8. Superposition

8.3 Interference

Paper 2

Question Paper

1 Two coherent sources X and Y of microwaves of frequency 2.5×10^{10} Hz are a distance of 0.18 m apart in a vacuum, as shown in Fig. 6.1.

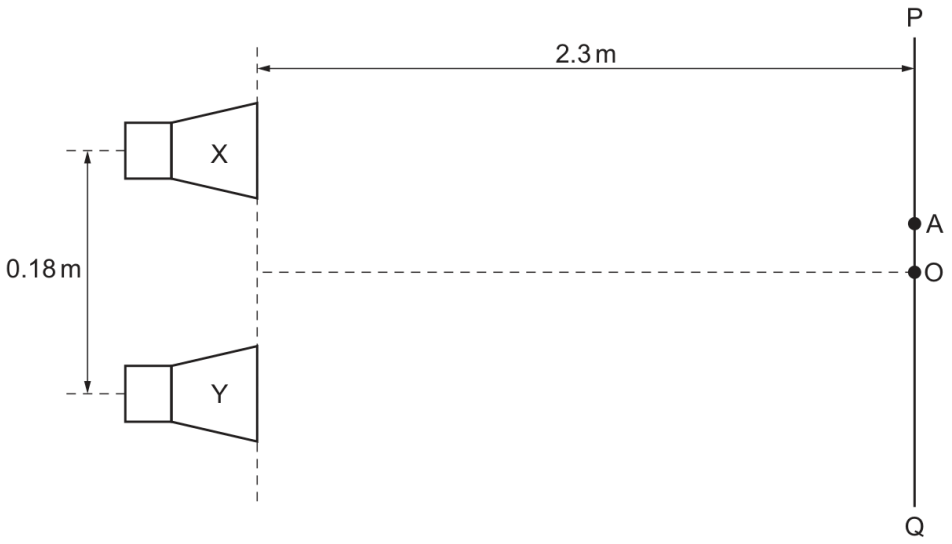


Fig. 6.1 (not to scale)

There is a phase difference of 90° between the waves emitted at the two sources.

A microwave detector moves along the line PQ, which is parallel to the line joining the two sources and 2.3 m away from it.

Point O is on the line PQ at a position that is equidistant from the two sources.
Point A is the position on line PQ where the intensity of the microwaves is the greatest.

(a) (i) Explain why the position of greatest intensity is **not** at point O.

.....

.....

.....

..... [2]

(ii) On Fig. 6.1, draw a cross (×) to show the position of the point on line PQ where the intensity minimum that is the closest to point O occurs. Label this point B. [2]

(b) (ii) For point A on line PQ, determine the difference in the distances Δx travelled by the microwaves from X and the microwaves from Y.

Δx = ... m [1]

(iii) Use the formula for the double-slit interference of light to calculate the distance between adjacent intensity maxima on line PQ.

distance = ... m [2]

2 **(b)** An arrangement that uses a double slit to demonstrate the interference of light from a laser is shown in Fig. 5.1.

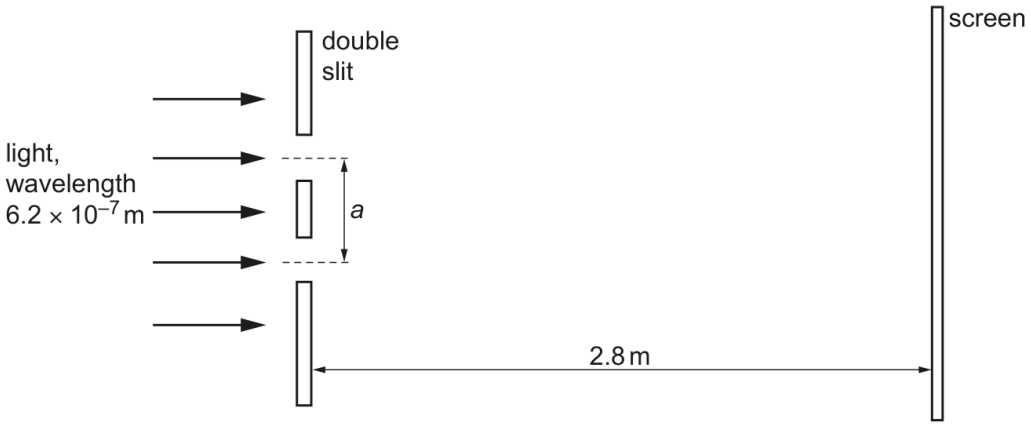


Fig. 5.1 (not to scale)

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.

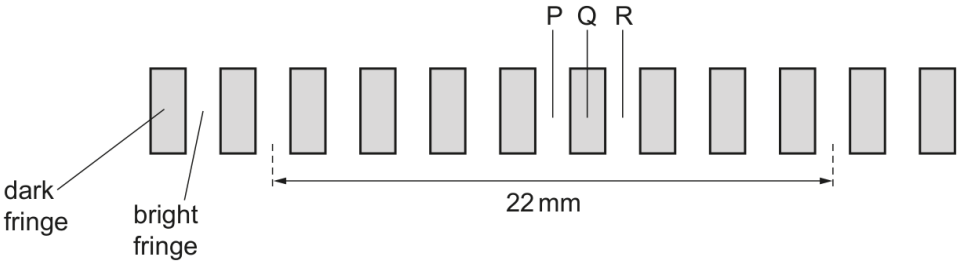


Fig. 5.2

(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]

3 **(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.

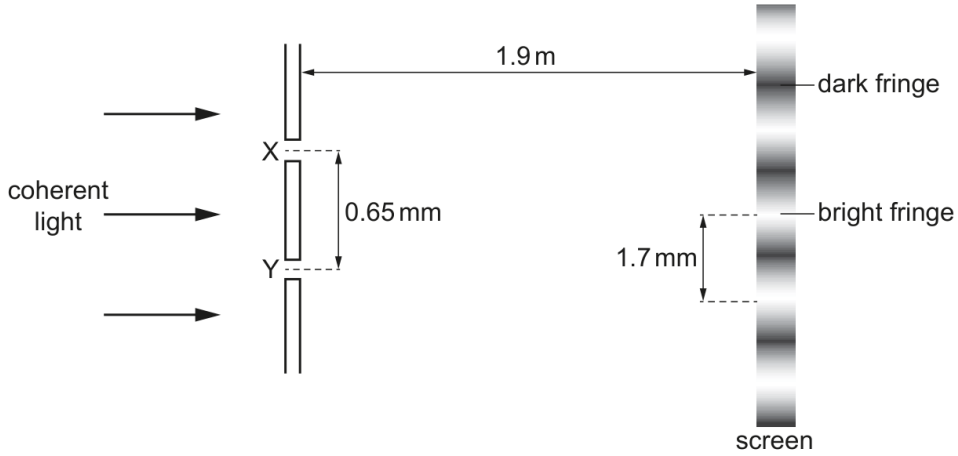


Fig. 4.1 (not to scale)

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.

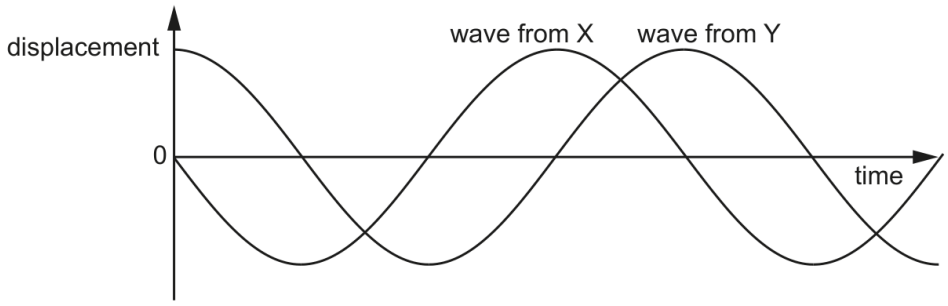


Fig. 4.2

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.

.....

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..... [1]

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

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..... [1]

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

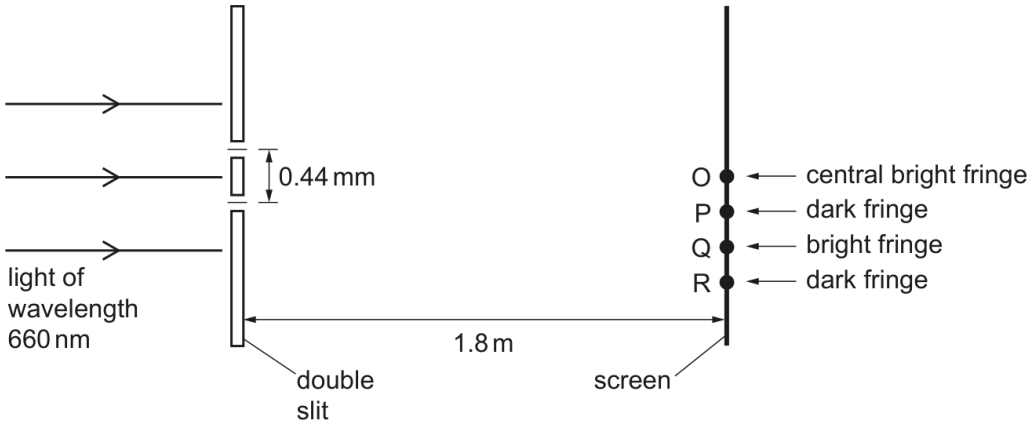


Fig. 5.1 (not to scale)

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]

(ii) their phase difference.

phase difference = ... ° [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.

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.....

.....

..... [2]

5 **(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.

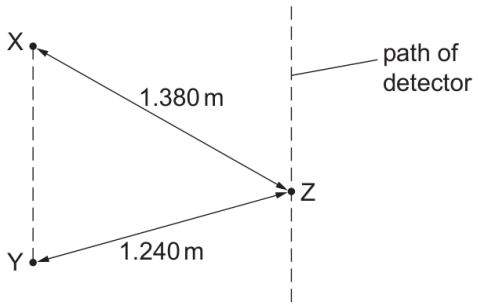


Fig. 4.1 (not to scale)

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.

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

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..... [1]

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

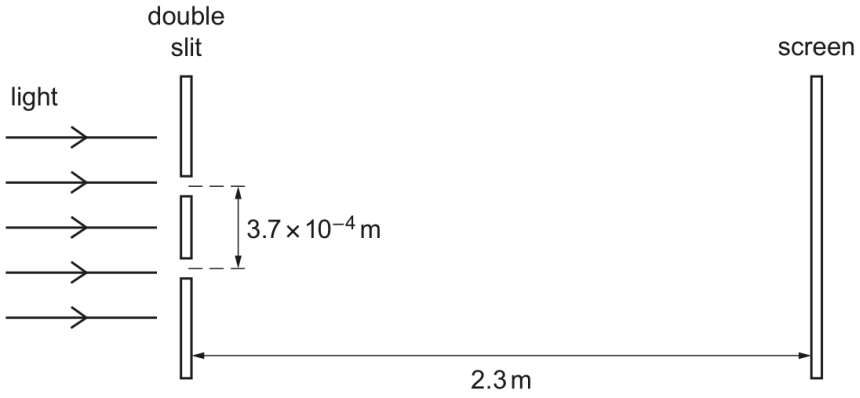


Fig. 4.1 (not to scale)

The light from the laser is incident normally on the plane of the double slit.
The separation of the two slits is 3.7×10^{-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 4.3×10^{-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.

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..... [2]

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

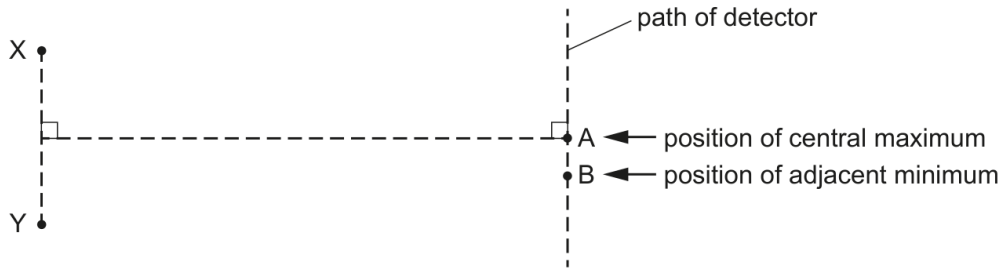


Fig. 5.1 (not to scale)

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.

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

(i) the path difference

path difference = ... m [1]

(ii) the phase difference.

phase difference = ...° [1]

(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.

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..... [1]

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

.....

..... [1]

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

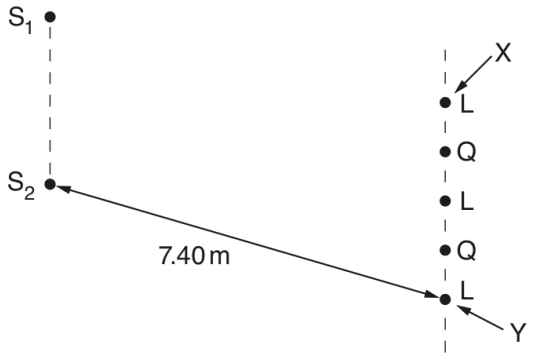


Fig. 5.2 (not to scale)

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]

9 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.

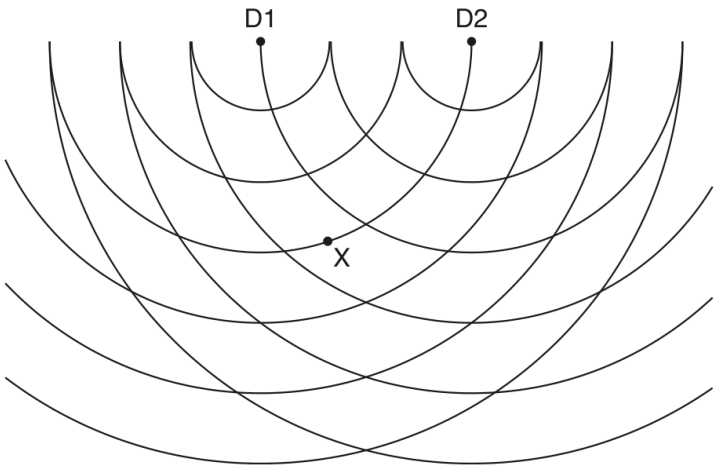


Fig. 5.1

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.

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..... [1]

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

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..... [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.

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..... [1]

(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]

10 **(c)** The source emitting the sound in **(b)** is at point A. Waves travel from the source to point C along two different paths, AC and ABC, as shown in Fig. 5.2.

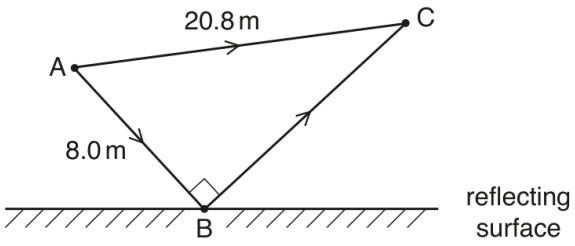


Fig. 5.2 (not to scale)

Distance AB is 8.0 m and distance AC is 20.8 m. Angle ABC is 90°. Assume that there is no phase change of the sound wave due to the reflection at point B. The wavelength of the waves is 1.6 m.

(i) Show that the waves meeting at C have a path difference of 6.4 m.

[1]

(ii) Explain why an intensity maximum is detected at point C.

.....

.....

..... [2]

(iv) The wavelength of the sound is gradually increased. Calculate the wavelength of the sound when an intensity maximum is next detected at point C.

wavelength = ... m [1]

11 **(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

(ii) *coherent* waves.

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.....[1]

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

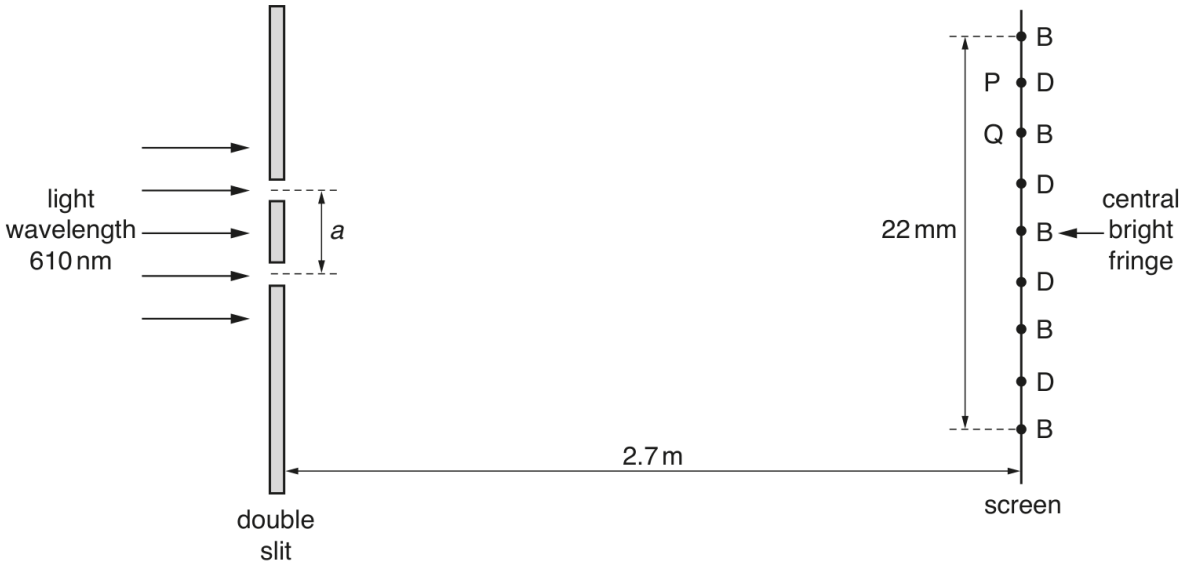


Fig. 4.1 (not to scale)

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.

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..... [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]