Answer **all** the questions in the spaces provided.

1 Make reasonable estimates of the following quantities.

(a) the frequency of an audible sound wave

frequency = ... Hz [1]

(b) the wavelength, in nm, of ultraviolet radiation

wavelength = ... nm [1]

(c) the mass of a plastic 30 cm ruler

mass = ... g [1]

(d) the density of air at atmospheric pressure

density = ... kg m^{-3} [1]

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.
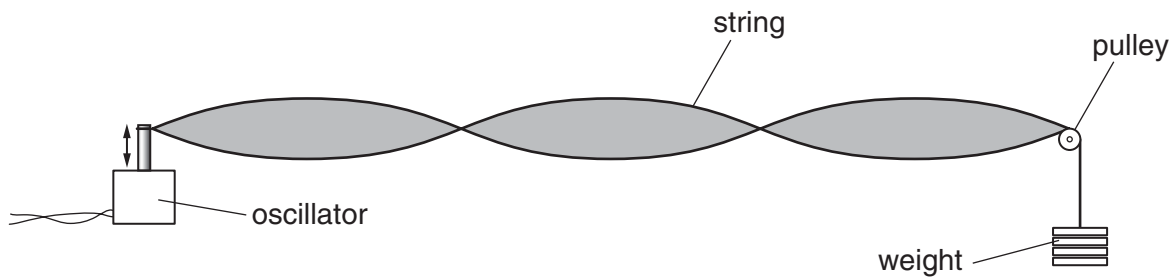

Fig. 5.1

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]

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.
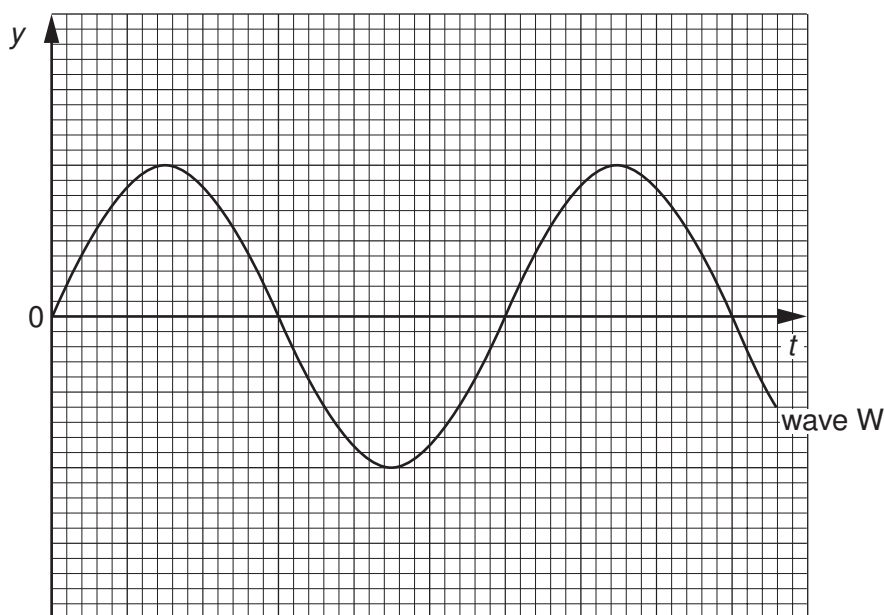

Fig. 5.1

A second wave X of the same frequency as wave W also passes point P.
This wave has intensity $\frac{1}{2}I$. 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).
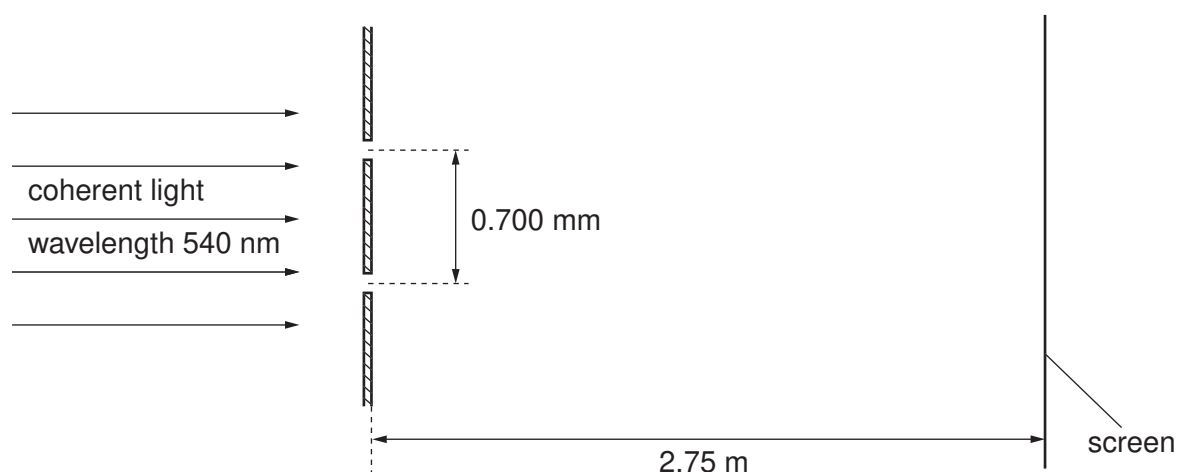

Fig. 5.2

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]

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.
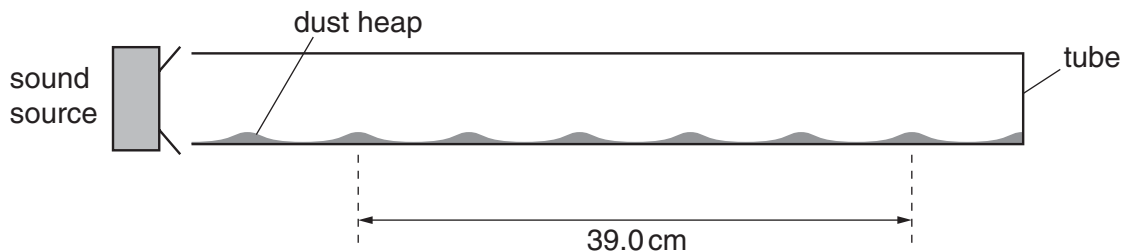

Fig. 5.1

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]

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.
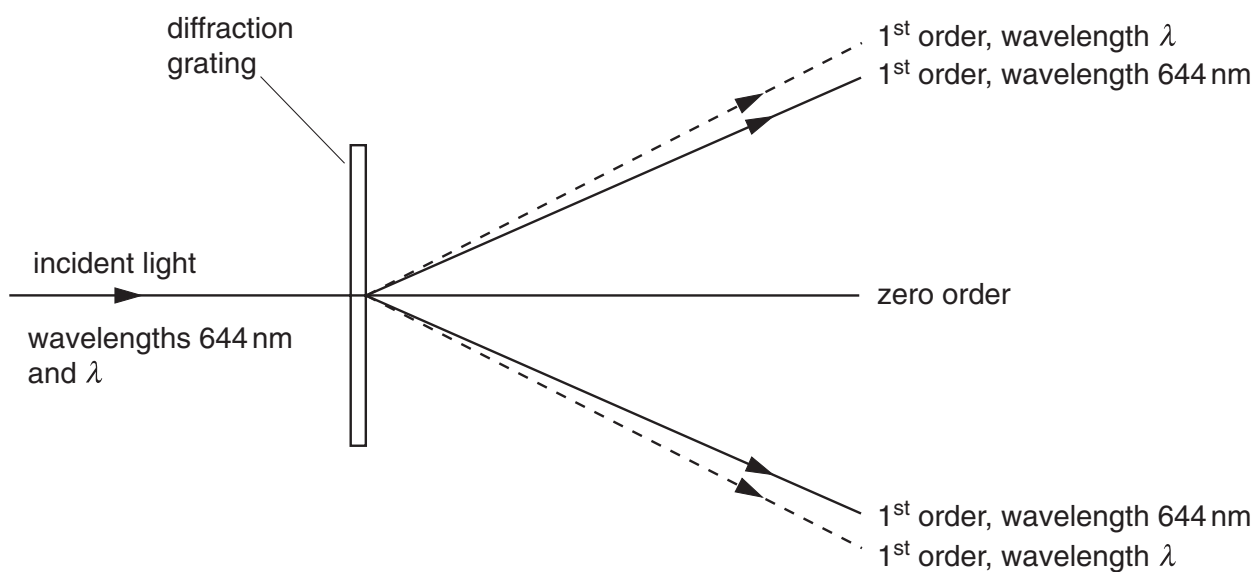
Fig. 4.1

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

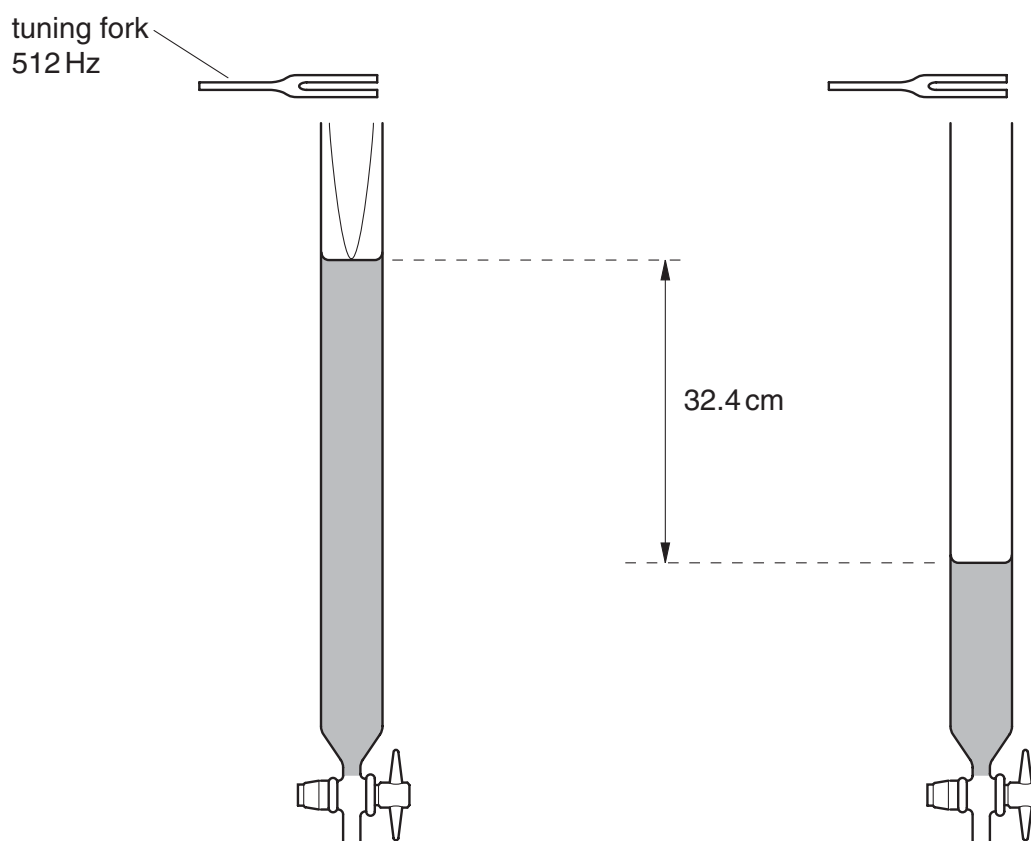1. whether λ is greater or smaller than 644 nm,

....

.... [1]

2. in which order of diffracted light there is the greatest separation of the two wavelengths.

....

....

.... [2]

.

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.

tuning fork
512 Hz

32.4 cm

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 512 Hz 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 = ... m s^{-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]

[Turn over

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

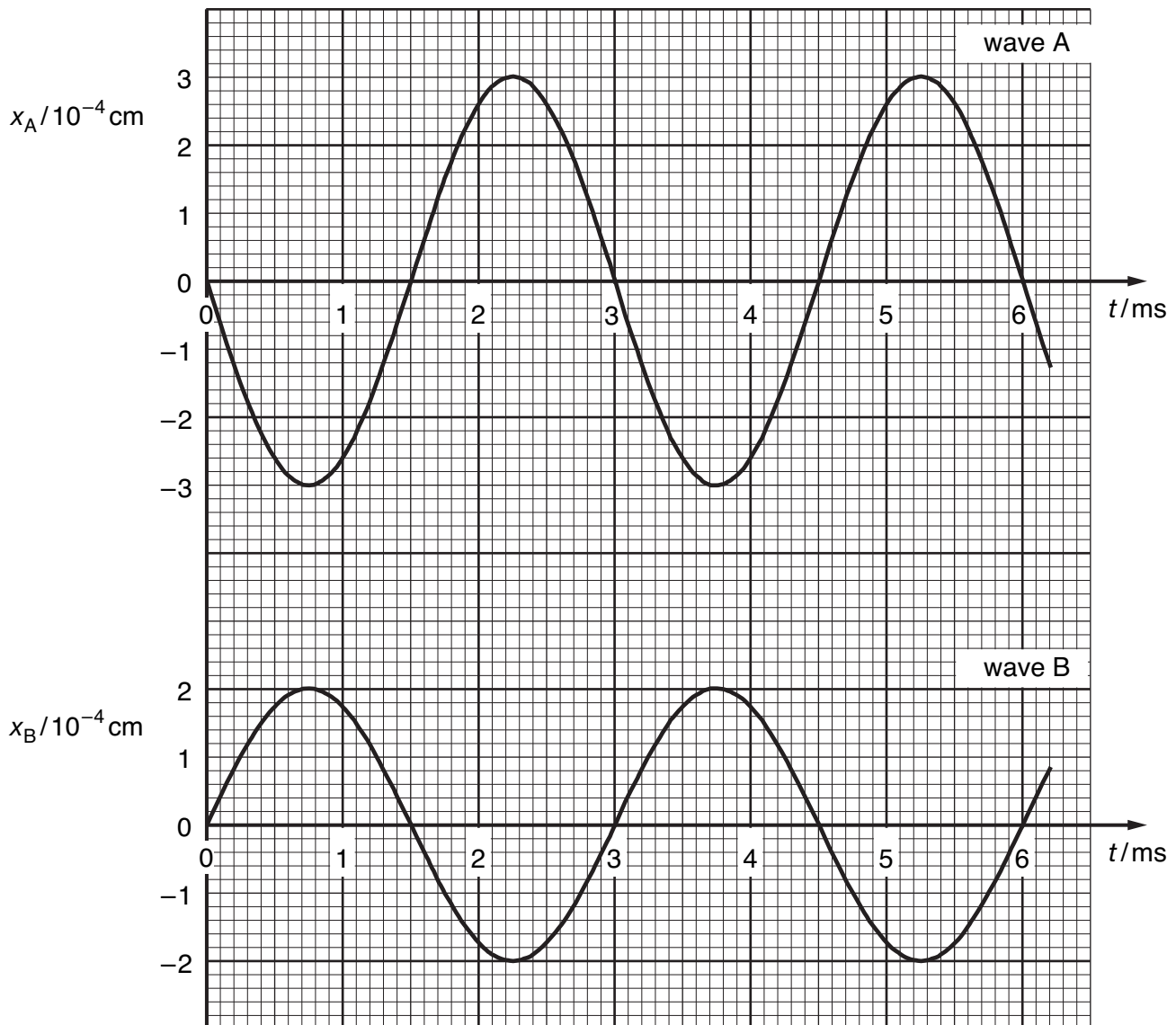**(a)** By reference to Fig. 5.1, state one similarity and one difference between these two waves.

similarity: ....

difference: .... [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 $\frac{4}{9}I$.

                                                                                          [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 $t = 3.0\,\text{ms}$,

                                    resultant displacement = ……………………………… cm [1]

   (ii) at time $t = 4.0\,\text{ms}$.

                                    resultant displacement = ……………………………… cm [2]

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]

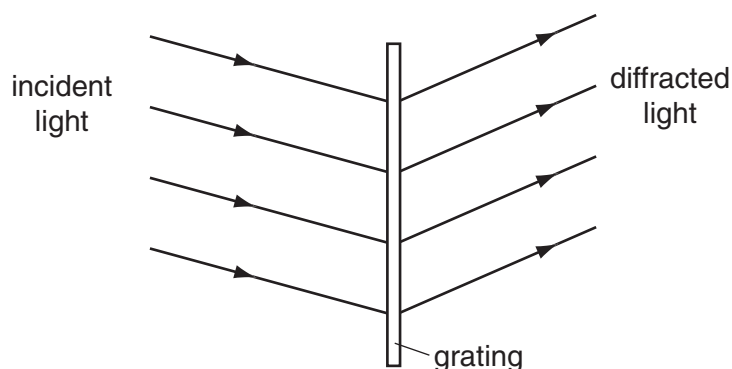**(iii)** Fig. 5.1 shows incident light that is not normal to the grating.

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.

1. ....

....

2. ....

....[2]

2 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.

1. ....

2. ....

3. .... [3]

(b) A typical wavelength of visible light is 495 nm. Calculate the number of wavelengths of this light in a wave of length 1.00 m.

number = ... [2]

(c) State a typical wavelength for

(i) X-rays,

wavelength = ... m

(ii) infra-red radiation.

wavelength = ... m

[2]

4 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.
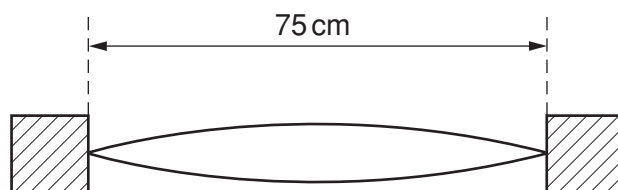
Fig. 4.1

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 = …………………………. m s^{-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]

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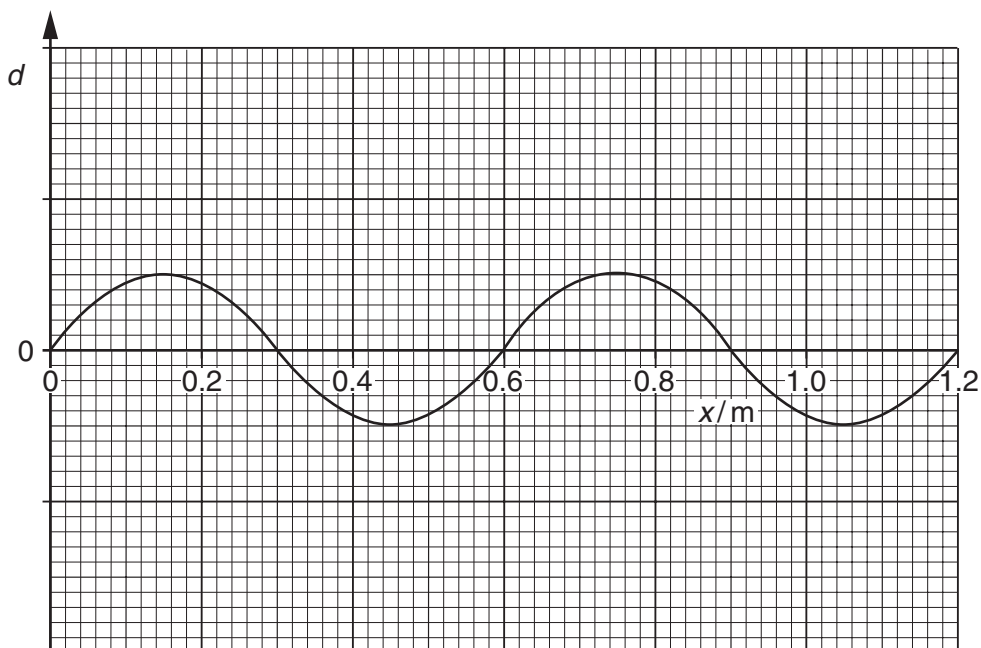

Fig. 2.1

The wave is a progressive wave having a speed of $330 \, \text{m s}^{-1}$.

(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]

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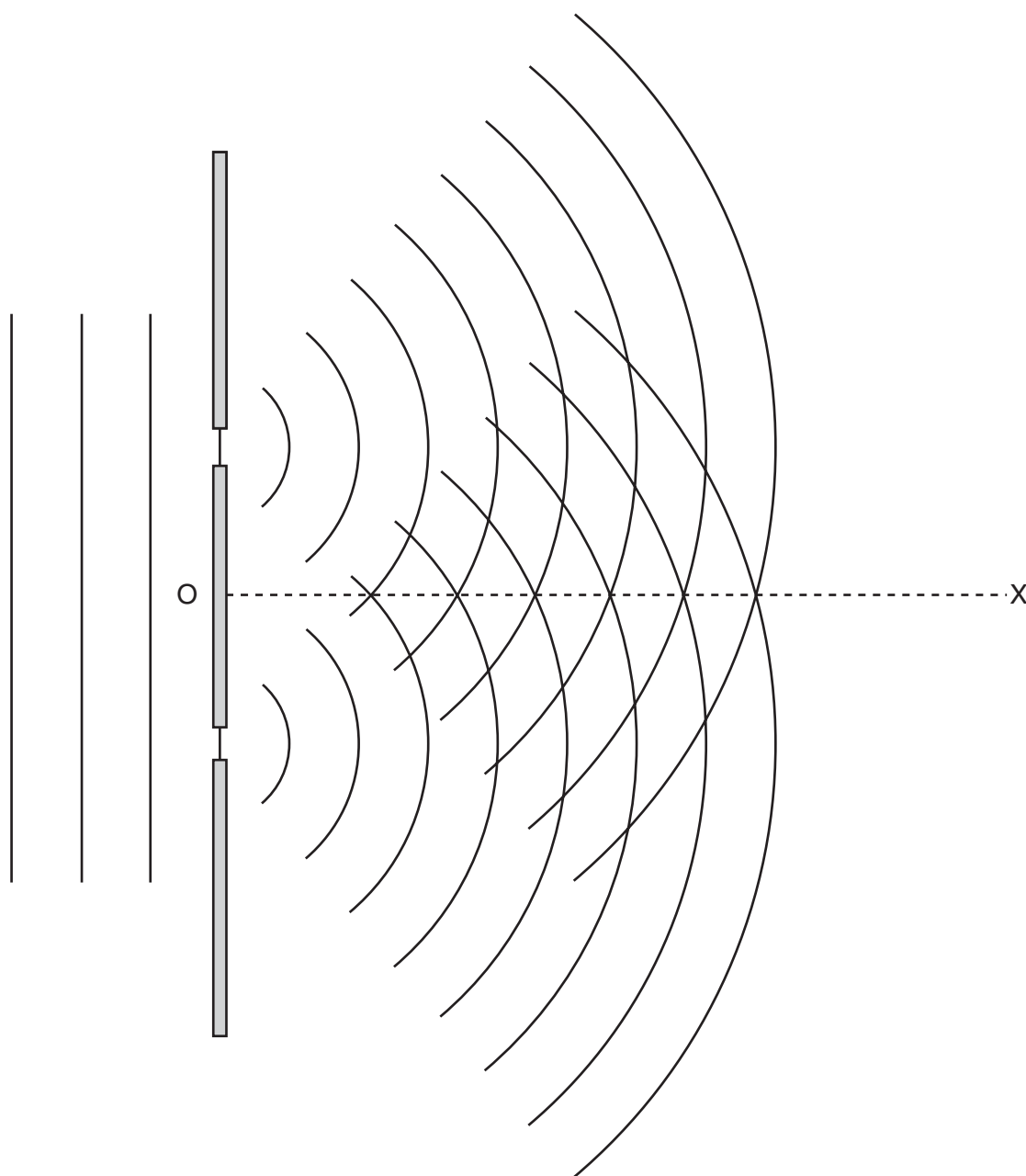

Fig. 6.1

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).

<div align="right">[2]</div>

(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 1.2 m from the plane of the double slit, as shown in Fig. 6.2.
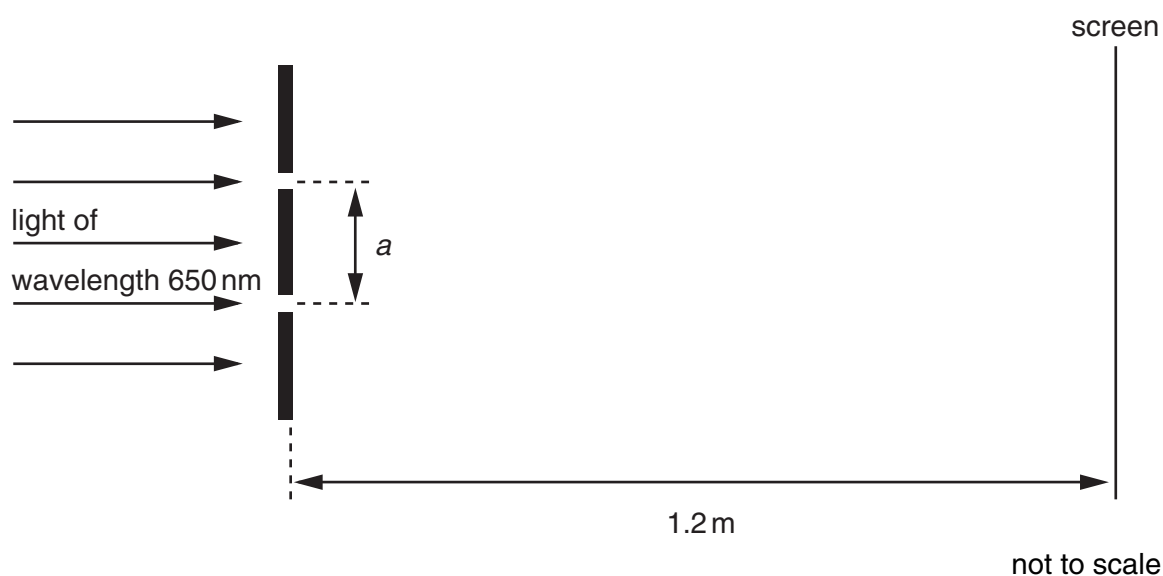

Fig. 6.2

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]

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.
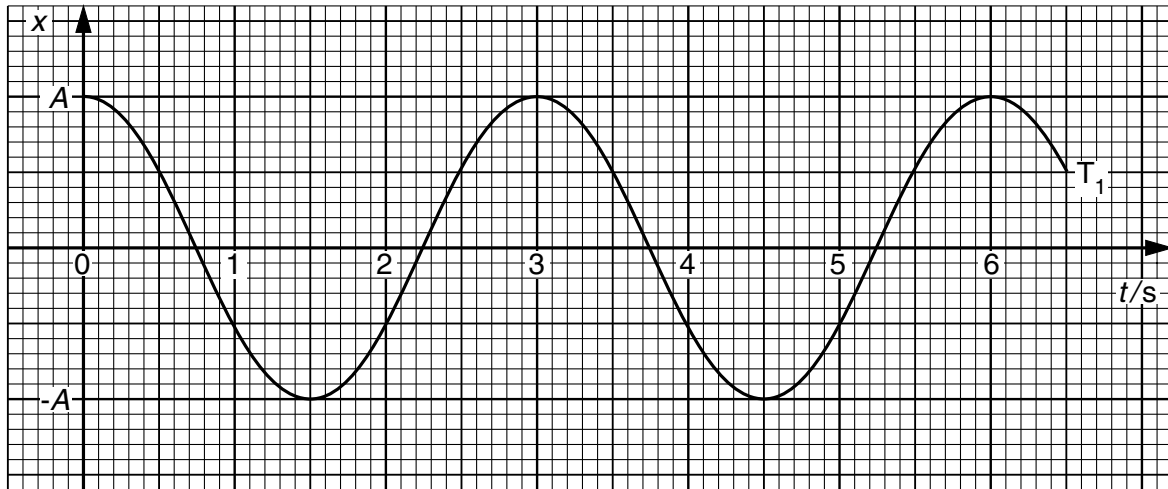

Fig. 5.1

(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 = ...
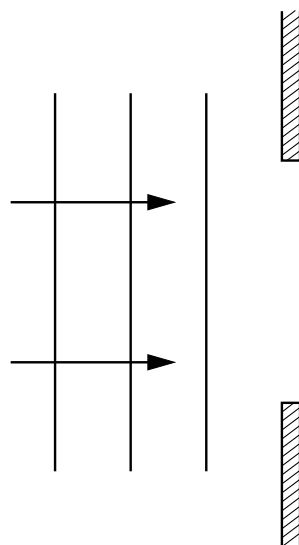[3]

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Turn over for question 6

[Turn over

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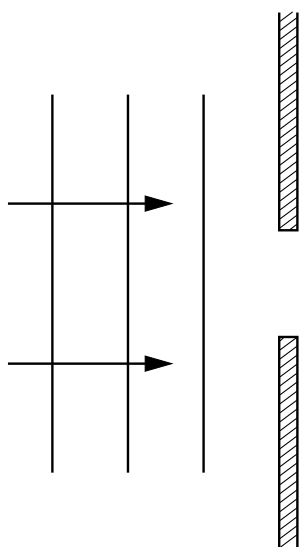
(a)   (b)

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.
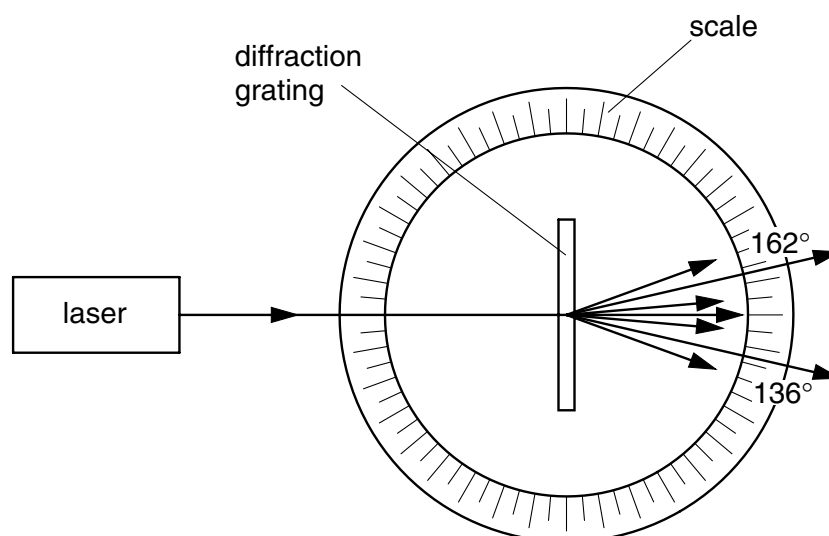

Fig. 7.2

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]

[Turn over

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

double slit

screen

light of

frequency

4.8×10^{14} Hz
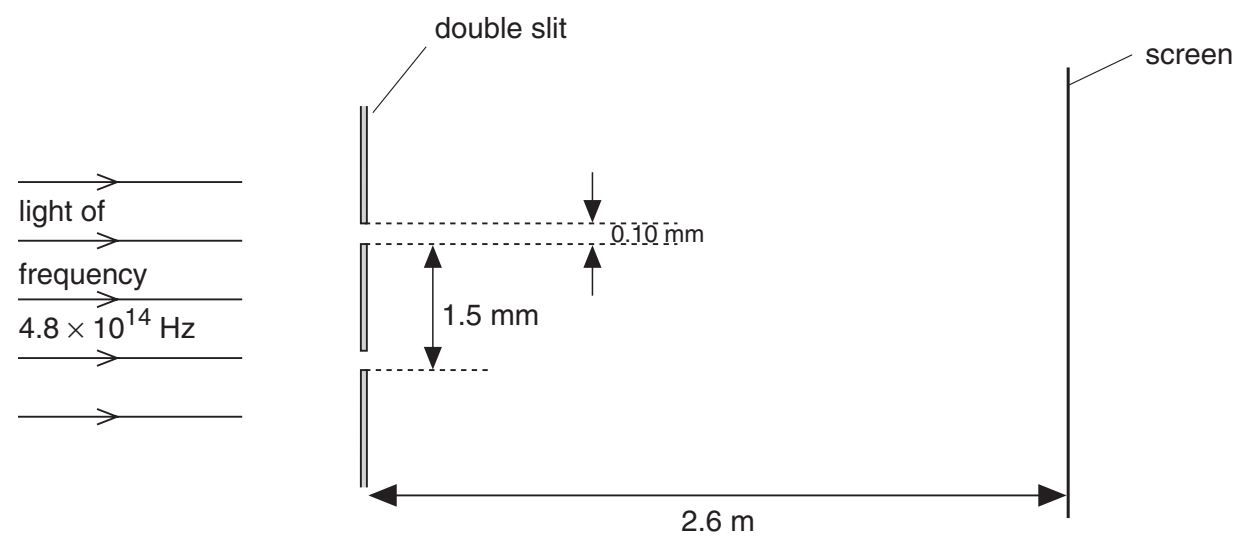
0.10 mm

1.5 mm

2.6 m

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]

[Turn over