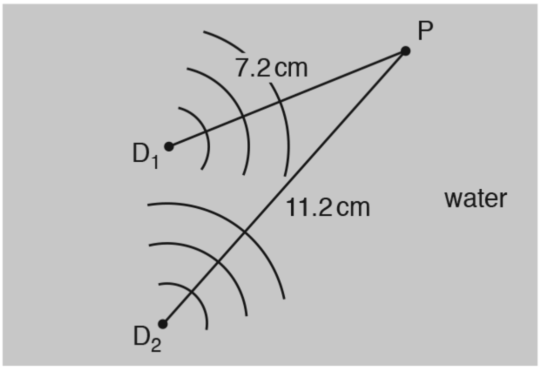


**Fig. 6.3** (not to scale)

Point P is 7.2 cm from $D_1$ and 11.2 cm from $D_2$.

The wavelength of the waves is 1.6 cm. The phase difference between the waves produced at $D_1$ and $D_2$ is zero.

**(i)** State and explain what is observed at P.

..........................................................................................................................................

..........................................................................................................................................

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

**(ii)** State and explain the effect on the answer to **(c)(i)** if the apparatus is changed so that, separately,

**1.** the phase difference between the waves at $D_1$ and at $D_2$ is 180°,

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..........................................................................................................................................

..........................................................................................................................................

**2.** the intensity of the wave from $D_1$ is less than the intensity of that from $D_2$.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

[2]

[Total: 10]

169. 9702_m16_qp_22 Q: 4

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

..........................................................................................................................................

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

**(ii)** State the principle of superposition.

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** Circular water waves may be produced by vibrating dippers at points P and Q, as illustrated in Fig. 4.1.

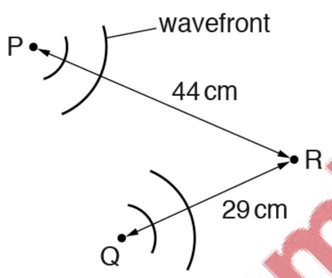


**Fig. 4.1** (not to scale)

The waves from P alone have the same amplitude at point R as the waves from Q alone. Distance PR is 44 cm and distance QR is 29 cm.

The dippers vibrate in phase with a period of 1.5 s to produce waves of speed 4.0 cm $s^{-1}$.

**(i)** Determine the wavelength of the waves.

wavelength = ...................................................... cm [2]

**(ii)** By reference to the distances PR and QR, explain why the water particles are at rest at point R.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

.................................................................................................................................... [3]

**(c)** A wave is produced on the surface of a different liquid. At one particular time, the variation of the vertical displacement *y* with distance *x* along the surface of the liquid is shown in Fig. 4.2.

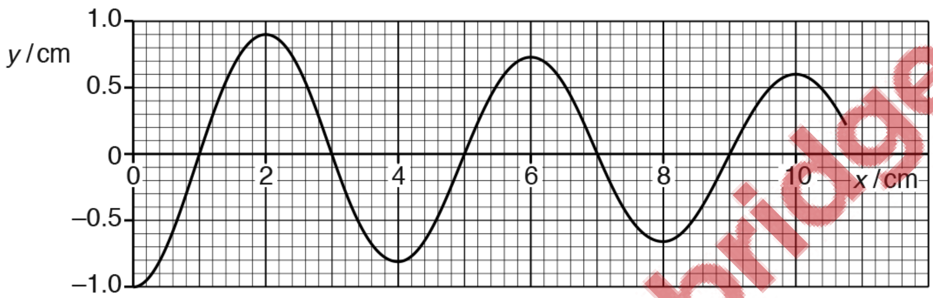


**Fig. 4.2**

**(i)** The wave has intensity $I_1$ at distance $x = 2.0$ cm and intensity $I_2$ at $x = 10.0$ cm.

Determine the ratio

$$\frac{\text{intensity } I_2}{\text{intensity } I_1}.$$

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

**(ii)** State the phase difference, with its unit, between the oscillations of the liquid particles at distances $x = 3.0$ cm and $x = 4.0$ cm.

phase difference = ........................................................ [1]

[Total: 11]

170. 9702_s16_qp_21 Q: 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.

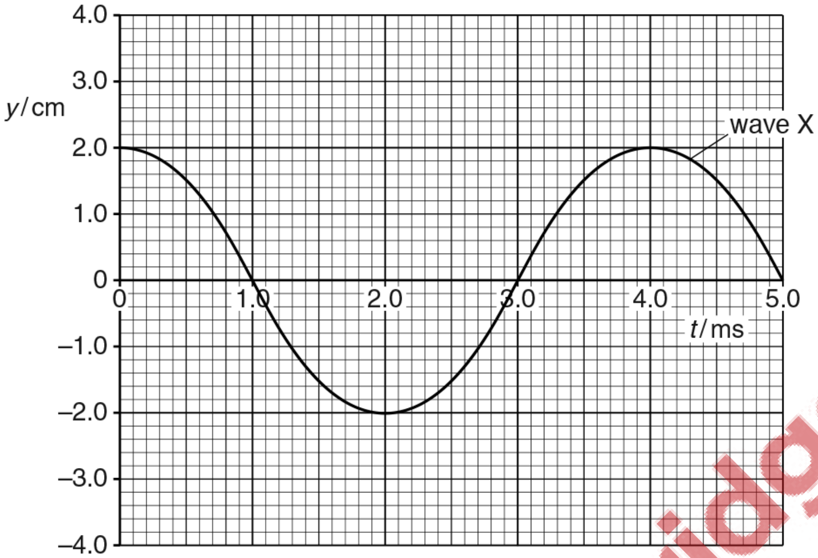


**Fig. 5.1**

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.

[3]

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

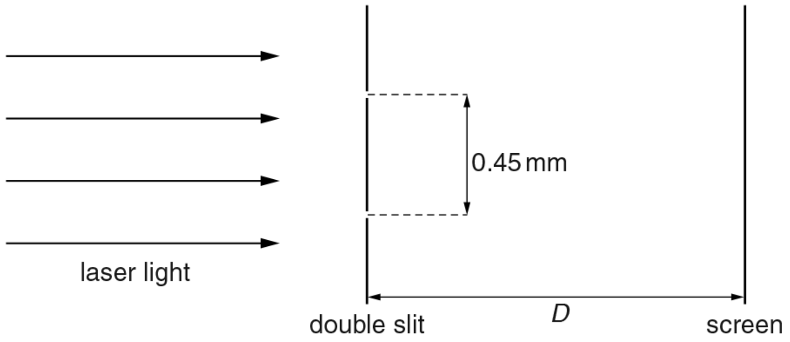


**Fig. 5.2** (not to scale)

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.

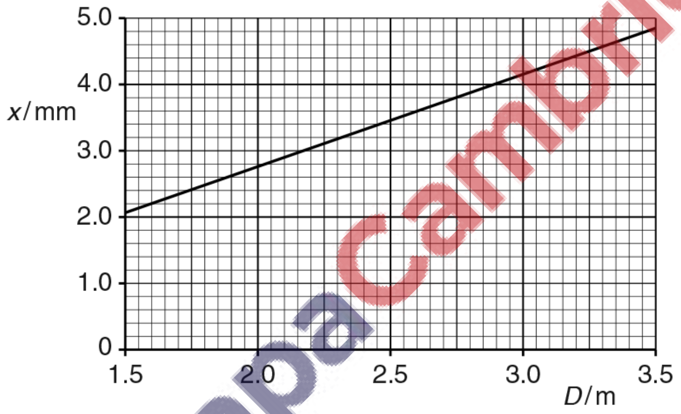


**Fig. 5.3**

**(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]

171. 9702_w16_qp_22 Q: 4

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

..........................................................................................................................................

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

**(b)** An arrangement for demonstrating the interference of light is shown in Fig. 4.1.

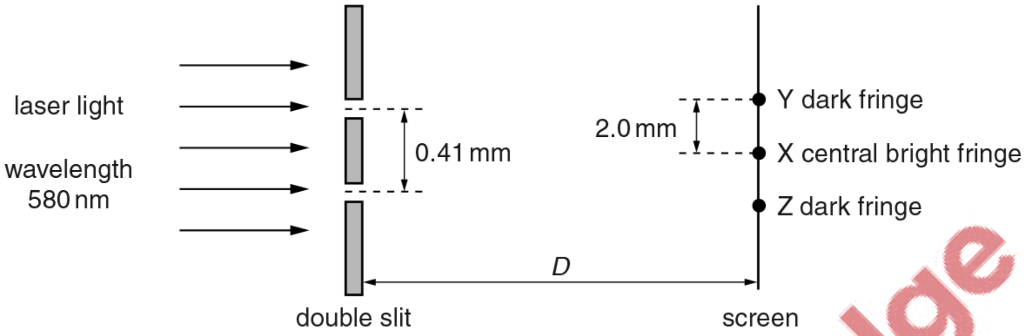


**Fig. 4.1** (not to scale)

The wavelength of the light from the laser is 580 nm. The separation of the slits is 0.41 mm. The perpendicular distance between the double slit and the screen is *D*.

Coherent light emerges from the slits and an interference pattern is observed on the screen. The central bright fringe is produced at point X. The closest dark fringes to point X are produced at points Y and Z. The distance XY is 2.0 mm.

**(i)** Explain why a bright fringe is produced at point X.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

**(ii)** State the difference in the distances, in nm, from each slit to point Y.

distance = .................................................... nm [1]

**(iii)** Calculate the distance *D*.

*D* = ........................................................ m [3]

**(iv)** The intensity of the light passing through the two slits was initially the same. The intensity of the light through **one** of the slits is now reduced. Compare the appearance of the fringes before and after the change of intensity.

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

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

[Total: 10]

172. 9702_s15_qp_23 Q: 6

**(a)** Two overlapping waves of the same type travel in the same direction. The variation with distance *x* of the displacement *y* of each wave is shown in Fig. 6.1.

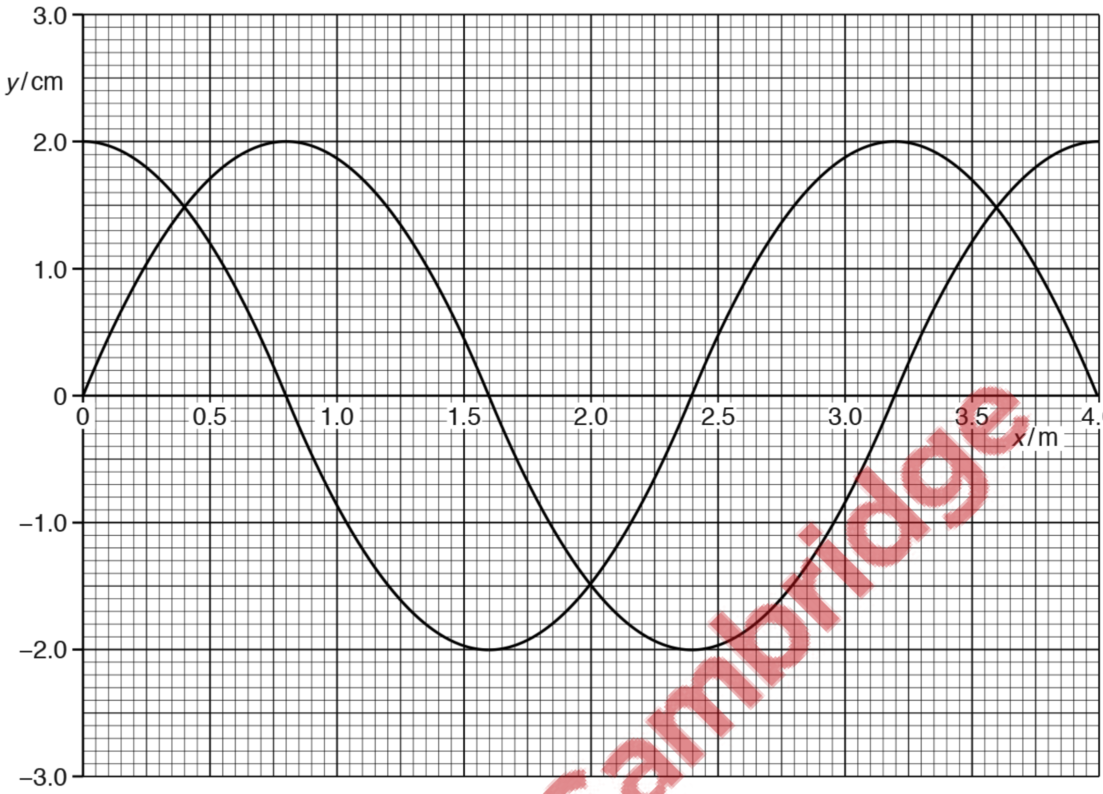


**Fig. 6.1**

The speed of the waves is 240 m s$^{-1}$. The waves are coherent and produce an interference pattern.

**(i)** Explain the meaning of *coherence* and *interference*.

coherence: ..........................................................................................................

..........................................................................................................

interference: ..........................................................................................................

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

**(ii)** Use Fig. 6.1 to determine the frequency of the waves.

frequency = .................................................... Hz [2]

**(iii)** State the phase difference between the waves.

phase difference = ........................................................ ° [1]

**(iv)** Use the principle of superposition to sketch, on Fig. 6.1, the resultant wave. [2]

**(b)** An interference pattern is produced with the arrangement shown in Fig. 6.2.

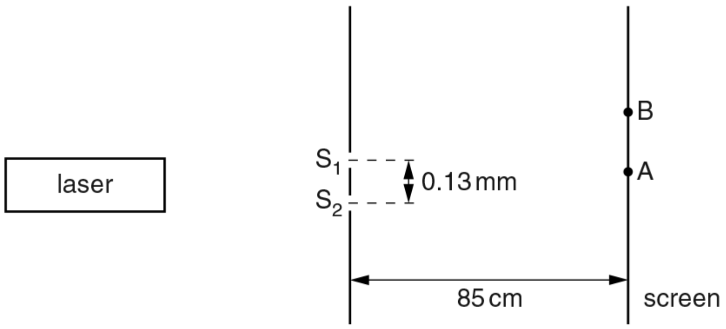


**Fig. 6.2** (not to scale)

Laser light of wavelength $\lambda$ of 546 nm is incident on the slits $S_1$ and $S_2$. The slits are a distance 0.13 mm apart. The distance between the slits and the screen is 85 cm.

Two points on the screen are labelled A and B. The path difference between $S_1A$ and $S_2A$ is zero. The path difference between $S_1B$ and $S_2B$ is $2.5\lambda$. Maxima and minima of intensity of light are produced on the screen.

**(i)** Calculate the distance AB.

distance = ........................................................ m [3]

**(ii)** The laser is replaced by a laser emitting blue light. State and explain the change in the distance between the maxima observed on the screen.

..............................................................................................................................

..............................................................................................................................

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

173. 9702_w15_qp_22 Q: 7

An arrangement that is used to demonstrate interference with waves on the surface of water is shown in Fig. 7.1.

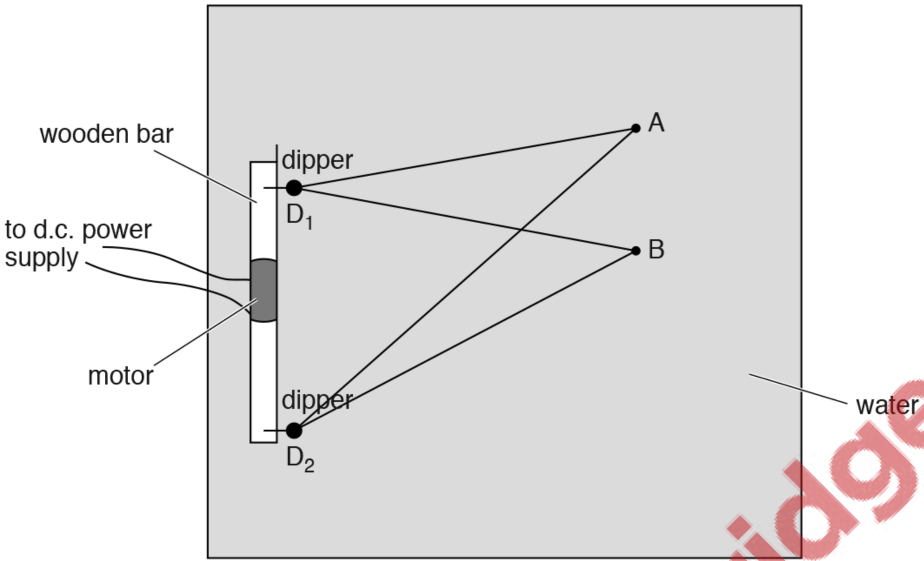


**Fig. 7.1** (view from above)

**(a)** Two dippers $D_1$ and $D_2$ are connected to a motor and a d.c. power supply. Initially only $D_1$ vibrates on the water surface to produce waves.
The variation with distance *x* from $D_1$ of the displacement *y* of the water at one instant of time is shown in Fig. 7.2.

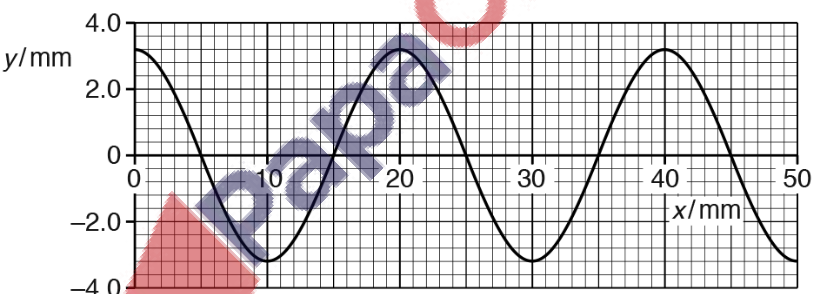


**Fig. 7.2**

Using Fig. 7.2, determine

**(i)** the amplitude of the wave,

amplitude = .................................................. mm [1]

**(ii)** the wavelength of the wave.

wavelength = .................................................. mm [1]

**(b)** The two dippers $D_1$ and $D_2$ are made to vibrate and waves are produced by both dippers on the water surface.

**(i)** State and explain whether these waves are stationary or progressive.

..................................................................................................................................

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

**(ii)** Explain why $D_1$ and $D_2$ are connected to the same motor.

..................................................................................................................................

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

**(c)** The points A and B on Fig. 7.1 are at the distances from $D_1$ and $D_2$ shown in Fig. 7.3.

| $D_1A$ | $D_2A$ | $D_1B$ | $D_2B$ |
|---|---|---|---|
| 5.0 cm | 7.0 cm | 5.0 cm | 6.0 cm |

**Fig. 7.3**

State and explain the variation with time of the displacement of the water on the surface at

**(i)** A,

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

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

**(ii)** B.

..................................................................................................................................

..................................................................................................................................

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

174. 9702_w15_qp_23 Q: 2

A signal generator is connected to two loudspeakers $L_1$ and $L_2$, as shown in Fig. 2.1.

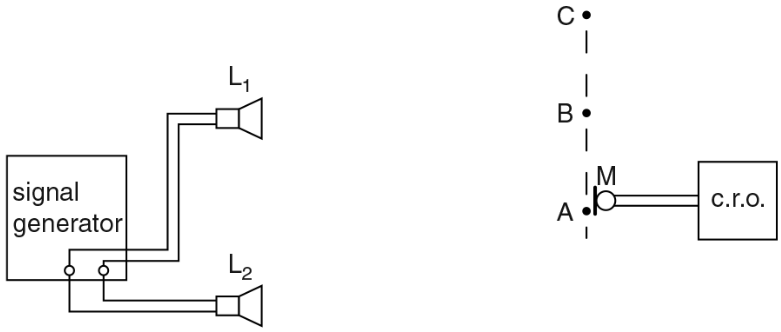


**Fig. 2.1**

A microphone M, connected to the Y-plates of a cathode-ray oscilloscope (c.r.o.), detects the intensity of sound along the line ABC.
The distances $L_1$A and $L_2$A are equal.
The time-base of the c.r.o. is switched off.

The traces on the c.r.o. when M is at A, then at B and then at C are shown on Fig. 2.2, Fig. 2.3 and Fig. 2.4 respectively.

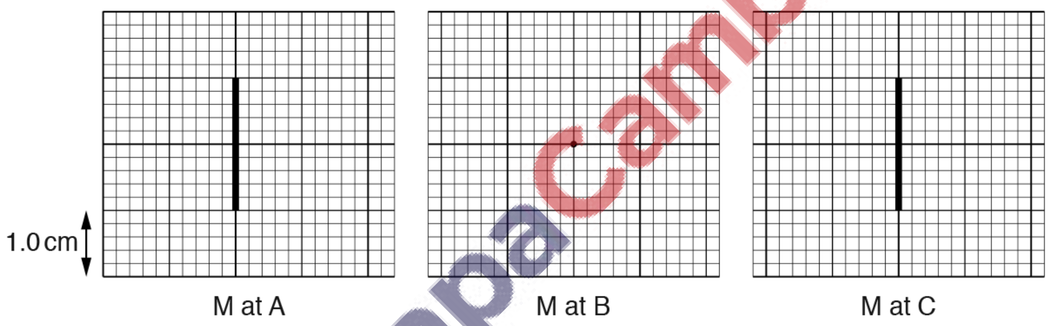


**Fig. 2.2** **Fig. 2.3** **Fig. 2.4**

For these traces, 1.0 cm represents 5.0 mV on the vertical scale.

**(a)** **(i)** Explain why coherent waves are produced by the loudspeakers.

..........................................................................................................................

..........................................................................................................................

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

**(ii)** Use the principle of superposition to explain the traces shown with M at

**1.** A,

..........................................................................................................................................

..........................................................................................................................................

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

**2.** B,

..........................................................................................................................................

..........................................................................................................................................

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

**3.** C.

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** The sound emitted from $L_1$ and $L_2$ has frequency 500 Hz. The time-base on the c.r.o. is switched on.

The microphone M is placed at A.

On Fig. 2.5, draw the trace seen on the c.r.o.

On the vertical scale, 1.0 cm represents 5.0 mV. On the horizontal scale, 1.0 cm represents 0.10 ms.

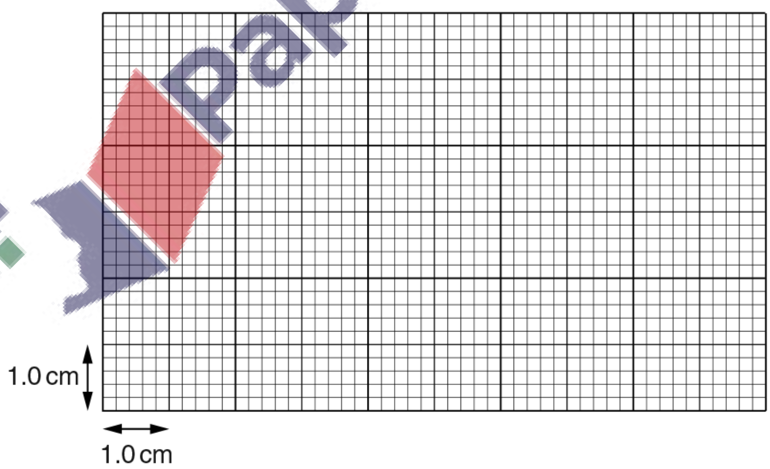


**Fig. 2.5**

[3]

## 9.3 Diffraction gratings

175. 9702_m20_qp_22 Q: 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.

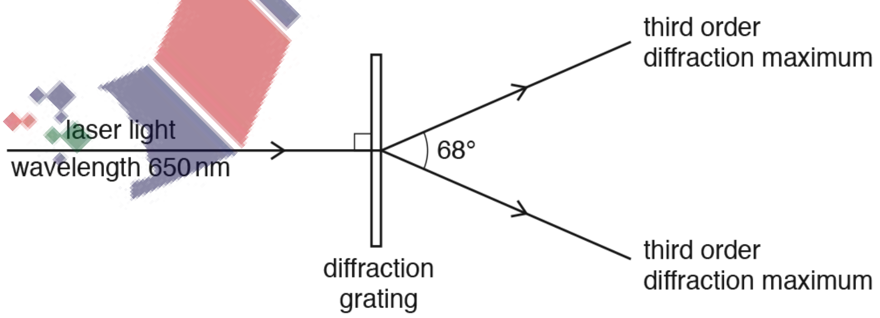


**Fig. 4.1** (not to scale)

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]

176. 9702_w20_qp_23 Q: 5

**(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.

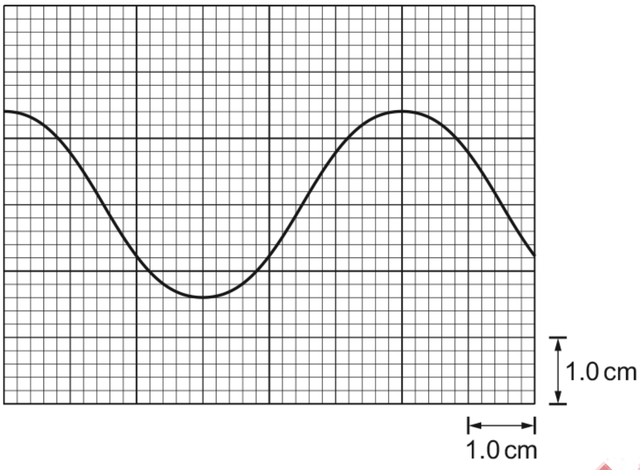


**Fig. 5.1**

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

**(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]

**(b)** A beam of light of a single wavelength is incident normally on a diffraction grating, as illustrated in Fig. 5.2.

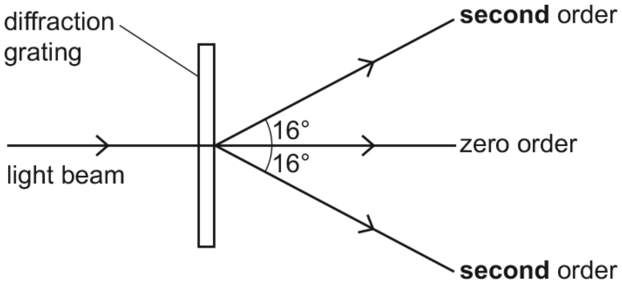


**Fig. 5.2** (not to scale)

Fig. 5.2 does not show all of the emerging beams from the grating. The angle between the **second**-order emerging beam and the central zero-order beam is 16°. The grating has a line spacing of $3.4 \times 10^{-6}$ m.

**(i)** Calculate the wavelength of the light.

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

**(ii)** Determine the highest order of emerging beam from the grating.

highest order = ....................................................... [2]

[Total: 9]

177. 9702_s19_qp_22 Q: 4

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

**(i)** *displacement*

..........................................................................................................................

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

**(ii)** *amplitude*.

..........................................................................................................................

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

**(b)** Two coherent waves X and Y meet at a point and superpose. The phase difference between the waves at the point is 180°. Wave X has an amplitude of 1.2 cm and intensity $I$. Wave Y has an amplitude of 3.6 cm.

Calculate, in terms of $I$, the resultant intensity at the meeting point.

intensity = ........................................................ [2]

**(c)** **(i)** Monochromatic light is incident on a diffraction grating. Describe the diffraction of the light waves as they pass through the grating.

..........................................................................................................................

..........................................................................................................................

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

**(ii)** A parallel beam of light consists of two wavelengths 540 nm and 630 nm. The light is incident normally on a diffraction grating. Third-order diffraction maxima are produced for each of the two wavelengths. No higher orders are produced for either wavelength.

Determine the smallest possible line spacing *d* of the diffraction grating.

*d* = ........................................................ m [3]

**(iii)** The beam of light in **(c)(ii)** is replaced by a beam of blue light incident on the same diffraction grating.

State and explain whether a third-order diffraction maximum is produced for this blue light.

..........................................................................................................................................

..........................................................................................................................................

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

[Total: 11]

178. 9702_w19_qp_23 Q: 5

**(a)** Light waves emerging from the slits of a diffraction grating are coherent and produce an interference pattern.

Explain what is meant by:

**(i)** *coherence*

...........................................................................................................................

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

**(ii)** *interference*.

...........................................................................................................................

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

**(b)** A narrow beam of light from a laser is incident normally on a diffraction grating, as shown in Fig. 5.1.

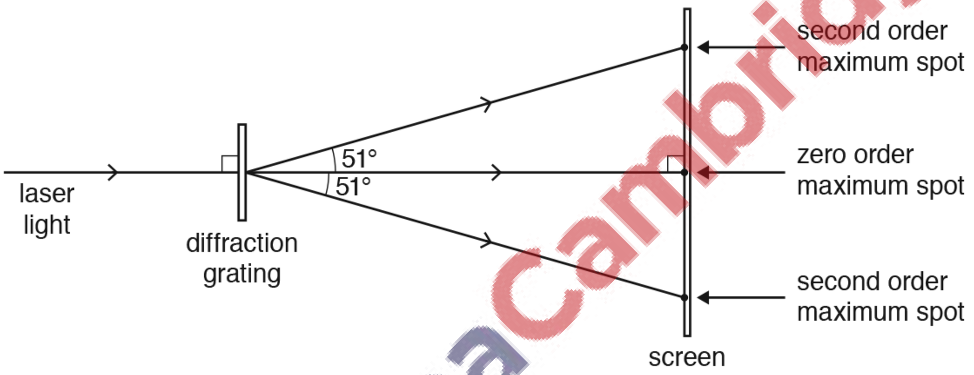


**Fig. 5.1** (not to scale)

Spots of light are seen on a screen positioned parallel to the grating. The angle corresponding to each of the **second** order maxima is 51°. The number of lines per unit length on the diffraction grating is $6.7 \times 10^5\,m^{-1}$.

**(i)** Determine the wavelength of the light.

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

**(ii)** State and explain the change, if any, to the distance between the second order maximum spots on the screen when the light from the laser is replaced by light of a shorter wavelength.

..........................................................................................................................................

..........................................................................................................................................

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

[Total: 5]

179. 9702_s18_qp_21 Q: 5

**(a)** When monochromatic light is incident normally on a diffraction grating, the emergent light waves have been diffracted and are coherent.

Explain what is meant by

**(i)** *diffracted* waves,

..........................................................................................................................

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

**(ii)** *coherent* waves.

..........................................................................................................................

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

**(b)** Light consisting of only two wavelengths $\lambda_1$ and $\lambda_2$ is incident normally on a diffraction grating.

The third order diffraction maximum of the light of wavelength $\lambda_1$ and the fourth order diffraction maximum of the light of wavelength $\lambda_2$ are at the same angle $\theta$ to the direction of the incident light.

**(i)** Show that the ratio $\frac{\lambda_2}{\lambda_1}$ is 0.75.

Explain your working.

[2]

**(ii)** The difference between the two wavelengths is 170 nm.

Determine wavelength $\lambda_1$.

$\lambda_1$ = ...................................................... nm [1]

[Total: 5]

180. 9702_w18_qp_22 Q: 5

Red light of wavelength 640 nm is incident normally on a diffraction grating having a line spacing of $1.7 \times 10^{-6}$ m, as shown in Fig. 5.1.

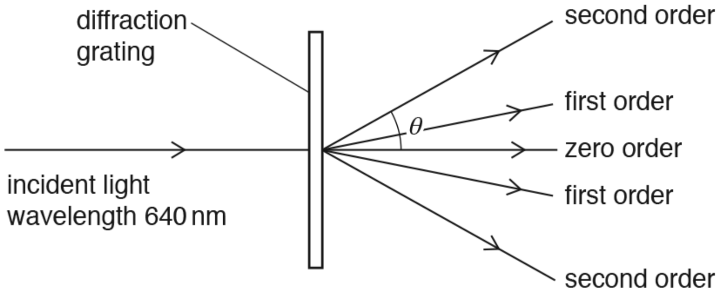


**Fig. 5.1** (not to scale)

The second order diffraction maximum of the light is at an angle $\theta$ to the direction of the incident light.

**(a)** Show that angle $\theta$ is 49°.

[3]

**(b)** Determine a different wavelength of **visible** light that will also produce a diffraction maximum at an angle of 49°.

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

[Total: 5]

181. 9702_s17_qp_23 Q: 5

**(a)** A diffraction grating is used to determine the wavelength of light.

**(i)** Describe the diffraction of light at a diffraction grating.

..........................................................................................................................

..........................................................................................................................

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

**(ii)** By reference to interference, explain

**1.** the zero order maximum,

..........................................................................................................................

..........................................................................................................................

..........................................................................................................................

**2.** the first order maximum.

..........................................................................................................................

..........................................................................................................................

[3]

**(b)** A diffraction grating is used with different wavelengths of light. The angle $\theta$ of the second order maximum is measured for each wavelength. The variation with wavelength $\lambda$ of $\sin\theta$ is shown in Fig. 5.1.

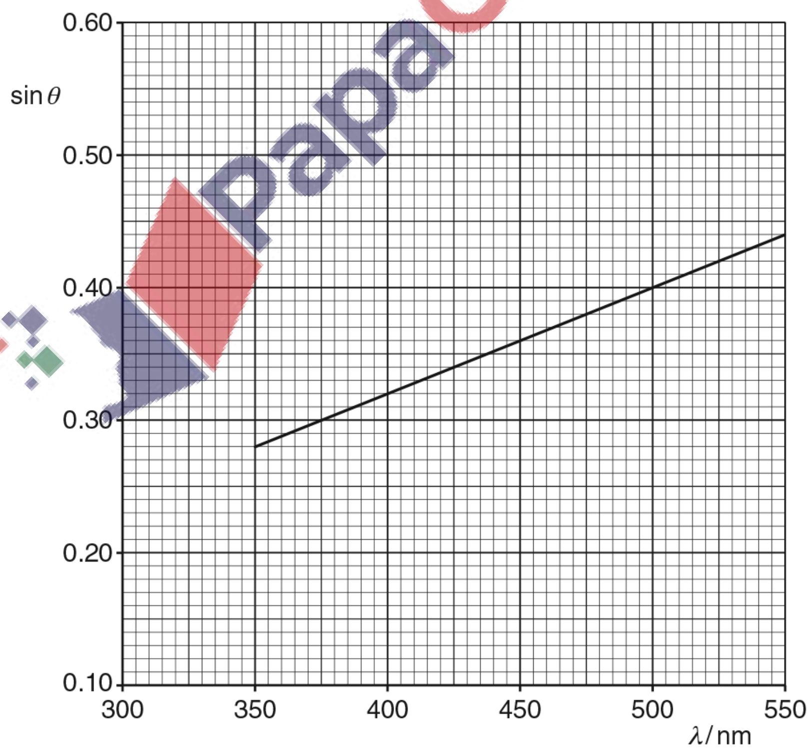


**Fig. 5.1**

**(i)** Determine the gradient of the line shown in Fig. 5.1.

gradient = ............................................................[2]

**(ii)** Use the gradient determined in **(i)** to calculate the slit separation *d* of the diffraction grating.

*d* = ........................................................m [2]

**(iii)** On Fig. 5.1, sketch a line to show the results that would be obtained for the first order maxima. [1]

[Total: 10]

182. 9702_s16_qp_22 Q: 5

**(a)** Light of a single wavelength is incident on a diffraction grating. Explain the part played by *diffraction* and *interference* in the production of the first order maximum by the diffraction grating.

diffraction: ..............................................................................................................

..............................................................................................................

interference: ..............................................................................................................

..............................................................................................................

..............................................................................................................

.............................................................................................................. [3]

**(b)** The diffraction grating illustrated in Fig. 5.1 is used with light of wavelength 486 nm.

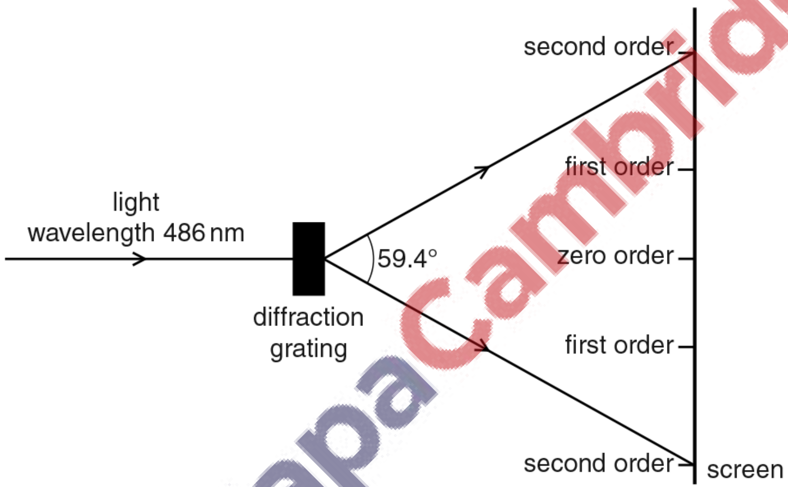


**Fig. 5.1** (not to scale)

The orders of the maxima produced are shown on the screen in Fig. 5.1. The angle between the two second order maxima is 59.4°.

Calculate the number of lines per millimetre of the grating.

number of lines per millimetre = .............................................. $mm^{-1}$ [3]

[Total: 6]

183. 9702_w16_qp_21 Q: 5

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

..........................................................................................................................................

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

**(b)** Laser light of wavelength 500 nm is incident normally on a diffraction grating. The resulting diffraction pattern has diffraction maxima up to and including the fourth-order maximum.

Calculate, for the diffraction grating, the minimum possible line spacing.

line spacing = ....................................................... m [3]

**(c)** The light in **(b)** is now replaced with red light. State and explain whether this is likely to result in the formation of a fifth-order diffraction maximum.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

[Total: 7]

184. 9702_w16_qp_23 Q: 5

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

..........................................................................................................................................

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

**(b)** Laser light of wavelength 500 nm is incident normally on a diffraction grating. The resulting diffraction pattern has diffraction maxima up to and including the fourth-order maximum.

Calculate, for the diffraction grating, the minimum possible line spacing.

line spacing = ...................................................... m [3]

**(c)** The light in **(b)** is now replaced with red light. State and explain whether this is likely to result in the formation of a fifth-order diffraction maximum.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

[Total: 7]

185. 9702_s15_qp_21 Q: 6

**(a)** State what is meant by *diffraction* and by *interference*.

diffraction: ..........................................................................................................................

..........................................................................................................................

interference: ..........................................................................................................................

..........................................................................................................................
[3]

**(b)** Light from a source $S_1$ is incident on a diffraction grating, as illustrated in Fig. 6.1.

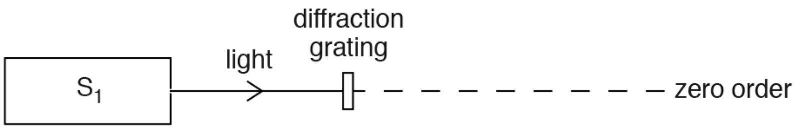


**Fig. 6.1** (not to scale)

The light has a single frequency of $7.06 \times 10^{14}$ Hz. The diffraction grating has 650 lines per millimetre.

Calculate the number of orders of diffracted light produced by the grating. Do not include the zero order.
Show your working.

number = ........................................................ [3]

**(c)** A second source $S_2$ is used in place of $S_1$. The light from $S_2$ has a single frequency lower than that of the light from $S_1$.

State and explain whether more orders are seen with the light from $S_2$.

..........................................................................................................................

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