SUPERPOSITION WORKSHEET

PHYSICS WITH CYRUS

Cyrus Ishaq

ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

Q1 **(a)** State the principle of superposition.

....

....

.... [2]

(b) Coherent light is incident normally on two identical slits X and Y. The diffracted light emerging from the slits superposes to produce an interference pattern on a screen positioned at a distance of 1.9 m from the slits.

Fig. 4.1 shows the arrangement and the central part of the interference pattern of bright and dark fringes formed on the screen.

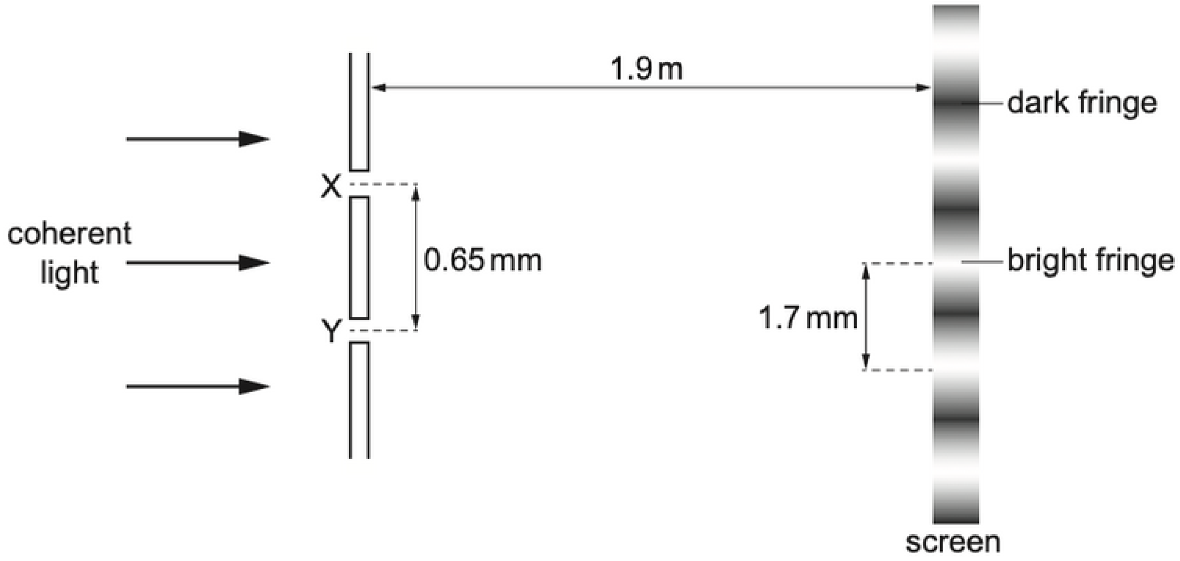


Fig. 4.1 (not to scale)

The separation of the slits is 0.65 mm. The distance between the centres of adjacent bright fringes is 1.7 mm.

Calculate the wavelength λ of the light.

λ = ... m [3]

(c) Light waves from slits X and Y in **(b)** arrive at a point between adjacent bright fringes on the screen. Fig. 4.2 shows the variation of displacement with time for the waves arriving at the point where they meet.

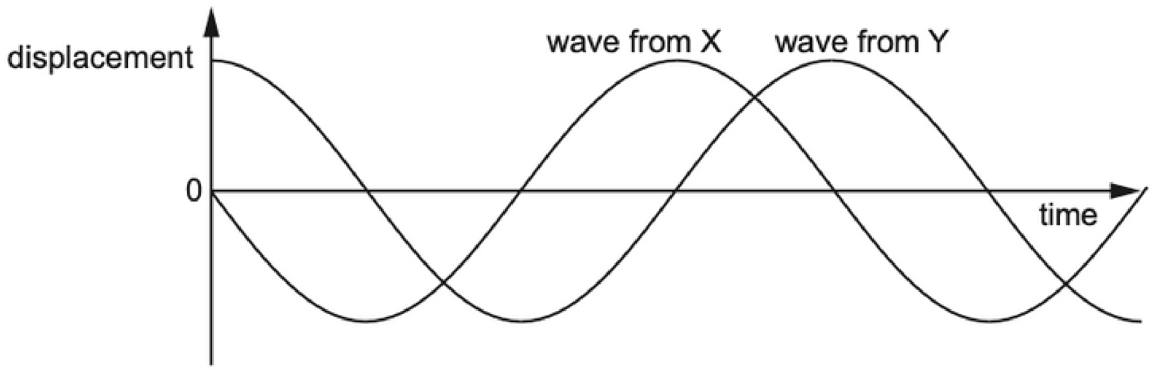


Fig. 4.2

A student makes two statements about the waves at this point:

Statement 1: 'The phase difference between the waves is 90°.'

Statement 2: 'The amplitude of the resultant wave is zero.'

(i) Explain how statement 1 is correct.

....

....

.... [1]

(ii) State and explain whether statement 2 is correct.

....

....

.... [1]

(d) The width of each slit in **(b)** is decreased by the same amount. There is no change to the separation of the slits.

Describe and explain the effect, if any, of this change on the appearance of the interference pattern.

....

....

.... [2]

[Total: 9]

Q2 State what is meant by the diffraction of a wave.

....

....

.... [2]

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

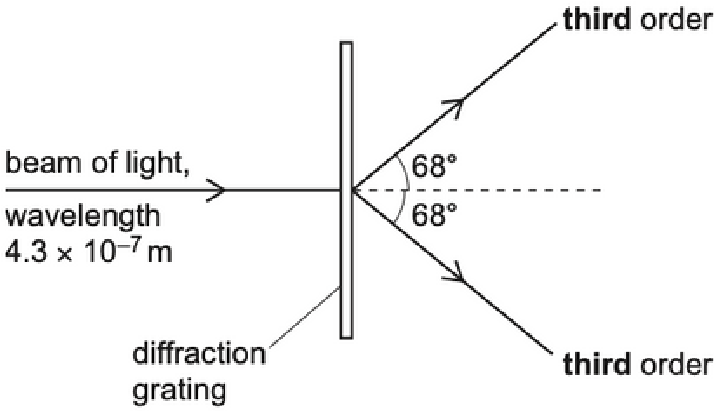


Fig. 5.3 (not to scale)

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

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

d = ... m [2]

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

wavelength = ... m [2]

Q3 An arrangement that uses a double slit to demonstrate the interference of light from a laser is shown in Fig. 5.1.

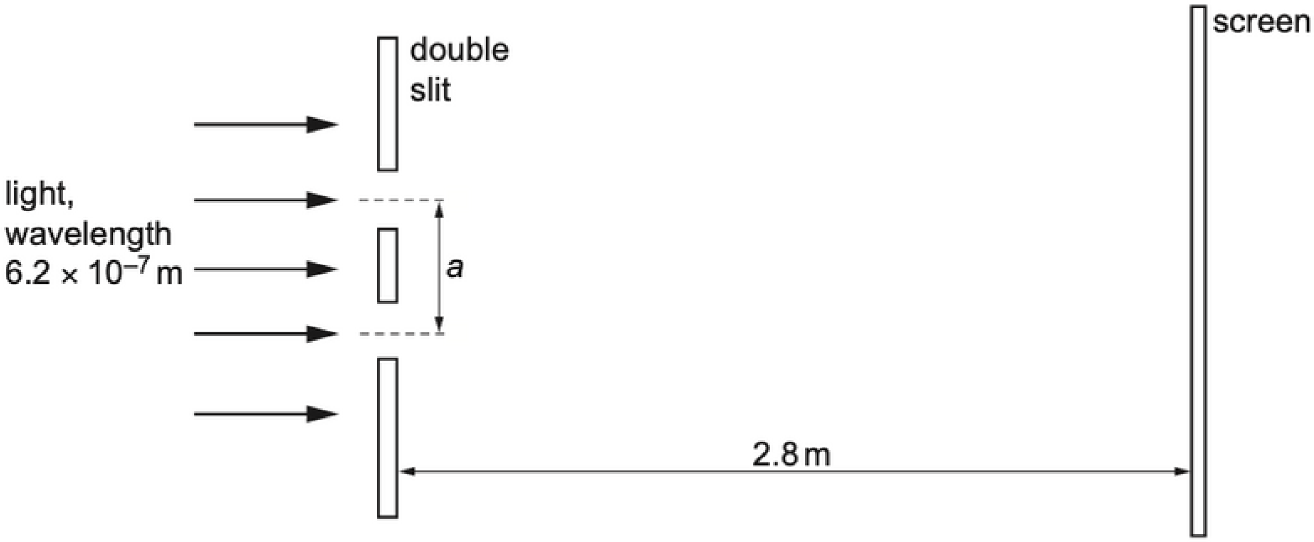
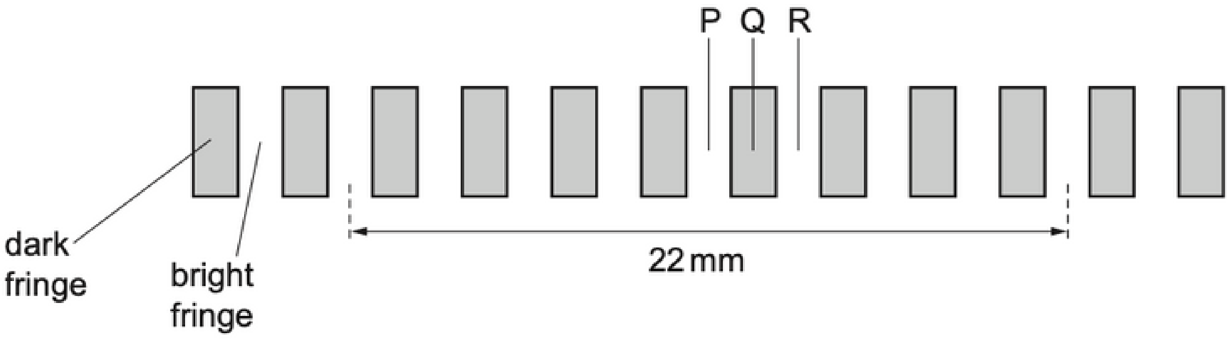


Fig. 5.1 (not to scale)

The light from the laser has a wavelength of 6.2×10^{-7} m and is incident normally on the slits. The separation of the two slits is *a*. The slits and screen are parallel and separated by a distance of 2.8 m.

An interference pattern of bright fringes and dark fringes is formed on the screen. The distance on the screen across 8 bright fringes is 22 mm, as illustrated in Fig. 5.2.



(i) The light waves emerging from the two slits are coherent.

State what is meant by coherent.

....

.... [1]

(ii) Calculate the separation *a* of the slits.

a = ... m [3]

(c) Fringe P is the central bright fringe of the interference pattern in **(b)**. Fringe Q and fringe R are the nearest dark fringe and the nearest bright fringe respectively to the right of fringe P, as shown in Fig. 5.2.

(i) Calculate the difference in the distances (the path difference) from each slit to the centre of fringe Q.

difference in the distances = ... m [1]

(ii) State the phase difference between the light waves meeting at the centre of fringe R.

phase difference = ... ° [1]

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

Q4 A tube is closed at one end. A loudspeaker is placed near the other end of the tube, as shown in Fig. 5.1.

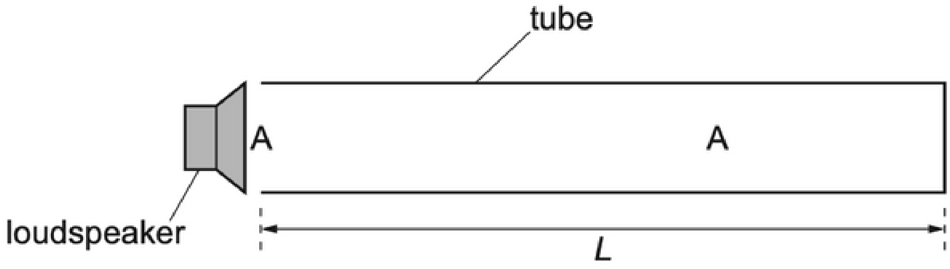


Fig. 5.1 (not to scale)

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

Determine:

(i) the wavelength of the sound

wavelength = ... m [2]

(ii) the length *L* of the tube

L = ... m [1]

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

maximum wavelength = ... m [1]

Q5 A loudspeaker, microphone and cathode-ray oscilloscope (CRO) are arranged as shown in Fig. 4.1.

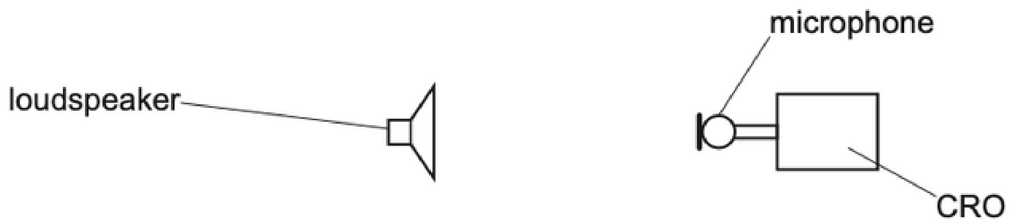


Fig. 4.1

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.

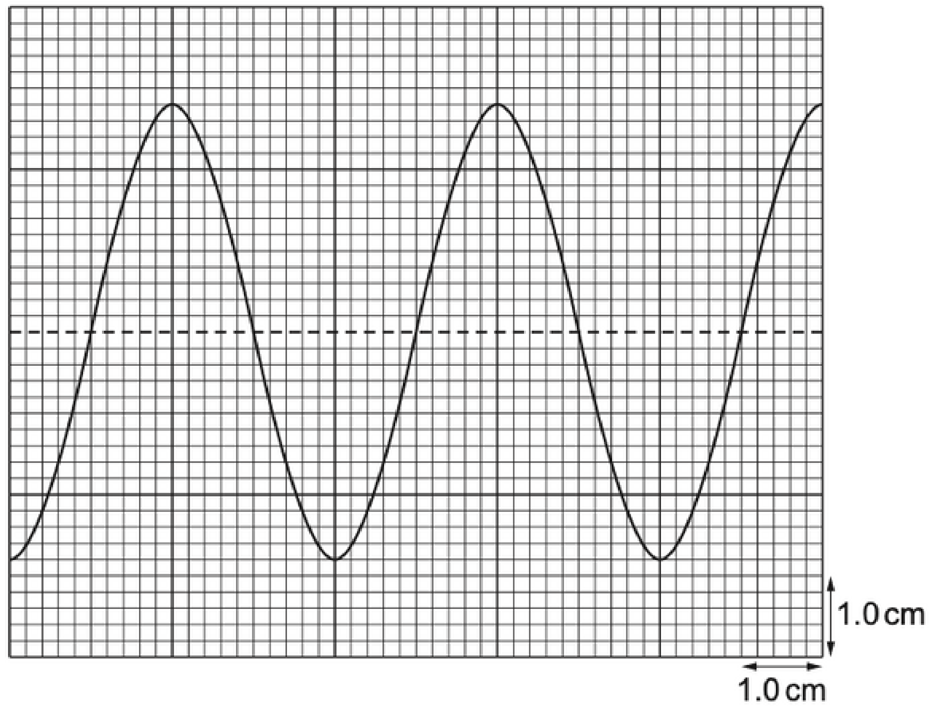


Fig. 4.2

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

Calculate:

(i) the frequency of the sound wave

frequency = ... Hz [2]

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

amplitude = ... V [1]

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

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

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

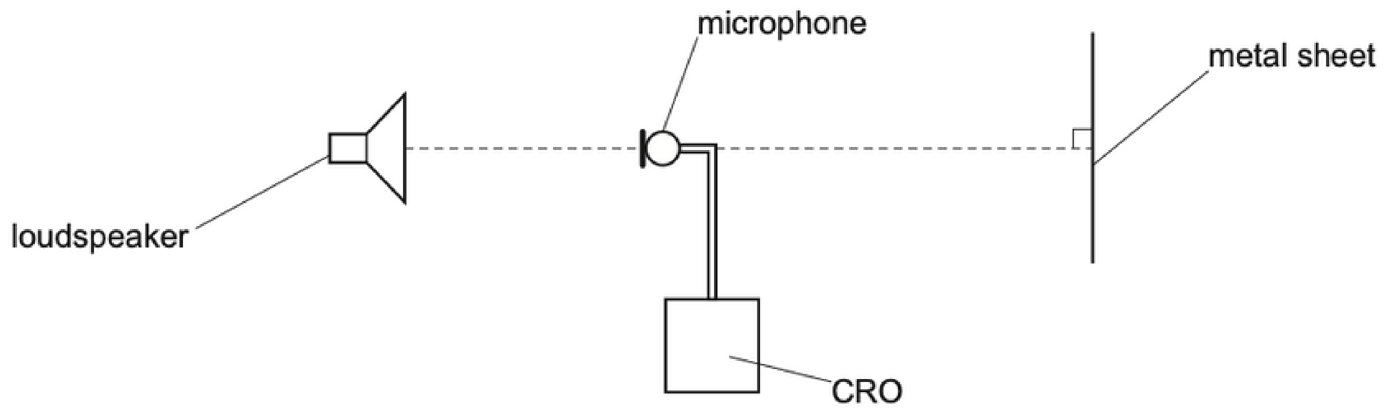


Fig. 4.3

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

(i) State the principle of superposition.

....

....

.... [2]

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

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

Determine the wavelength of the sound wave.

wavelength = ... m [2]

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

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

Q6

(b) An arrangement for demonstrating interference using light is shown in Fig. 5.2.

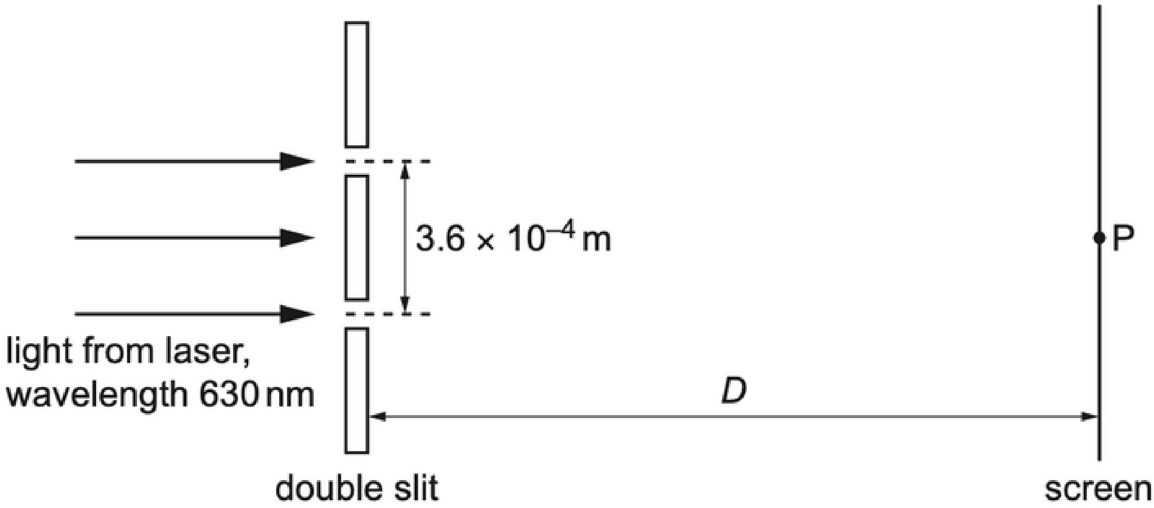


Fig. 5.2 (not to scale)

The wavelength of the light from the laser is 630 nm. The light is incident normally on the double slit. The separation of the two slits is 3.6×10^{-4} m. The perpendicular distance between the double slit and the screen is *D*.

Coherent light waves from the slits form an interference pattern of bright and dark fringes on the screen. The distance between the centres of two adjacent bright fringes is 4.0×10^{-3} m. The central bright fringe is formed at point P.

(i) Explain why a bright fringe is produced by the waves meeting at point P.

....

.... [1]

(ii) Calculate distance *D*.

D = ... m [3]

(c) The wavelength λ of the light in **(b)** is now varied. This causes a variation in the distance x between the centres of two adjacent bright fringes on the screen. The distance D and the separation of the two slits are unchanged.

On Fig. 5.3, sketch a graph to show the variation of x with λ from λ = 400 nm to λ = 700 nm. Numerical values of x are not required.

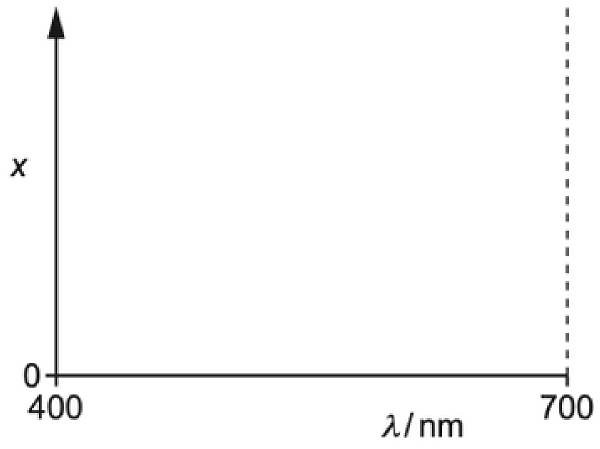


Fig. 5.3

[1]

Q7 **(a)** Two progressive sound waves meet to form a stationary wave. The two waves have the same amplitude, wavelength, frequency and speed.

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

.... [1]

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

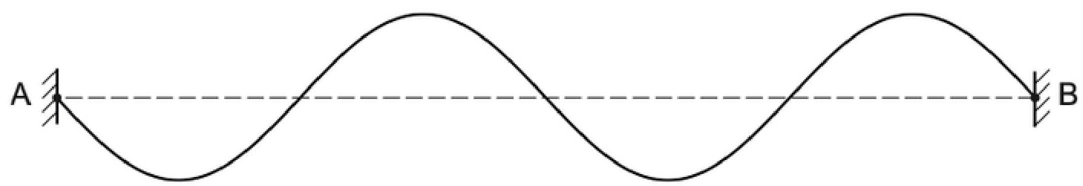


Fig. 5.1

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

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

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

[2]

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

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

Q8 A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

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

Fig. 5.1

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

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

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

....

....

....

.... [2]

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

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

distance = ... m [3]

Q9 Light from a laser is used to produce an interference pattern on a screen, as shown in Fig. 5.1.

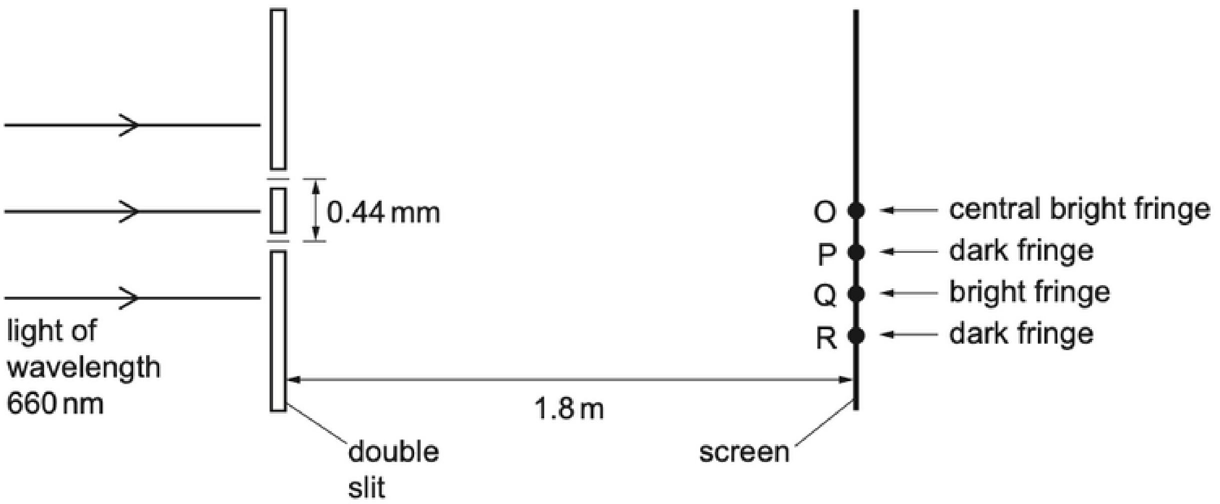


Fig. 5.1 (not to scale)

The light of wavelength 660 nm is incident normally on two slits that have a separation of 0.44 mm. The double slit is parallel to the screen. The perpendicular distance between the double slit and the screen is 1.8 m.

The central bright fringe on the screen is formed at point O. The next dark fringe below point O is formed at point P. The next bright fringe and the next dark fringe below point P are formed at points Q and R respectively.

(a) The light waves from the two slits are coherent.

State what is meant by coherent.

....

.... [1]

(b) For the two light waves superposing at R, calculate:

(i) the difference in their path lengths, in nm, from the slits

path difference = ... nm [1]

(c) Calculate the distance OQ.

distance OQ = ... m [3]

(d) The intensity of the light incident on the double slit is increased without changing the frequency.

Describe how the appearance of the fringes after this change is different from, and similar to, their appearance before the change.

....

....

....

....

.... [3]

(e) The light of wavelength 660 nm is now replaced by blue light from a laser.

State and explain the change, if any, that must be made to the separation of the two slits so that the fringe separation on the screen is the same as it was for light of wavelength 660 nm.

....

....

....

.... [2]

[Total: 11]

Q10 **(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.

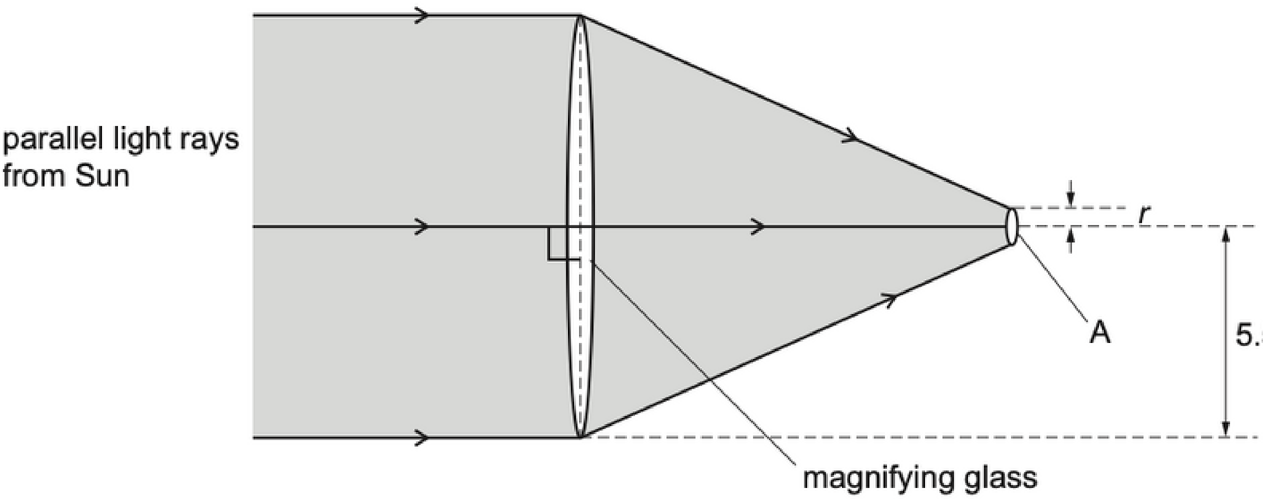


Fig. 5.1 (not to scale)

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 $1.3\,\text{kW}\,\text{m}^{-2}$.

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 = ... $\text{W}\,\text{m}^{-2}$ [1]

Calculate the number of maxima detected as the detector moves through 180° along the line shown in Fig. 5.2. Show your working.

number of maxima detected = ... [4]

(iv) The laser is now replaced with one that emits electromagnetic waves with a wavelength of 300 nm.

Explain, without calculation, what happens to the number of maxima now detected. Assume that the detector is also sensitive to this wavelength of electromagnetic waves.

....

....

.... [2]

[Total: 12]

Q11 a) **(i)** State the conditions required for the formation of a stationary wave.

....

....

....

.... [2]

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

phase difference = ...° [1]

Q12 A tube is initially fully submerged in water. The axis of the tube is kept vertical as the tube is slowly raised out of the water, as shown in Fig. 5.1.

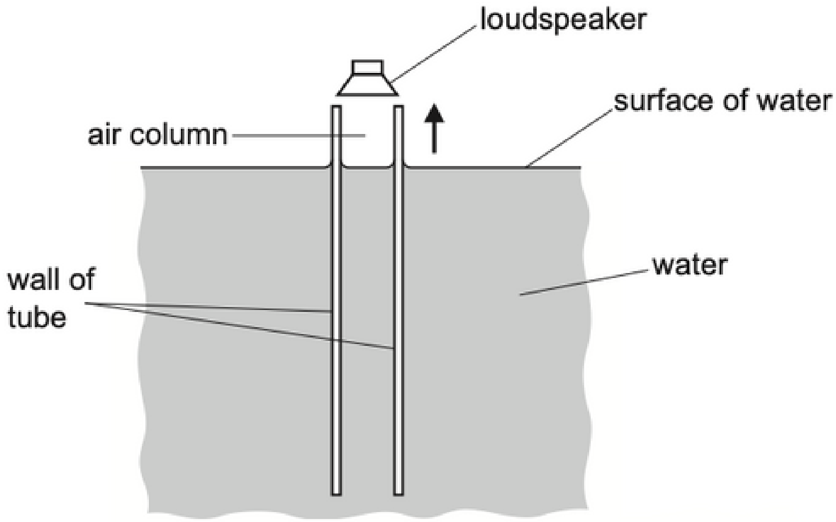


Fig. 5.1

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

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

....

.... [1]

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

height = ... m [3]

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

distance = ... m [1]

[Total: 5]

Q13 A two-source interference experiment uses the arrangement shown in Fig. 5.1.

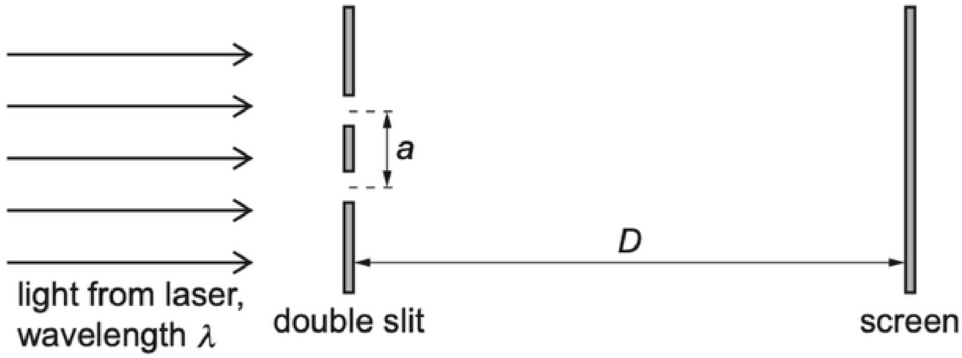


Fig. 5.1 (not to scale)

Light from a laser is incident normally on a double slit. A screen is parallel to the double slit.

Interference fringes are seen on the screen at distance D from the double slit. The separation of the centres of the slits is a. The light has wavelength λ.

The separation x of the centres of adjacent bright fringes is measured for different values of distance D.

The variation with D of x is shown in Fig. 5.2.

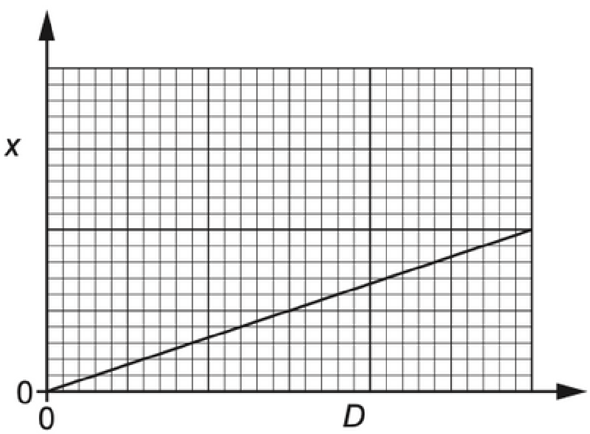


Fig. 5.2

The gradient of the graph is G.

(i) Determine an expression, in terms of G and λ, for the separation a of the slits.

a = ... [2]

(ii) The experiment is repeated with slits of separation $2a$. The wavelength of the light is unchanged.

On Fig. 5.2, sketch a graph to show the results of this experiment. [2]

[Total: 8]

Q14 (a) For a progressive wave, state what is meant by its *period*.

....

.... [1]

(b) State the principle of superposition.

....

....

.... [2]

(c) Electromagnetic waves of wavelength 0.040 m are emitted in phase from two sources X and Y and travel in a vacuum. The arrangement of the sources is shown in Fig. 4.1.

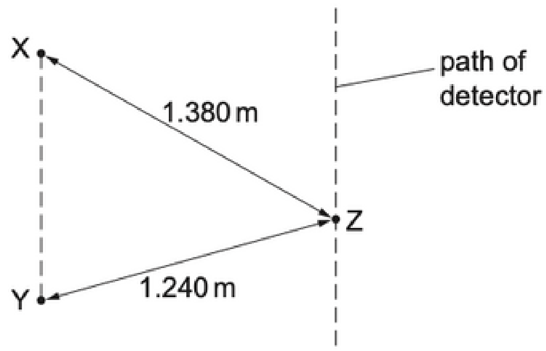


Fig. 4.1 (not to scale)

A detector moves along a path that is parallel to the line XY. A pattern of intensity maxima and minima is detected.

Distance XZ is 1.380 m and distance YZ is 1.240 m.

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

(i) State the name of the region of the electromagnetic spectrum that contains the waves from X and Y.

.... [1]

(ii) Calculate the period, in ps, of the waves.

period = ... ps [3]

(iii) Show that the path difference at point Z between the waves from X and Y is 3.5 λ, where λ is the wavelength of the waves.

[1]

(iv) Calculate the phase difference between the waves at point Z.

phase difference = ...° [1]

(v) The waves from X alone have the same amplitude at point Z as the waves from Y alone.

State the intensity of the waves at point Z.

.... [1]

(vi) The frequencies of the waves from X and Y are both decreased to the same lower value. The waves stay within the same region of the electromagnetic spectrum.

Describe the effect of this change on the pattern of intensity maxima and minima along the path of the detector.

....

.... [1]

[Total: 11]

Q15 **(a)** State the principle of superposition.

....

....

.... [2]

(b) Two waves, with intensities I and $4I$, superpose. The waves have the same frequency.

Determine, in terms of I, the maximum possible intensity of the resulting wave.

maximum intensity = ... I [2]

(c) Coherent light of wavelength 550 nm is incident normally on a double slit of slit separation 0.35 mm. A series of bright and dark fringes forms on a screen placed a distance of 1.2 m from the double slit, as shown in Fig. 4.1. The screen is parallel to the double slit.

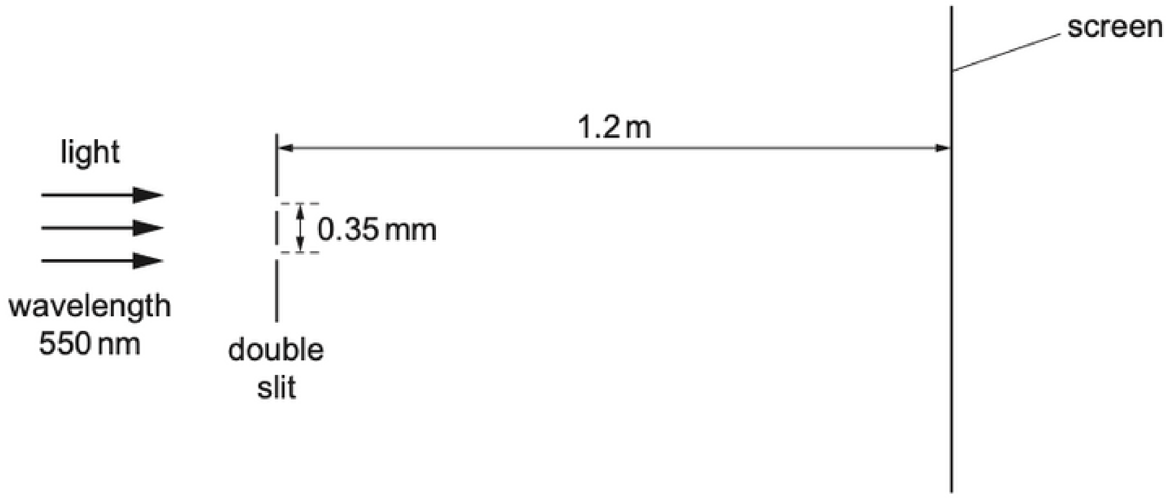


Fig. 4.1 (not to scale)

(i) Determine the distance between the centres of adjacent bright fringes on the screen.

distance = ... m [3]

(ii) The light of wavelength 550 nm is replaced with red light of a single frequency.

State and explain the change, if any, in the distance between the centres of adjacent bright fringes.

....

....

.... [1]

[Total: 8]

Q16 **(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]

Q17 Microwaves with the same wavelength and amplitude are emitted in phase from two sources X and Y, as shown in Fig. 5.1.

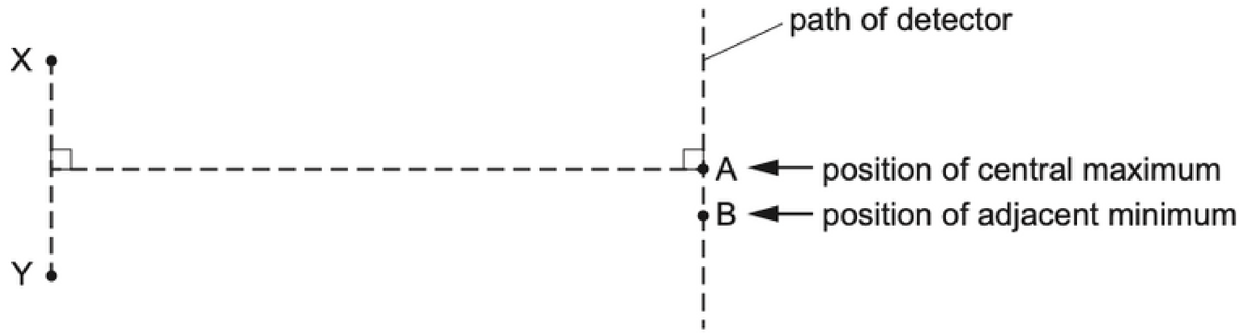


Fig. 5.1 (not to scale)

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]

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

(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]

Q18 **(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.

ude = ... cm [2]

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

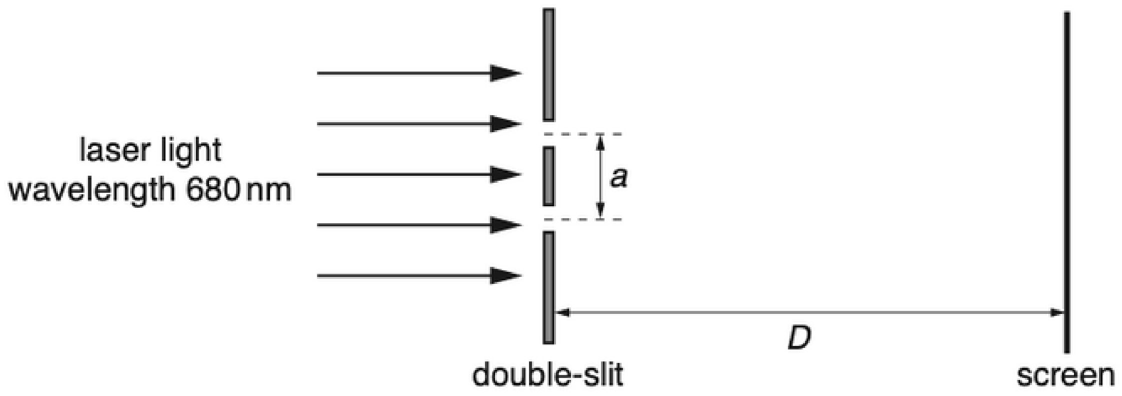


Fig. 5.1 (not to scale)

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.

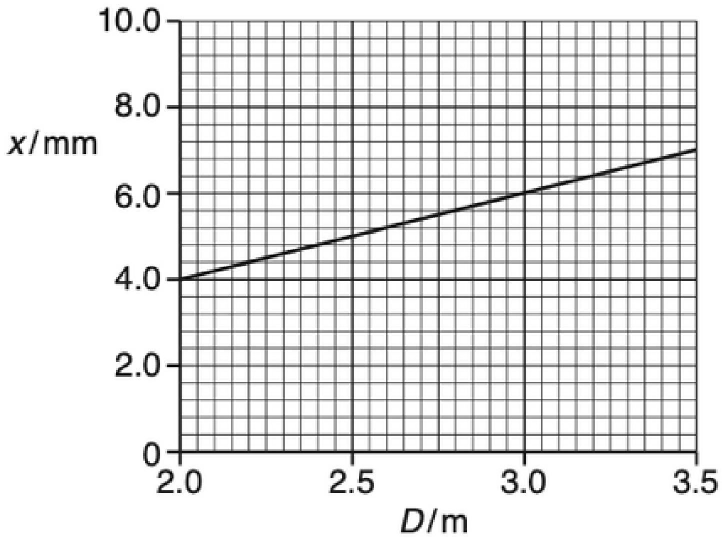


Fig. 5.2

(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]

Q19 Red light of wavelength 640 nm is incident normally on a diffraction grating having a line spacing of 1.7×10^{-6} m, as shown in Fig. 5.1.

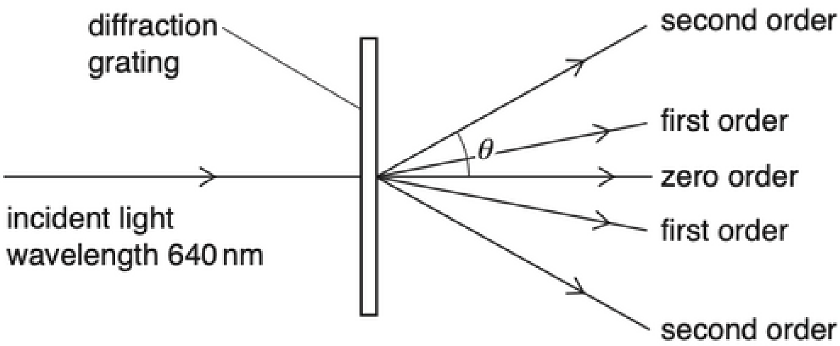


Fig. 5.1 (not to scale)

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

(a) Show that angle θ 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]

Q20 **(a)** State the principle of superposition.

....

....

.... [2]

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

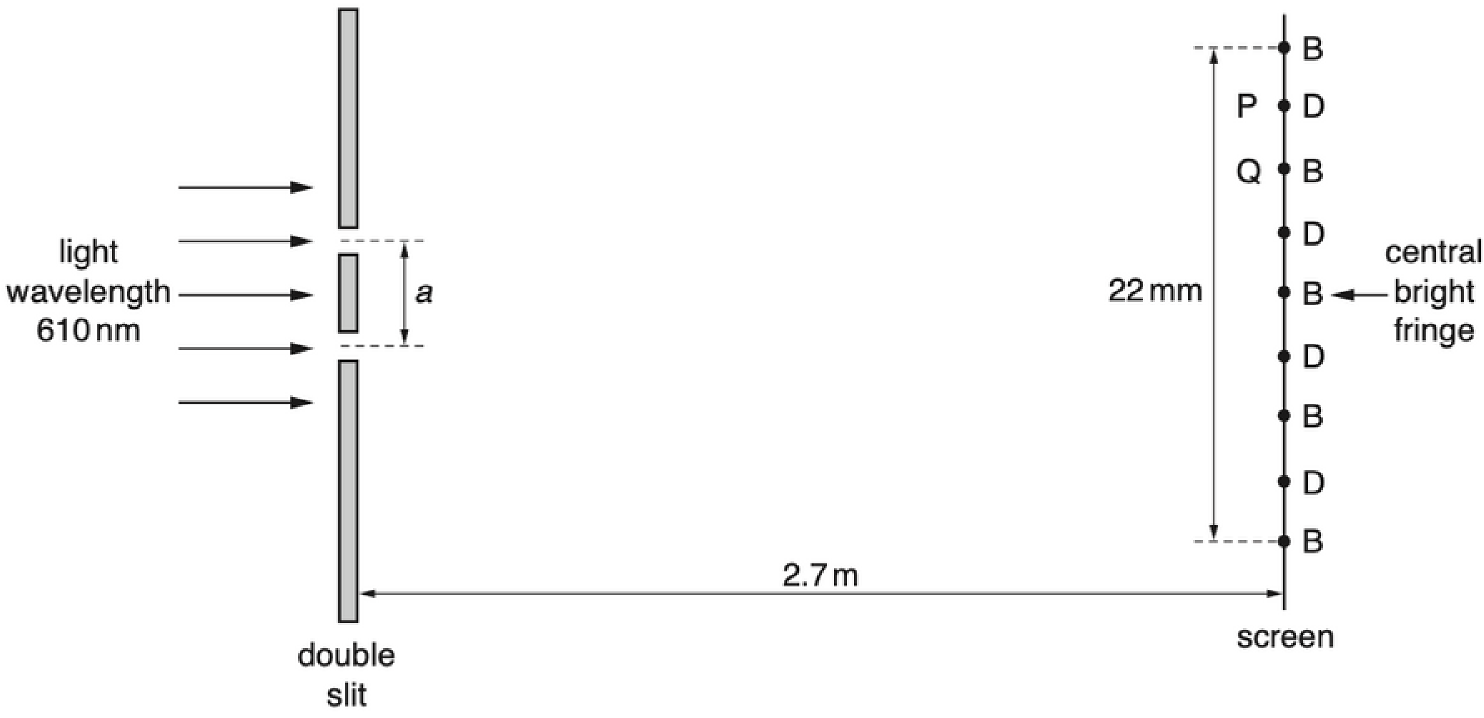


Fig. 4.1 (not to scale)

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.

....

....

....

.... [2]

[Total: 11]

Q21 **(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.

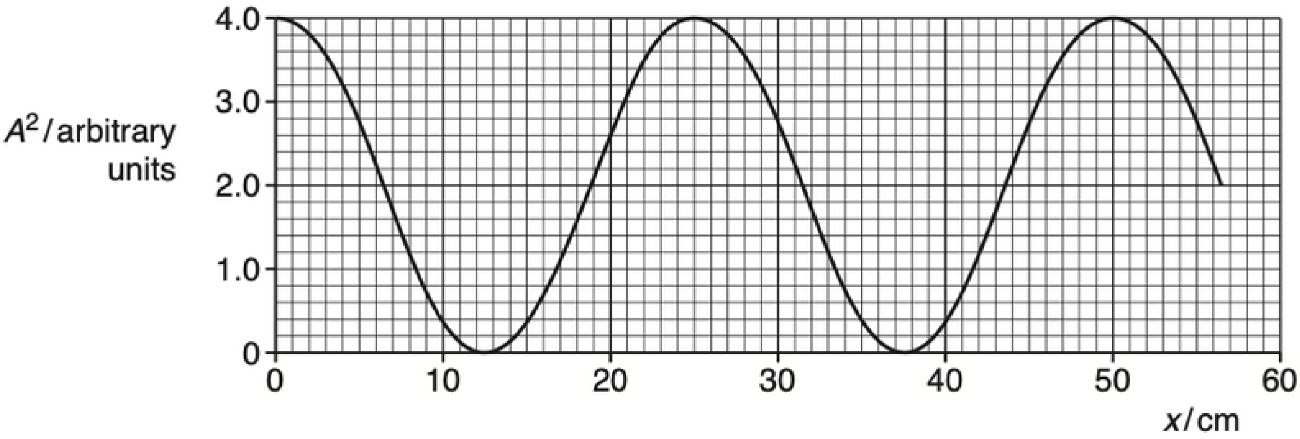


Fig. 4.1

(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 m 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]

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

Q22 **(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.

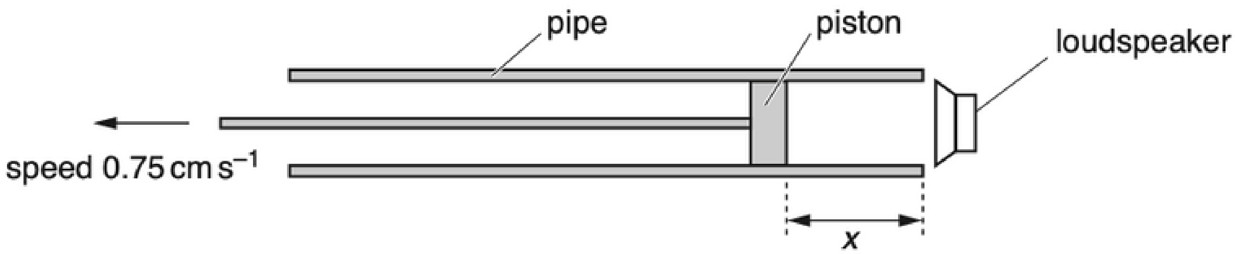


Fig. 4.1

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

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

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

Determine the frequency of the sound in the pipe.

frequency = ... Hz [3]

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

time interval = ... s [2]

[Total: 7]

Q23 **(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 λ_1 and λ_2 is incident normally on a diffraction grating.

The third order diffraction maximum of the light of wavelength λ_1 and the fourth order diffraction maximum of the light of wavelength λ_2 are at the same angle θ 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 λ_1.

λ_1 = ... nm [1]

[Total: 5]

Q24 **(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.

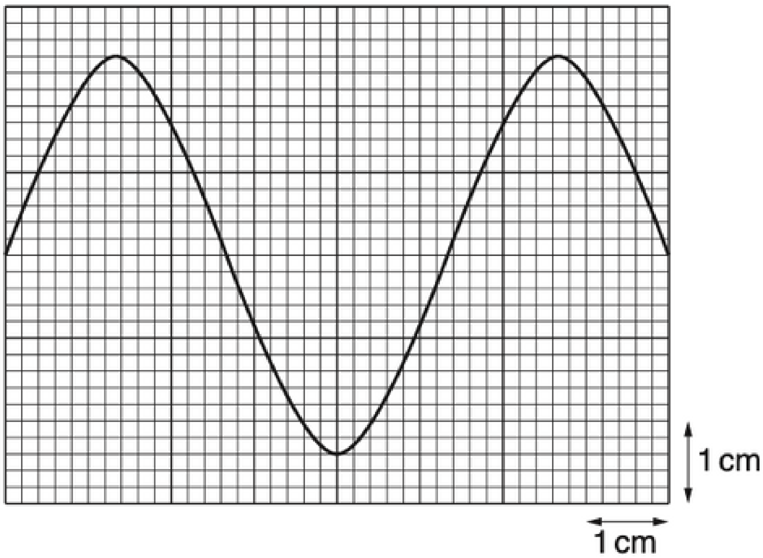


Fig. 4.1

In air, the sound wave has a speed of $330\,\text{m}\,\text{s}^{-1}$ 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 $\text{s}\,\text{cm}^{-1}$, of the c.r.o.

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

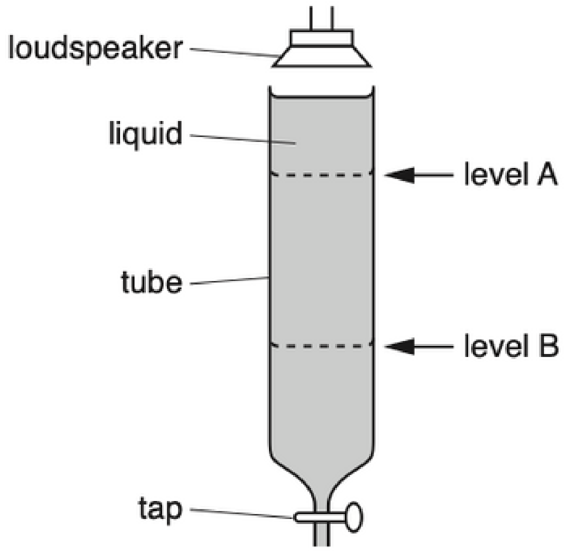


Fig. 4.2

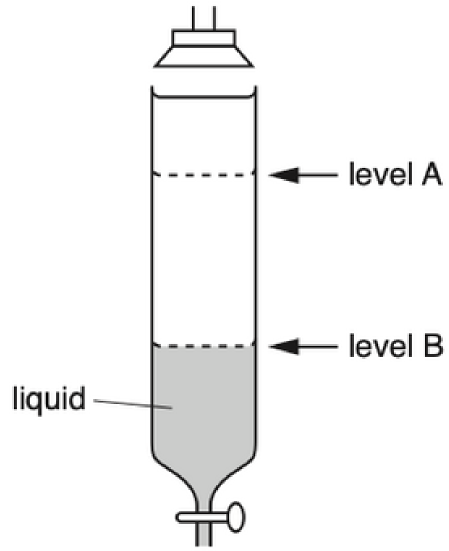


Fig. 4.3

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 $6.7\,\text{g}\,\text{s}^{-1}$. The tube has an internal cross-sectional area of $13\,\text{cm}^2$. The density of the liquid is $0.79\,\text{g}\,\text{cm}^{-3}$.

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

time = ... s [2]

[Total: 12]

Q25 **(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.

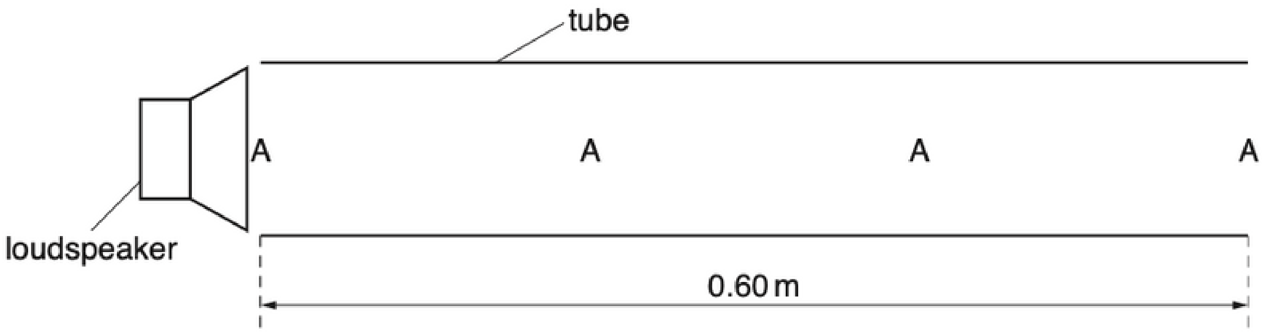


Fig. 3.1

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]

Q1

	(when two or more) waves meet / overlap (at a point)	B1
	(resultant) displacement is the sum of the individual displacements	B1
4(b)	$\lambda = ax / D$	C1
	$\lambda = [(0.65 \times 10^{-3}) \times (1.7 \times 10^{-3})] / 1.9$	C1
	$\lambda = 5.8 \times 10^{-7}$ m	A1
4(c)(i)	waves are out of phase by a quarter of a cycle / period **or** when one wave has maximum/minimum displacement, the other wave has zero displacement	B1
4(c)(ii)	(statement 2 is) not correct (because) waves do not have phase difference of 180° / not in antiphase **or** one wave has some displacement when other has no displacement **or** the displacements of the waves are not always equal and opposite	B1
4(d)	more diffraction (of light/waves by slits) **or** light/waves are more spread (by slits) **or** light/waves (from slits) have less intensity	B1
	more (bright/dark) fringes **or** bright fringes are less bright / are dimmer / have lower intensity **or** no change to fringe spacing/separation/width	B1

Q2

(b)	wave passes (through) an aperture **or** wave passes (by / through / around) an edge	B1
	wave spreads (into geometrical shadow)	B1
5(c)(i)	$n\lambda = d \sin\theta$	C1
	$d = (3 \times 4.3 \times 10^{-7}) / \sin 68°$ $= 1.4 \times 10^{-6}$ m	A1
5(c)(ii)	$1.4 \times 10^{-6} \times \sin 68° = 2 \times \lambda$ **or** $3 \times 4.3 \times 10^{-7} = 2 \times \lambda$	C1
	$\lambda = 6.5 \times 10^{-7}$ m	A1

Q3

(i)	constant phase difference (between the waves) (with time)	B1
5(b)(ii)	$\lambda = ax / D$	C1
	$x = 22 / 8$ **or** 2.75 (mm) **or** $22 \times 10^{-3} / 8$ **or** 2.75×10^{-3} (m)	C1
	$a = (6.2 \times 10^{-7} \times 2.8) / (22 \times 10^{-3} / 8)$ $= 6.3 \times 10^{-4}$ m	A1
5(c)(i)	difference in distances $= 6.2 \times 10^{-7} / 2$ $= 3.1 \times 10^{-7}$ m	A1
5(c)(ii)	phase difference = 360°	A1

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

Q4

)	$\lambda = v / f$	C1
	$= 340 / 1700$ $= 0.20$ m	A1
5(b)(ii)	$L = \frac{3}{4} \times \lambda = \frac{3}{4} \times 0.20$ $= 0.15$ m	A1
5(b)(iii)	$\lambda = 4 \times 0.15$ **or** 0.20×3 $= 0.60$ m	A1

Q5

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 $= 2.8 \times 0.20$ $= 0.56$ 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
4(d)(i)	when (two or more) waves meet (at a point)	B1
	(resultant) displacement is the sum of the individual displacements	B1
4(d)(ii)	node-to-node separation is $\lambda / 2$ **or** microphone moves through 3 node-to-node separations **or** $d = 1.5\lambda$	C1
	$\lambda = 1.05 / 1.5$ $= 0.70$ m	A1
4(d)(iii)	$v = f \times \lambda$	C1
	$= 500 \times 0.70$ $= 350$ m s^{-1}	A1

Q6

(b)(i)	path difference (from slits to P) is zero **or** phase difference (between waves at P) is zero (so constructive interference)	B1
5(b)(ii)	$\lambda = ax / D$	C1
	$D = (3.6 \times 10^{-4} \times 4.0 \times 10^{-3}) / 630 \times 10^{-9}$	C1
	$= 2.3$ m	A1
5(c)	upward sloping straight line starting from a non-zero value of x at $\lambda = 400$ nm	B1

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

Q7

)	(they travel in) opposite directions	B1
5(b)(i)	straight line from A to B, labelled P	B1
	line that is 'mirror image' of given line, labelled Q	B1
5(b)(ii)	$\lambda = 0.80 / 2$ $(= 0.40\ \text{m})$	C1
	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$v = 0.40 / 0.016$ **or** 62.5×0.40 $= 25\ \text{m s}^{-1}$	A1
5(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

Q8

a)	wave(s) (travel along string and) reflect at fixed point / A / B / end	B1
	incident and reflected waves superpose / interfere **or** two waves travelling / with speed in opposite directions superpose / interfere	B1
5(b)	line has an approximate sinusoidal shape with maximum downward displacement at P and zero displacement at each node	B1
5(c)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$\lambda = 35 \times 0.040$ **or** $35 / 25$ $(= 1.4\ \text{m})$	C1
	distance $= 1.4 \times 2.5$ $= 3.5\ \text{m}$	A1
5(d)	(number of periods / cycles) $(= t / T) = 0.060 / 0.040$ $(= 1.5)$	C1
	amplitude $= 72 / 6$ $= 12\ \text{mm}$	A1

Q9

a)	constant phase difference (between the waves)	B1
5(b)(i)	path difference $= 1.5 \times 660$ $= 990\ \text{nm}$	A1
5(b)(ii)	phase difference $= 360° \times 1.5$ $= 540°$	A1
5(c)	$\lambda = ax / D$	C1
	$x = (660 \times 10^{-9} \times 1.8) / 0.44 \times 10^{-3}$	C1
	$= 2.7 \times 10^{-3}\ \text{m}$	A1

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

5(d)	bright fringes are brighter	B1
	no change to dark fringes	B1
	no change to (fringe) separation / (fringe) spacing	B1
5(e)	(blue light has) shorter wavelength	M1
	(so) decrease (slit) separation	A1

Q10

	power = intensity × area	C1
	$= 1.3 \times 10^3 \times (\pi \times 0.055^2)$ = 12 W	A1
5(a)(ii)	intensity = power / area $= 12 / (\pi \times 0.0015^2)$ $= 1.7 \times 10^6$ 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
5(b)(iii)	$d \sin \theta = n\lambda$ **or** $(1 / N) \times \sin \theta = n\lambda$	C1
	$d = 1 / 2400 \times 10^3$ (m) $= 4.2 \times 10^{-7}$ (m) **or** $N = 2400 \times 10^3$ (m^{-1})	C1
	$n = 4.2 \times 10^{-7} \times \sin 90° / 8.1 \times 10^{-8}$ **or** $\sin 90° / 2400 \times 10^3 \times 8.1 \times 10^{-8}$ n = 5.2 or 5.1 **or** when $n = 5$, $\theta = 76.4°$ and when $n = 6$, $\sin\theta > 1$ (so) $n = 5$	B1
	number of maxima = (2 × 5) + 1 = 11	A1
5(b)(iv)	the wavelength has increased	M1
	(so) number of maxima decreases	A1

Q11

i)	(two) waves travelling (at same speed) in opposite directions overlap	B1
	waves (of the same type) have same frequency/wavelength	B1
5(a)(ii)	phase difference = 0	A1

Q12 (a)	a (much) louder sound can be heard	B1
5(b)	$v = f\lambda$	C1
	λ = 340 / 530 (= 0.64 m)	C1
	height = 0.64 / 4 = 0.16 m	A1
5(c)	distance = 0.64 / 2 **or** 0.16 × 2 **or** (¾ × 0.64 – ¼ × 0.64) = 0.32 m	A1

Q13)(i)	$\lambda = ax / D$	C1
	$G = x / D$ (so) $a = \lambda / G$	A1
5(c)(ii)	straight line from origin always below printed line	M1
	line is half the height of printed line at maximum *D*	A1

Q14 a)	time for one oscillation/vibration/cycle **or** time between adjacent wavefronts (passing the same point) **or** shortest time between two wavefronts (passing the same point)	B1
4(b)	(when two or more) waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of the individual displacements	B1
4(c)(i)	microwave(s)	B1
4(c)(ii)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1/T$	C1
	$T = 0.040 / 3.00 \times 10^{8}$	C1
	$= 1.33 \times 10^{-10}$ (s) $= 1.33 \times 10^{-10} / 10^{-12}$ (ps) = 130 ps	A1
4(c)(iii)	(1.380 – 1.240) / 0.040 = 3.5 **or** 1.380 / 0.040 – 1.240 / 0.040 = 3.5	A1
4(c)(iv)	phase difference = 1260° **or** 180°	A1
4(c)(v)	(always) zero	A1
4(c)(vi)	increase in distance between (adjacent intensity) maxima/minima	A1

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504

Q15

(a)	(when two or more) waves meet/overlap (at a point)	**B1**
	(resultant) displacement is sum of the individual displacements	**B1**
4(b)	intensity ∝ amplitude^2	**C1**
	maximum intensity = 9I	**A1**
4(c)(i)	$x = \lambda D / a$	**C1**
	$= (550 \times 10^{-9} \times 1.2) / (0.35 \times 10^{-3})$	**C1**
	$= 1.9 \times 10^{-3}$ m	**A1**
4(c)(ii)	red light has longer wavelength (than 550 nm) so distance (between fringes) increases	**B1**

Q16

(a)	the waves (of the same type) move in opposite directions and overlap	**B1**
	the waves have the same (speed and) frequency/wavelength	**B1**
6(b)(i)	zero amplitude	**B1**
6(b)(ii)	distance $= 6.0 \times 4$ $= 24$ cm	**A1**
6(b)(iii)	180°	**A1**

Q17

(a)	$v = f\lambda$ **or** $c = f\lambda$	**C1**
	$f = 3.0 \times 10^8 / 0.040$	**C1**
	$= 7.5 \times 10^9$ (Hz) $= 7.5$ GHz	**A1**
5(b)(i)	path difference = 0.020 m	**A1**
5(b)(ii)	phase difference = 180°	**A1**
5(c)	(intensity) increases	**C1**
	(intensity) increases by a factor of 4	**A1**
5(d)(i)	minimum moves closer to the maximum **or** decrease in separation of maximum and minimum	**B1**
5(d)(ii)	the maximum and minimum exchange places **or** the maximum becomes a minimum **and** the minimum becomes a maximum	**B1**

Q18

a)(i)	(two) waves meet/overlap (at a point)	**B1**
	(resultant) displacement is sum of the displacement of each wave	**B1**
5(a)(ii)	constant phase difference (between the waves)	**B1**
5(b)	$I \propto A^2$ $3I / I = (A + 1.5)^2 / 1.5^2$	**C1**
	$A = 1.1$ cm	**A1**
5(c)(i)	$\lambda = ax / D$	**C1**
	e.g. $a = 680 \times 10^{-9} \times 2.0 / 4.0 \times 10^{-3}$	**C1**
	$a = 3.4 \times 10^{-4}$ m	**A1**
5(c)(ii)	straight line from positive value on x-axis and always below 'old' line	**B1**
	straight line with a smaller positive gradient than 'old' line	**B1**

Q19	(a)	$n\lambda = d\sin\theta$	C1
		$\lambda = 640 \times 10^{-9}$ (m)	C1
		$2 \times 640 \times 10^{-9} = 1.7 \times 10^{-6} \times \sin\theta$ so $\theta = 49(°)$	A1
	5(b)	$2 \times 640 \times 10^{-9} = 3 \times \lambda$ **or** $1.7 \times 10^{-6} \times \sin 49° = 3 \times \lambda$	C1
		$\lambda = 4.3 \times 10^{-7}$ m	A1

Q20	(a)	when (two or more) waves meet (at a point)	B1
		(resultant) displacement is the sum of the individual displacements	B1
	4(b)(i)	constant phase difference (between the waves)	B1
	4(b)(ii)	**1.** phase difference = 360° **or** 0	B1
		2. path difference = 1.5λ = 1.5×610 = 920 nm	A1
	4(b)(iii)	$\lambda = ax/D$	C1
		$x = 22/4$ (= 5.5 mm) **or** $22 \times 10^{-3}/4$ (= 5.5×10^{-3} m)	C1
		$a = (610 \times 10^{-9} \times 2.7)/(5.5 \times 10^{-3})$ $= 3.0 \times 10^{-4}$ m	A1
	4(b)(iv)	shorter wavelength **and** (so) separation decreases	B1
	4(b)(v)	• no change to fringe separation/fringe width/number of fringes • bright fringes are brighter • dark fringes are unchanged *Any two of the above three points, 1 mark each.*	B2

Q21	(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
		$f = 330/0.50$ = 660 Hz	A1
	4(b)(iii)	(readings from graph =) 2.6 <u>and</u> 4.0	C1
		ratio = $(2.6/4.0)^{1/2}$ = 0.81	A1

Q22)(i)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	**B1**
4(a)(ii)	(position where) maximum amplitude	**B1**
4(b)(i)	$\lambda = 4 \times 0.045$ (= 0.18 (m) or 18 (cm))	**C1**
	$v = f\lambda$	**C1**
	$f = 340/0.18$ = 1900 Hz	**A1**
4(b)(ii)	distance = $\lambda/2$ (= 0.09 (m) or 9 (cm))	**C1**
	time = 0.09 / 0.0075 = 12 s	**A1**
	or	
	$t = 4.5/0.75$ **and** $t = 13.5/0.75$	**(C1)**
	time = 18 – 6 = 12 s	**(A1)**

Q23)	waves spread at (each) slit/gap	**B1**
5(a)(ii)	constant phase difference (between (each of) the waves)	**B1**
5(b)(i)	$n\lambda = d\sin\theta$	**B1**
	$d\sin\theta$ is the same **and** $3\lambda_1 = 4\lambda_2$ so $\lambda_2/\lambda_1 = 0.75$	**A1**
5(b)(ii)	$\lambda_2/\lambda_1 = 0.75$ and $\lambda_1 - \lambda_2 = 170$ $\lambda_1 = 680$ nm	**A1**

Q24 a)	(two) waves (travelling at same speed) in opposite directions overlap	**B1**
	(waves are same type and) have same frequency / wavelength	**B1**
4(b)(i)	$v = f\lambda$ $f = 330/0.18$	**C1**
	= 1800 Hz (1830 Hz)	**A1**
4(b)(ii)	$T = 1/1800$ (= 5.5×10^{-4}) time-base setting = ($1.5 \times 5.5 \times 10^{-4}$) / 8.0 or 1 / (1800 × 5.3)	**C1**
	= 1.0×10^{-4} s cm^{-1}	**A1**
4(b)(iii)	waveform drawn with same period as original waveform	**B1**
	waveform drawn with amplitude of 1.7 cm	**B1**
4(c)(i)	distance = $\lambda/2 = 0.18/2$ = 0.090 m	**A1**
4(c)(ii)	letter N shown at level B and at level A and not anywhere else.	**B1**
4(c)(iii)	$m = \rho Ax$ = 0.79 × 13 × 9.0 (=92.4) or 790 × 13×10^{-4} × 0.090 (=0.0924) t = 92.4 / 6.7 or 0.0924 / 0.0067	**C1**
	= 14 s	**A1**

Q25 (i)	in a stationary wave energy is not transferred **or** in a progressive wave energy is transferred	**B1**
3(a)(ii)	in a stationary wave (adjacent) particles are in phase **or** in a progressive wave (adjacent) particles are out of phase/have a phase difference/not in phase	**B1**
3(b)(i)	(position where) maximum amplitude	**B1**
3(b)(ii)	distance = 0.10 m	**B1**
3(b)(iii)	**1.** λ = 0.60/1.5 = 0.40 m	**A1**
	2. $v = f\lambda$	**C1**
	f = 340/0.40 = 850 Hz	**A1**
3(b)(iv)	$\lambda = 2 \times 0.60$ **or** $\lambda = 3 \times 0.40$ **or** f = 850/3	**C1**
	f = 280 (283) Hz	**A1**

PHYSICS WITH CYRUS
Cyrus Ishaq
ISL, BLL, BCCG, LGS, Roots IVY P5
+923008471504