Waves

1. Nov 01-Q/6

Light of frequency 4.8 x 10^{14} Hz is incident normally on a double slit, as illustrated in Fig. 6.1.

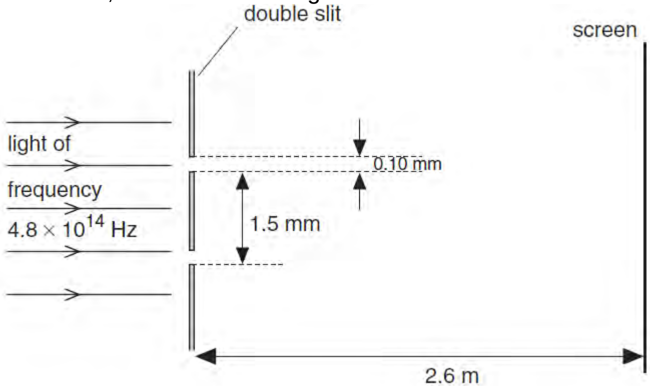


Fig. 6.1 (not to scale)

Each slit of the double slit arrangement is 0.10 mm wide and the slits are separated by 1.5 mm. The pattern of fringes produced is observed on a screen at a distance 2.6 m from the double slit.

(a) (i) Show that the width of each slit is approximately 160 times the wavelength of the incident light. [3]

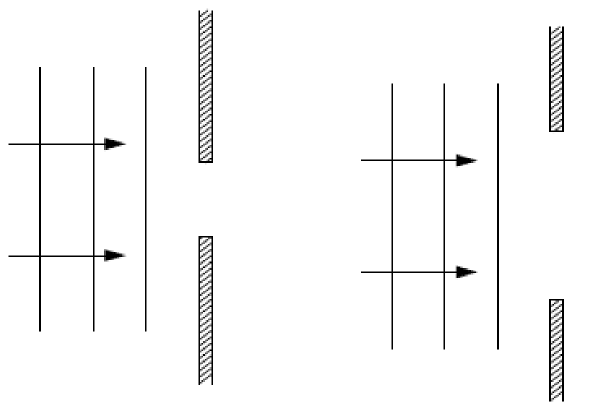
(ii) Hence explain why the pattern of fringes on the screen is seen over a *limited* area of the screen.[3]

(b) Calculate the separation of the fringes observed on the screen. separation = ... mm [3]

(c) The intensity of the light incident on the double slit is increased. State the effect, if any, on the separation and on the appearance of the fringes. [3]

2. May 02-Q/7

(a) Figs. 7.1(a) and (b) show plane wavefronts approaching a narrow gap and a wide gap respectively.



(a) **(b)**

Fig. 7.1

On Figs. 7.1(a) and (b), draw three successive wavefronts to represent the wave after it has passed through each of the gaps. [5]

(b) Light from a laser is directed normally at a diffraction grating, as illustrated in Fig. 7.2.

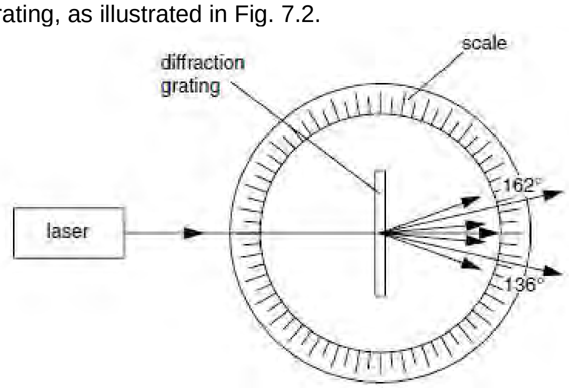


Fig. 7.2

The diffraction grating is situated at the centre of a circular scale, marked in degrees.

The readings on the scale for the second order diffracted beams are 136° and 162°.

The wavelength of the laser light is 630 nm.

Calculate the spacing of the slits of the diffraction grating.

spacing = ... m [4]

(c) Suggest one reason why the fringe pattern produced by light passing through a diffraction grating is brighter than that produced from the same source with a double slit. [1]

3. Nov 02-Q/5

The variation with time *t* of the displacement *x* of a point in a transverse wave T_1 is shown in Fig. 5.1.

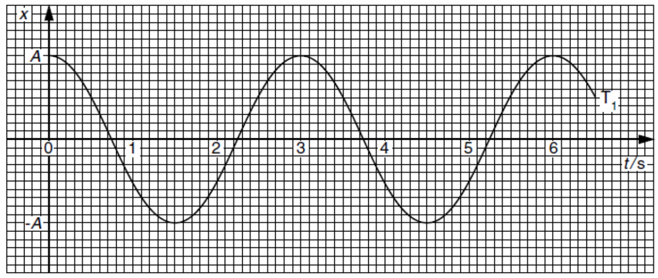


Fig. 5.1

(a) By reference to displacement and direction of travel of wave energy, explain what is meant by a *transverse wave*.[1]

(b) A second transverse wave T_2, of amplitude *A* has the same waveform as wave T_1 but lags behind T_1 by a phase angle of 60°. The two waves T_1 and T_2 pass through the same point.

(i) On Fig. 5.1, draw the variation with time *t* of the displacement *x* of the point in wave T_2. [2]

(ii) Explain what is meant by the *principle of superposition* of two waves.[2]

(iii) For the time *t* = 1.0 s, use Fig. 5.1 to determine, in terms of *A*,

1. the displacement due to wave T_1 alone,

displacement = ……………………………………

2. the displacement due to wave T_2 alone,

displacement = ……………………………………

3. the resultant displacement due to both waves.

displacement = ……………………………….[3]

4. May 03-Q/4

(a) State three conditions that must be satisfied in order that two waves may interfere.

(b) The apparatus illustrated in Fig. 4.1 is used to demonstrate two-source interference using light.

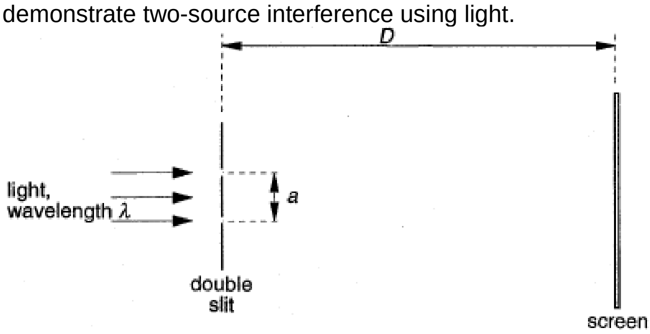


Fig. 4.1 (not to scale)

The separation of the two slits in the double slit arrangement is *a* and the interference fringes are viewed on a screen at a distance D from the double slit. When light of wavelength A is incident on the double slit, the separation of the bright fringes on the screen is x.

(i) 1. Suggest a suitable value for the separation *a* of the slits in the double slit.

2. Write down an expression relating A, a, D and x. [2]

(ii) Describe the effect, if any, on the separation and on the maximum brightness of the fringes when the following changes are made.

1. The distance *D* is increased to 2D, keeping *a* and A constant.

2. The wavelength A is increased to 1.5A, keeping *a* and *D* constant.
3. The intensity of the light incident on the double slit is increased, keeping A, *a* and D constant. [7]

5. Nov 03-Q/4

4 (a) Fig. 4.1 shows the variation with time *t* of the displacement *x* of one point in a progressive wave.

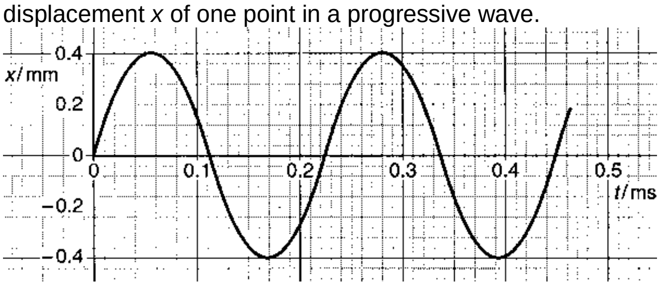


Fig. 4.1

Fig. 4.2 shows the variation with distance *d* along the same wave of the displacement

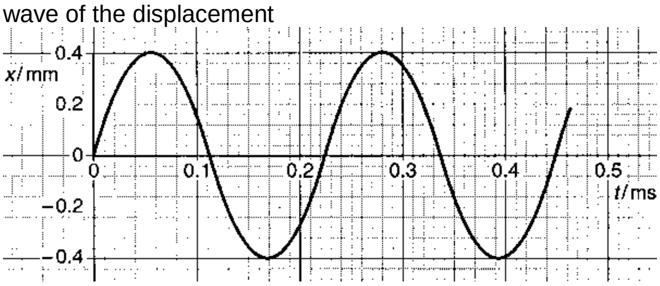


Fig. 4.2

(i) Use Figs. 4.1 and 4.2 to determine, for this wave,
1. the amplitude amplitude =..................... mm
2. the wavelength, wavelength =......................m
3. the frequency, frequency =................... Hz
4. the speed speed =......................... ms^{-1} [6]

(ii) On Fig. 4.2, draw a second wave having the same amplitude but half the frequency as that shown. [1]

(b) Light of wavelength 590 nm is incident at right angles to a diffraction grating having 5.80×10^5 lines per metre, as illustrated in Fig. 4.3.

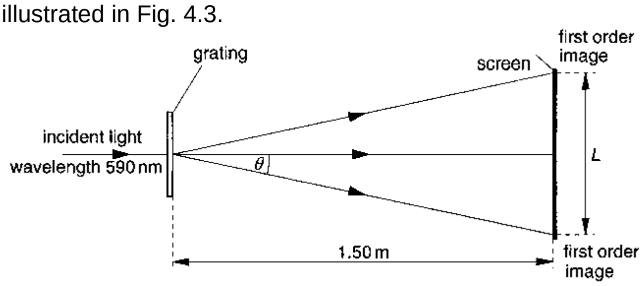


Fig. 4.3

A screen is placed parallel to and 1.50 m from the grating.
Calculate (i) the spacing, in μm, of the lines of the grating,
spacing=…………….μm
(ii) the angle θ to the original direction of the light at which the first order diffracted image is seen, θ=………………

(iii) the minimum length L of the screen so that both first order diffracted images may be viewed at the same time on the screen. Length:………………………[5]

6. May04-Q/2

Fig. 2.1 shows the variation with distance *x* along a wave of its displacement *d* at a particular time.

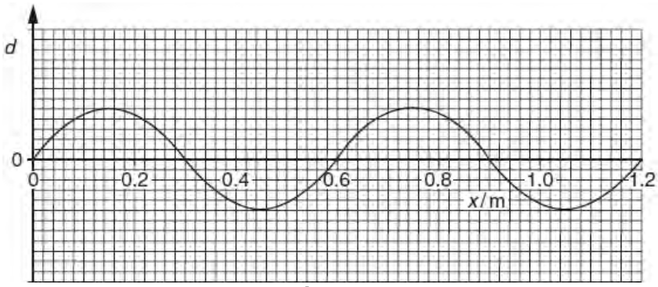


Fig. 2.1

The wave is a progressive wave having a speed of 330ms–1.
(a) (i) Use Fig. 2.1 to determine the wavelength of the wave.
wavelength = ... m
(ii) Hence calculate the frequency of the wave.
frequency = ... Hz [3]
(b) A second wave has the same frequency and speed as the wave shown in Fig. 2.1 but has double the intensity. The phase difference between the two waves is 180°.
On the axes of Fig. 2.1, sketch a graph to show the variation with distance *x* of the displacement *d* of this second wave. [2]

7. May 04-Q/6

Fig. 6.1 shows wavefronts incident on, and emerging from, a double slit arrangement.

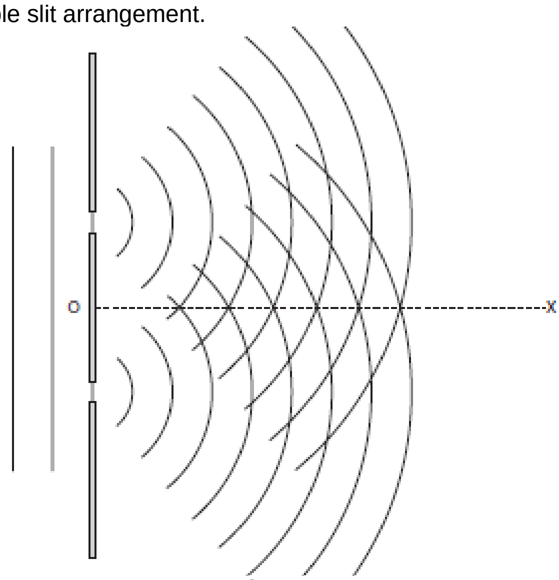


Fig. 6.1

The wavefronts represent successive crests of the wave. The line OX shows one direction along which constructive interference may be observed.
(a) State the principle of superposition. [3]
(b) On Fig. 6.1, draw lines to show
(i) a second direction along which constructive interference may be observed (label this line CC),
(ii) a direction along which destructive interference may be observed (label this line DD). [2]
(c) Light of wavelength 650 nm is incident normally on a double slit arrangement. The interference fringes formed are viewed on a screen placed parallel to and 1.2m from the plane of the double slit, as shown in Fig. 6.2.

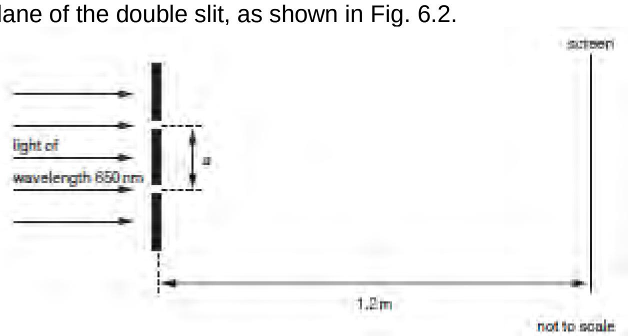


Fig. 6.2

The fringe separation is 0.70 mm.
(i) Calculate the separation *a* of the slits.
separation = ... m [3]

(ii) The width of both slits is increased without changing their separation *a*. State the effect, if any, that this change has on
1. the separation of the fringes,
2. the brightness of the light fringes,
3. the brightness of the dark fringes. [3]

8. Nov 04-Q2

The spectrum of electromagnetic waves is divided into a number of regions such as radio waves, visible light and gamma radiation.
(a) State three distinct features of waves that are common to all regions of the electromagnetic spectrum. [3]
(b) A typical wavelength of visible light is 495 nm. Calculate the number of wavelengths of this light in a wave of length 1.00m. number = ………………………… [2]
(c) State a typical wavelength for
(i) X-rays, wavelength = ………………………… m
(ii) infra-red radiation. wavelength = ………… m [2]

9. Nov 04-Q4

A string is stretched between two fixed points. It is plucked at its centre and the string vibrates, forming a stationary wave as illustrated in Fig. 4.1.

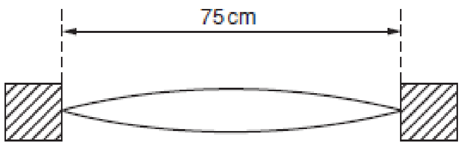


Fig. 4.1

The length of the string is 75 cm.
(a) State the wavelength of the wave.
wavelength = ………………………… m [1]
(b) The frequency of vibration of the string is 360 Hz. Calculate the speed of the wave on the string. speed = …………………………… ms^{-1} [2]
(c) By reference to the formation of the stationary wave on the string, explain what is meant by the speed calculated in **(b)**. [3]

10. May 05-Q/5

5 (a) Explain what is meant by the *diffraction* of a wave. [2]
(b) Light of wavelength 590 nm is incident normally on a diffraction grating having 750 lines per millimetre.
The diffraction grating formula may be expressed in the form

$$d \sin\theta = n\lambda.$$

(i) Calculate the value of *d*, in metres, for this grating.
d = ... m [2]
(ii) Determine the maximum value of *n* for the light incident normally on the grating.
maximum value of *n* = ... [2]
(iii) Fig. 5.1 shows incident light that is not normal to the grating.

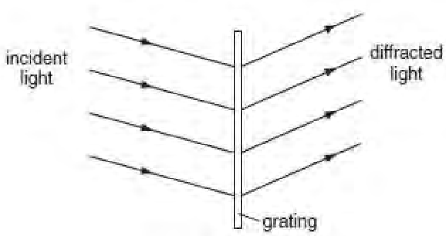


Fig. 5.1

Suggest why the diffraction grating formula, $d \sin\theta = n\lambda$, should **not** be used in this situation.[1]
(c) Light of wavelengths 590 nm and 595 nm is now incident normally on the grating.
Two lines are observed in the first order spectrum and two lines are observed in the second order spectrum, corresponding to the two wavelengths.
State two differences between the first order spectrum and the second order spectrum. [2]

11.Nov 05-Q/5

Fig. 5.1 shows the variation with time *t* of the displacements x_A and x_B at a point P of two sound waves A and B.

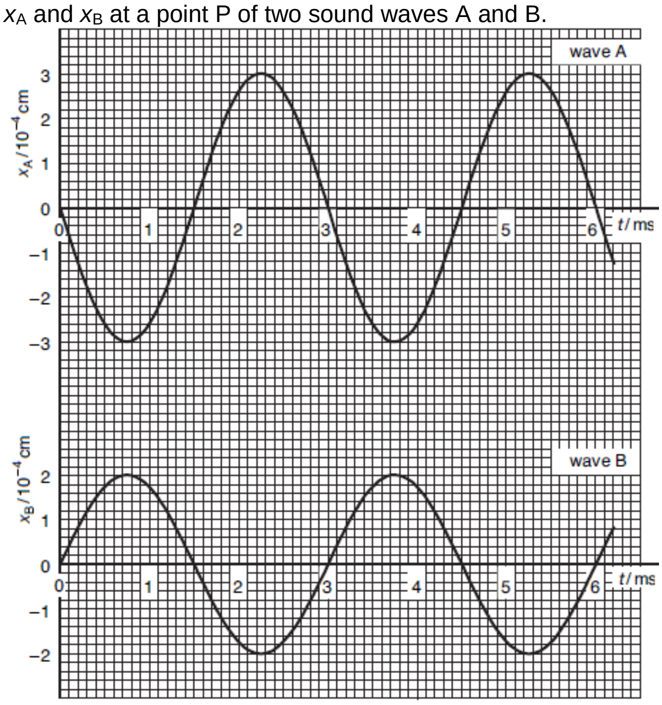


Fig. 5.1

(a) By reference to Fig. 5.1, state one similarity and one difference between these two waves. [2]
(b) State, with a reason, whether the two waves are coherent. [1]
(c) The intensity of wave A alone at point P is *I*.
(i) Show that the intensity of wave B alone at point P is $^{4}/_{9}I$.[2]
(ii) Calculate the resultant intensity, in terms of *I*, of the two waves at point P. resultant intensity =…………….. *I* [2]
(d) Determine the resultant displacement for the two waves at point P
(i) at time *t* = 3.0ms, resultant displacement = …… cm [1]
(ii) at time *t* = 4.0ms. resultant displacement = …… cm [2]

12. Nov 06-Q/6

A long tube, fitted with a tap, is filled with water. A tuning fork is sounded above the top of the tube as the water is allowed to run out of the tube, as shown in Fig. 6.1.

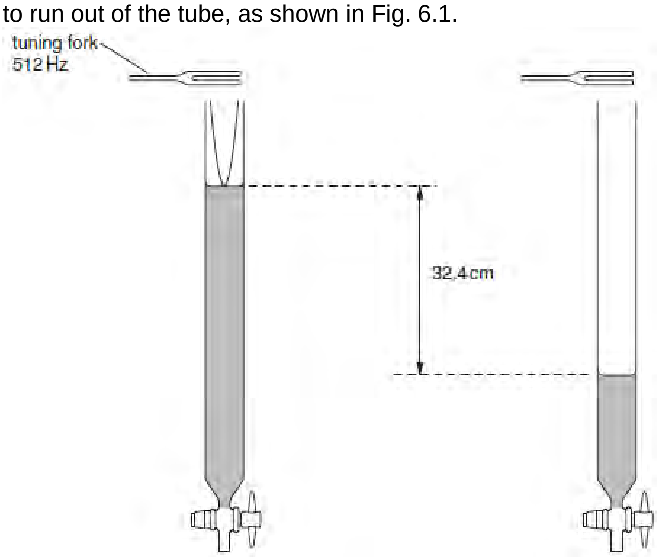


Fig. 6.1 **Fig. 6.2**

A loud sound is first heard when the water level is as shown in Fig. 6.1, and then again when
the water level is as shown in Fig. 6.2.
Fig. 6.1 illustrates the stationary wave produced in the tube.
(a) On Fig. 6.2, **(i)** sketch the form of the stationary wave set up in the tube, [1]
(ii) mark, with the letter N, the positions of any nodes of the stationary wave. [1]
(b) The frequency of the fork is 512Hz and the difference in the height of the water level for the two positions where a

loud sound is heard is 32.4 cm. Calculate the speed of sound in the tube. speed = …………………… ms^{-1} [3]
(c) The length of the column of air in the tube in Fig. 6.1 is 15.7 cm.
Suggest where the antinode of the stationary wave produced in the tube in Fig. 6.1 is likely to be found. [2]

13. Nov 06-Q/4
(a) In order that interference between waves from two sources may be observed, the waves must be coherent. Explain what is meant by
(i) *interference*, [2] **(ii)** *coherence*. [1]
(b) Red light of wavelength 644 nm is incident normally on a diffraction grating having 550 lines per millimetre, as illustrated in Fig. 4.1.

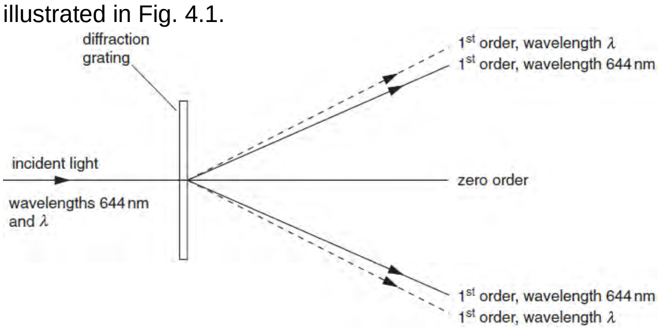


Fig. 4.1

Red light of wavelength λ is also incident normally on the grating. The first order diffracted light of both wavelengths is illustrated in Fig. 4.1.
(i) Calculate the number of orders of diffracted light of wavelength 644 nm that are visible on each side of the zero order. number = ……………………….. [4]
(ii) State and explain
1. whether λ is greater or smaller than 644 nm, [1]
2. in which order of diffracted light there is the greatest separation of the two wavelengths. [2]

14. May 07-Q/5
5 Light reflected from the surface of smooth water may be described as a polarised transverse wave.
(a) By reference to the direction of propagation of energy, explain what is meant by
(i) a *transverse wave*, [1] **(ii)** *polarisation*. [1]
(b) A glass tube, closed at one end, has fine dust sprinkled along its length. A sound source is placed near the open end of the tube, as shown in Fig. 5.1.

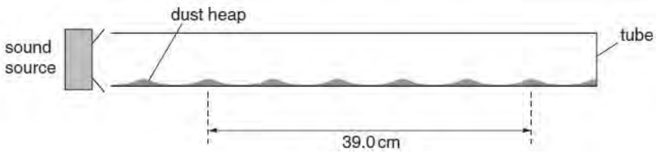


Fig. 5.1

The frequency of the sound emitted by the source is varied and, at one frequency, the dust forms small heaps in the tube.
(i) Explain, by reference to the properties of stationary waves, why the heaps of dust are formed. [3]
(ii) One frequency at which heaps are formed is 2.14 kHz. The distance between six heaps, as shown in Fig. 5.1, is 39.0 cm. Calculate the speed of sound in the tube.
speed = ...m s^{-1} [3]
(c) The wave in the tube is a stationary wave. Explain, by reference to the formation of a stationary wave, what is meant by the speed calculated in **(b)(ii)**. [3]

15. Nov 07-Q/5
(a) Fig. 5.1 shows the variation with time t of the displacement y of a wave W as it passes a point P. The wave has intensity I.

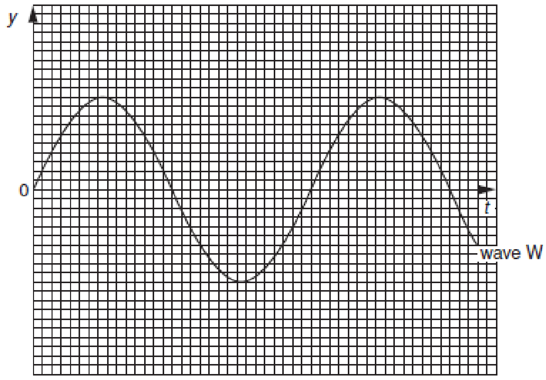


Fig. 5.1

A second wave X of the same frequency as wave W also passes point P. This wave has intensity ½ I. The phase difference between the two waves is 60°.
On Fig. 5.1, sketch the variation with time t of the displacement y of wave X. [3]
(b) In a double-slit interference experiment using light of wavelength 540 nm, the separation of the slits is 0.700 mm. The fringes are viewed on a screen at a distance of 2.75 m from the double slit, as illustrated in Fig. 5.2 (not to scale).

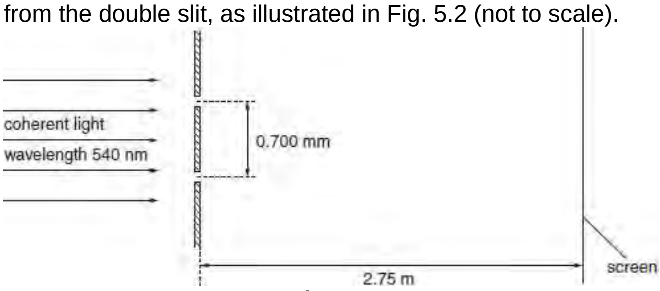


Fig. 5.2

Calculate the separation of the fringes observed on the screen. separation = ... mm [3]
(c) State the effect, if any, on the appearance of the fringes observed on the screen when the following changes are made, separately, to the double-slit arrangement in **(b).**
(i) The width of each slit is increased but the separation remains constant. [3]
(ii) The separation of the slits is increased. [2]

16. May 08-Q/5
(a) State what is meant by
(i) the *frequency* of a progressive wave, [2]
(ii) the *speed* of a progressive wave. [1]
(b) One end of a long string is attached to an oscillator. The string passes over a frictionless pulley and is kept taut by means of a weight, as shown in Fig. 5.1.

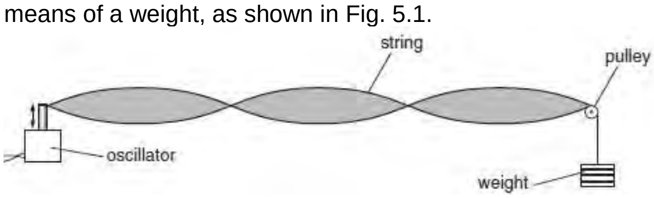


Fig. 5.1

The frequency of oscillation is varied and, at one value of frequency, the wave formed
on the string is as shown in Fig. 5.1.
(i) Explain why the wave is said to be a *stationary wave*. [1]
(ii) State what is meant by an *antinode*. [1]
(iii) On Fig. 5.1, label the antinodes with the letter A. [1]
(c) A weight of 4.00 N is hung from the string in **(b)** and the frequency of oscillation is adjusted until a stationary wave is formed on the string. The separation of the antinodes on the string is 17.8 cm for a frequency of 125 Hz.
The speed v of waves on a string is given by the expression

$$v = \sqrt{\frac{T}{m}},$$

where T is the tension in the string and m is its mass per unit length. Determine the mass per unit length of the string.
mass per unit length = ... kg m^{-1} [5]

17. Nov 08-Q/6

(a) Explain what is meant by the *diffraction* of a wave. [2]
(b) (i) Outline briefly an experiment that may be used to demonstrate diffraction of a transverse wave. [3]
(ii) Suggest how your experiment in **(i)** may be changed to demonstrate the diffraction of a longitudinal wave. [3]

18. May 09-Q/5
Two sources S_1 and S_2 of sound are situated 80 cm apart in air, as shown in Fig. 5.1.

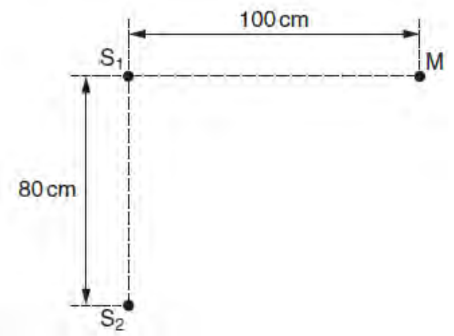


Fig. 5.1

The frequency of vibration can be varied. The two sources always vibrate in phase but have different amplitudes of vibration.
A microphone M is situated a distance 100 cm from S_1 along a line that is normal to S_1S_2.
As the frequency of S_1 and S_2 is gradually increased, the microphone M detects maxima and minima of intensity of sound.
(a) State the two conditions that must be satisfied for the intensity of sound at M to be zero. [2]
(b) The speed of sound in air is 330 m s^{-1}.
The frequency of the sound from S_1 and S_2 is increased.
Determine the number of minima that will be detected at M as the frequency is increased from 1.0 kHz to 4.0 kHz.

number = ... [4]