H2 Physics Revision Topic : Superposition

Structured Questions Name: ______________________

1 **(a)** State the *Principle of Superposition*.

....

....

.... [2]

(b) A Young's double slit experiment is set up as shown in Fig 5.1. Monochromatic light of wavelength 650 nm is incident on slit S_0. Light emerging from slits S_1 and S_2 are in phase and the distance between the slits is 1.65 mm. A screen is placed 6.5 m away from the slits.

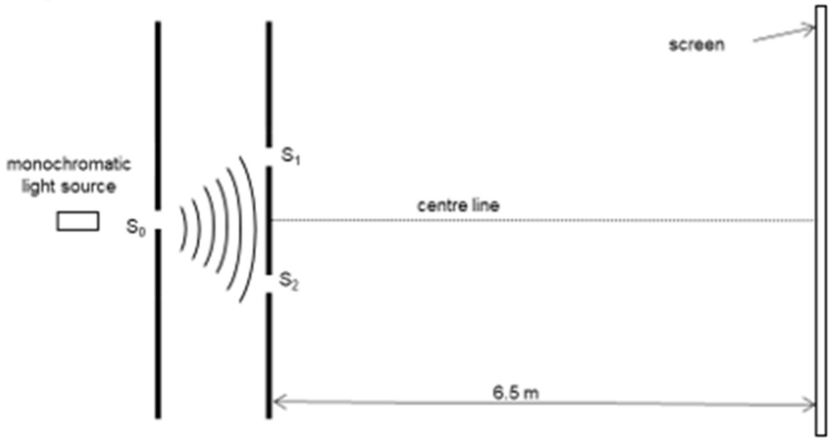

Fig 5.1

(i) Determine the separation of the bright fringes when they are formed on the screen.

separation = ... m [2]

1

(ii) Suggest changes to the appearance of the fringes when a darken film is now placed in front of slit S_1.

....

....

....

....

.... [2]

(iii) The screen is removed and a man stands directly in front of the two slits during day time. The diameter of the pupil of the eyes can be taken to be 3.5 mm.

Determine the maximum distance the man can stand away from the two slits before he can no longer resolve them.

maximum distance = ... m [2]

(iv) As the diameter of the pupil of the eyes increases during night time, explain if the man is still able to resolve the two slits if he is to stand at the same location as determined in **(b)(iii)**.

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.... [2]

1 **(c)** The setup is modified as shown in Fig 5.2 to demonstrate single slit diffraction. Monochromatic light of wavelength 550 nm is incident on slit S_0 with slit width of 2.20 μm. A screen is placed 0.7 m away from the slit and the centre of the interference pattern formed on the screen is at W.

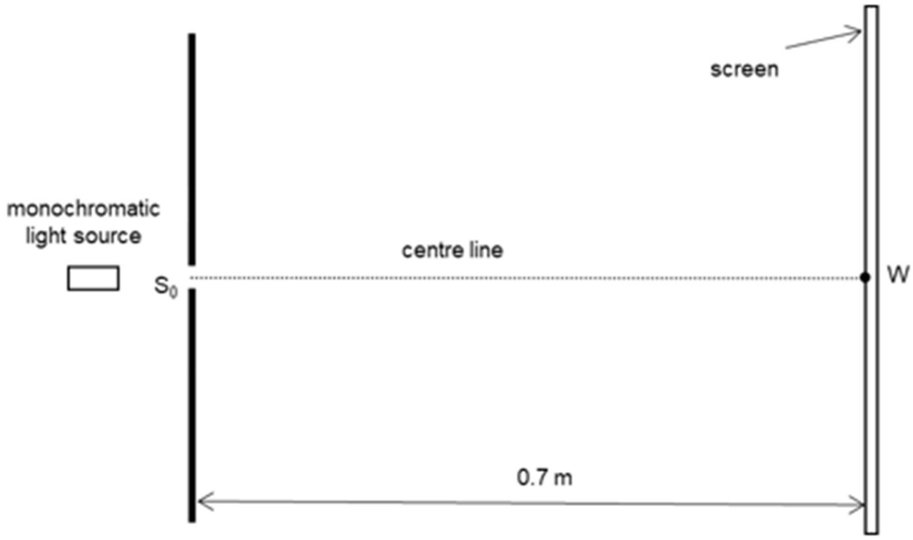

Fig 5.2

(i) Determine the width of the centre bright fringe formed on the screen.

width = ... m [2]

1

(ii) On Fig 5.3, sketch the variation with distance x from point W of the intensity of the light on the screen.

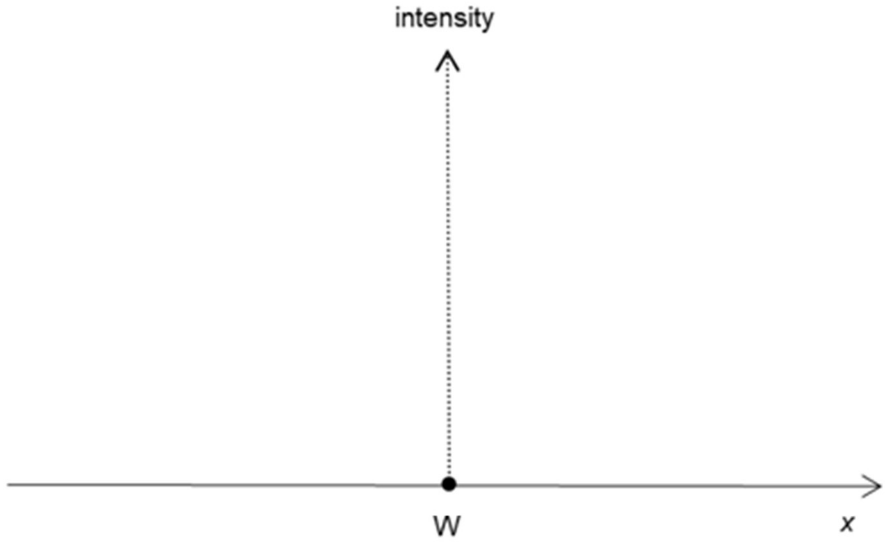

Fig 5.3

[2]

(iii) The amplitude of the light at a point 0.8 m away from S_0 is measured to be A_0. The screen is now moved to a new position such that the point is now 1.1 m away from S_0.

Assuming that the light from S_0 acts like a point source, determine in terms of A_0, the amplitude of the light at the new position.

amplitude = ... A_0 [2]

2 **(a)** A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

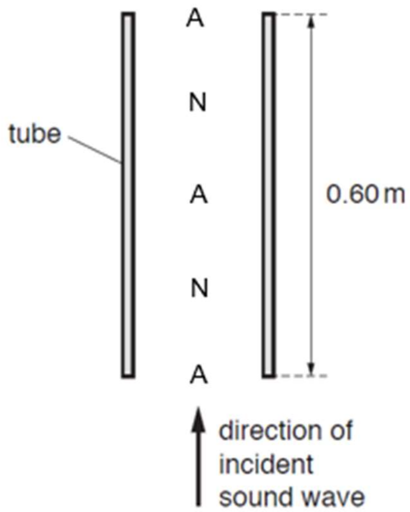

Fig. 5.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A and nodes N.

(i) Explain how the stationary wave is formed from the incident sound wave.

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.... [2]

(ii) On Fig. 5.2, sketch a graph to show the variation of the amplitude of the stationary wave with height h above the bottom of the tube.

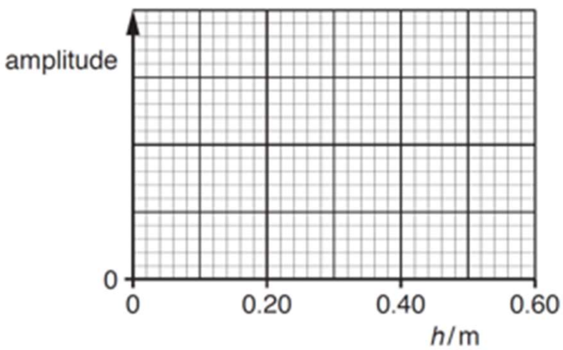


Fig. 5.2

2 **(iii)** For the stationary wave, state

1. the direction of the oscillations of an air particle at a height of 0.30 m above the bottom of the tube,

.... [1]

2. the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ...° [1]

(iv) The speed of the sound wave is 340 m s^{-1}. The frequency of the sound wave is gradually increased.

Determine the frequency of the wave when a stationary wave is next formed.

frequency = ...Hz [2]

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

....

....

.... [1]

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

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

d = ...m [2]

2

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

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

....

....

.... [1]

[Total: 12]

3 **(a)** Explain what is meant by the *principle of superposition*.

....

....

.... [2]

(b) Two identical loudspeakers are driven by the same oscillator of frequency 200 Hz. The loudspeakers are located on a vertical pole, a distance of 4.0 m from each other. A man walks straight towards the lower loudspeaker in a direction perpendicular to the pole, as shown in Fig. 5.1.

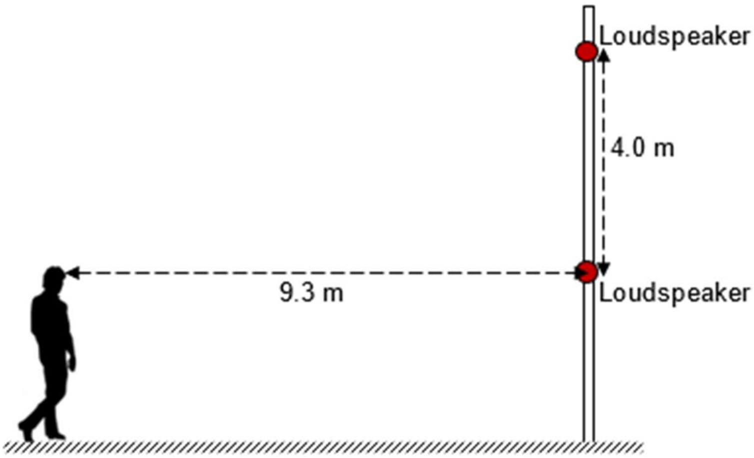


Fig. 5.1 (not to scale)

(i) Calculate the wavelength, λ, of the sound emitted by the loudspeaker, if the speed of sound in air is 330 m s^{-1}.

λ = ... m [1]

(ii) Determine whether the man will hear a maximum or minimum in sound intensity when he is 9.3 m from the pole. You may ignore any sound reflection from the ground.

[3]

3

(iii) State two changes that can be made to the set-up in Fig. 5.1 in order to increase the number of intensity fluctuations detected by the man as he walks towards the pole.

1. ....

....

2. ....

....[2]

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

....

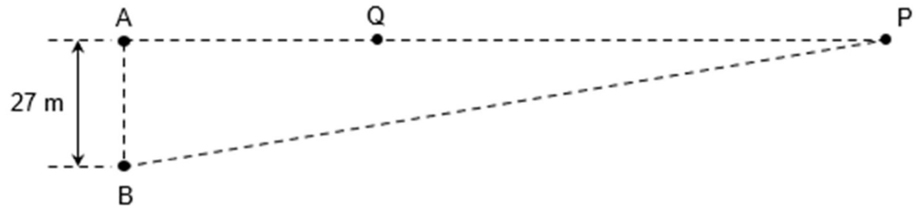
....

....

....[2]

(b) Two microwave transmitters are positioned 27 m apart at points A and B as shown in Fig. 3.1. Operating at different power, they each transmit a microwave of wavelength 4.0 m uniformly in all directions. The two waves emitted are in phase at the transmitters.

Line AB and AP are perpendicular to each other.



(not drawn to scale)

Fig. 3.1

The variation with time t of the displacement x of the microwave arriving at point P is shown in Fig. 3.2.

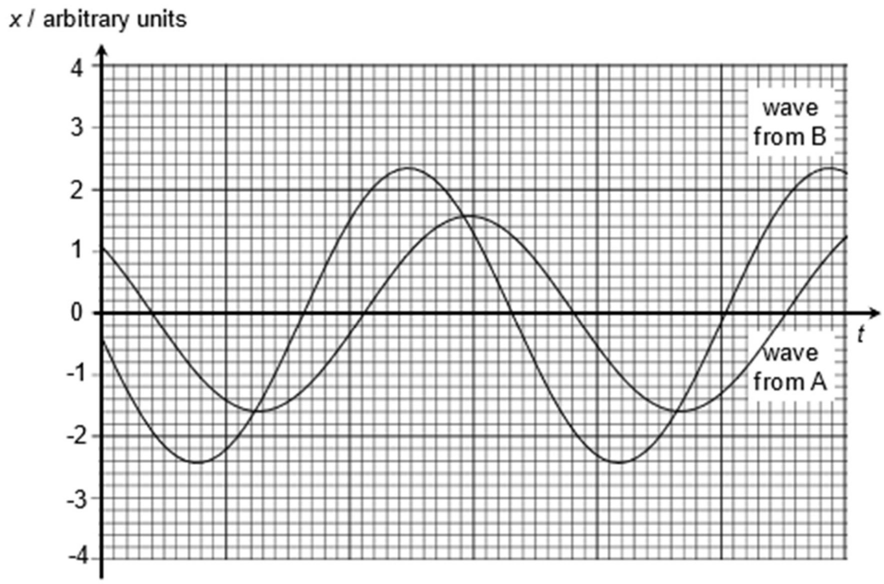


Fig. 3.2

4 **(i)** Determine the phase difference between the waves from transmitter A and from transmitter B that arrive at point P.

phase difference = ……………………… rad [2]

(ii) The waves from the two transmitters interfere to form positions of maximum intensity and minimum intensity.

Use Fig. 3.2 to determine, for points of maximum and minimum intensity closest to point P, the ratio

$$\frac{\text{maximum wave intensity}}{\text{minimum wave intensity}}$$

ratio = …………………………………… [3]

(c) The path difference between the waves arriving from A and B at Q is 6.5 m.

Determine the number of maxima found along the line between A and Q.

number of maxima = …………………………………… [2]

(d) A student thinks that a stationary wave is formed along the line joining A and B. Comment on the student's thought.

……………………………………………………………………………………………………

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……………………………………………………………………………………………………

……………………………………………………………………………………………………[2]

5 A ripple tank is used to demonstrate the interference of water waves.
Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 4.1.

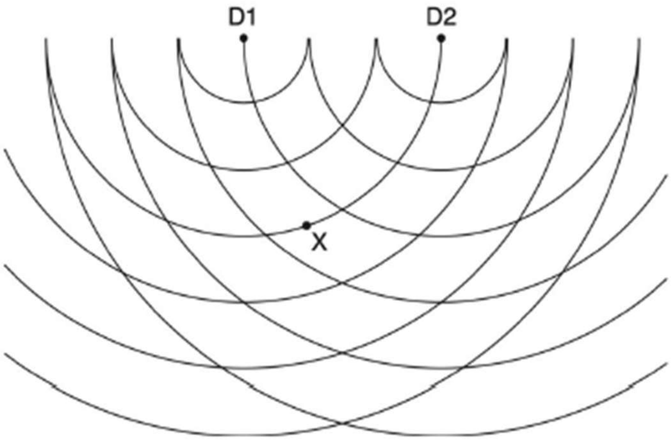

Fig. 4.1 (not to scale)

The lines in the Fig. 4.1 represent crests.

(a) (i) 1. Explain what is meant by *coherent waves* produced by the dippers.

....

.... [1]

2. Describe how the apparatus can be arranged to ensure that the waves from the dippers are coherent.

....

.... [1]

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

....

.... [1]

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

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.... [1]

5 **(c)** Fig. 4.2 shows the water level at one of the dippers.

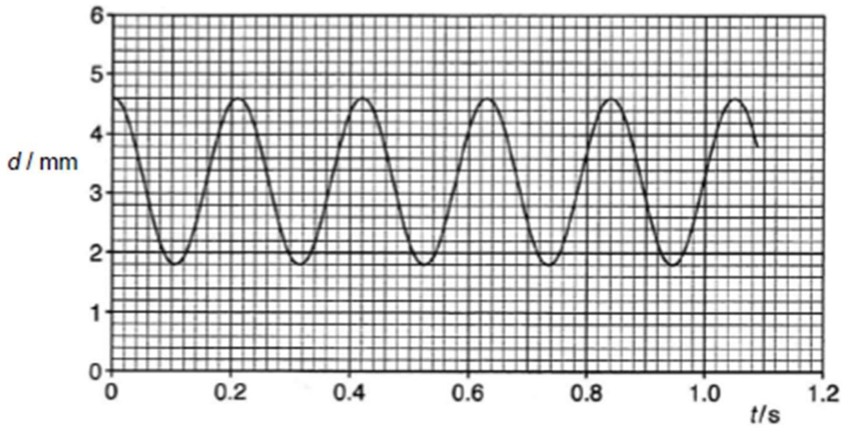

Fig. 4.2

The speed of waves is 0.40 m s^{-1}.
Show that the waves have a wavelength of 8.4 cm.

[2]

(d) Fig. 4.1 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,

(i) determine the path difference,

path difference = ... cm [2]

(ii) state the phase difference.

phase difference = ... ° [1]

(e) On Fig. 4.1, draw **one** line, at least 4 cm long, which joins points of the interference pattern where only maxima of path difference equal to two wavelengths are observed. [1]

[Total: 10]

6 A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating, as shown in Fig. 4.1.

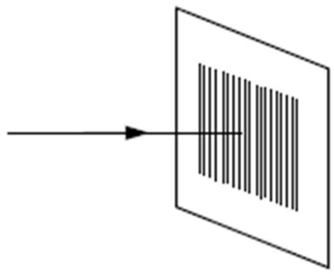

Fig. 4.1

(a) Describe how diffraction of light takes place at the grating.

....

....

.... [1]

6 **(b)** The diffraction pattern on the screen is shown in Fig. 4.2. The brightest spot is O. The two bright spots closest to O is 3.5 cm away from O.

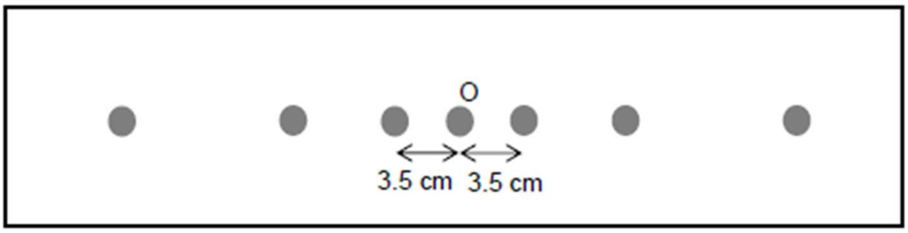

Fig. 4.2 (Not to scale)

The diffraction grating is placed 10 cm from the screen.

Determine the number of lines per metre on the grating.

number of lines per metre = ... [3]

(c) A second laser is directed normally to another diffraction grating with the same number of lines as in **(b)**.

Describe and explain how the new appearance of the diffraction grating pattern provide evidence for any changes to the following.

(i) the wavelength of the second laser,

....

....

....

.... [2]

(ii) the orientation of the diffraction grating.

....

....

.... [1]

6

(d) The diffraction grating in **(c)** is added directly in front of the first grating such that the orientation of the two diffraction gratings are perpendicular to each other. The diffraction pattern in Fig. 4.3 is observed.

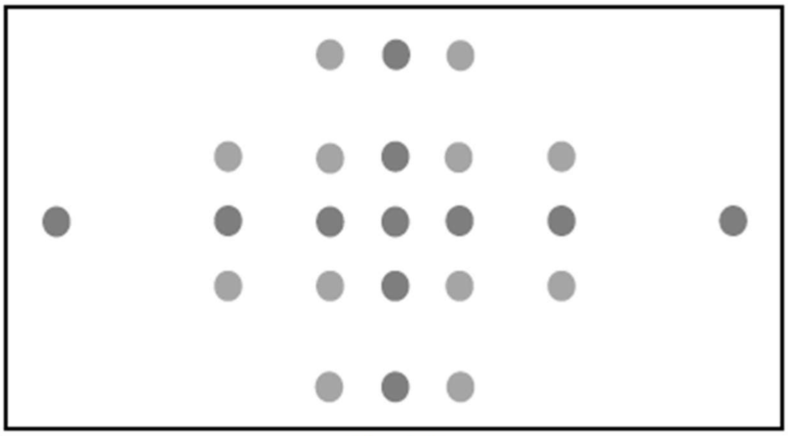

Fig. 4.3

Suggest how the pattern in Fig. 4.3 is formed.

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.... [2]

(e) A student sets up the apparatus in Fig. 4.1 but rotates the diffraction grating by 45° such that the laser is no longer normal to the grating.

Suggest and explain whether the position of the brightest spot O in Fig. 4.2 will change.

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.... [1]

[Total: 10]

7

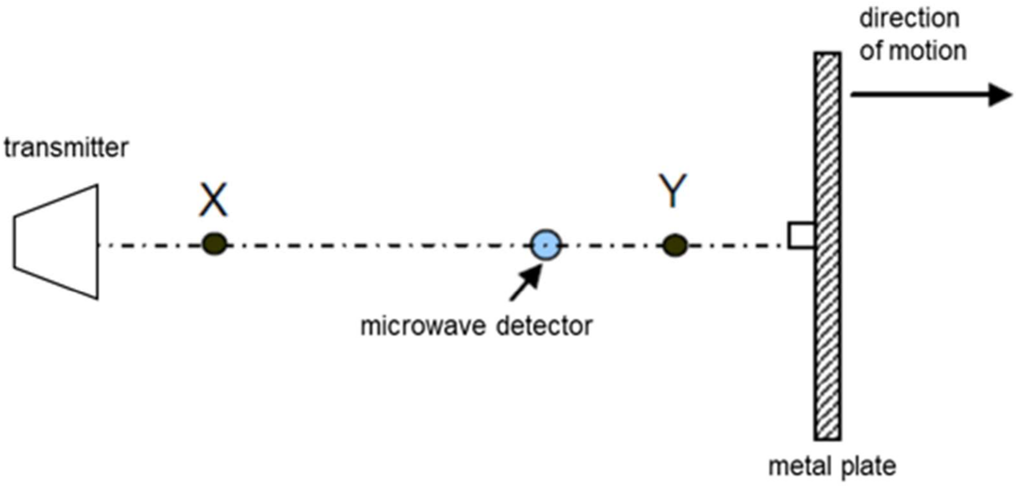

Fig. 7.1

(a) A small detector, moved along the line XY, travels 16 cm in moving from the first to the 12^{th} consecutive nodal position.

Show that the microwaves emitted have a frequency of 10 GHz. [3]

(b) The detector is now at position Y and the metal plate is moved to the right, along the direction XY at a constant speed.

State and explain what is observed at the detector.

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....

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....

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.... [2]

7 **(a)** A pair of identical speakers, S_1 and S_2, 1.2 m apart makes up a stereo system in a large hall. The voltage input to each speaker is adjustable. The arrangement is shown in Fig. 7.1.

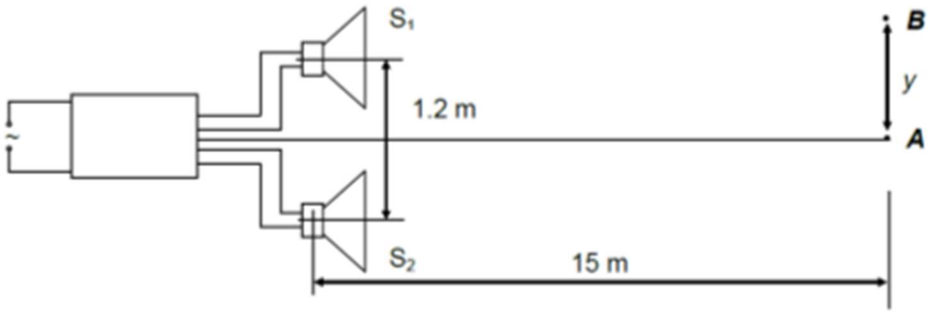

Fig. 7.1

The speakers are initially emitting signals of frequency 1000 Hz which are in phase. Assume that the speed of sound is 330 m s^{-1}. The voltage across each speaker is 6.0 V. An observer holding a sound detector stands on the centre line at point **A**, 15 m away from the point halfway between the speakers and registers a loud sound of intensity I_{max}. As he moves along the line **AB** at right angles to the centre line, the intensity of the sound falls to zero at point **B**, a distance *y* from **A**.

(i) Determine the distance *y*.

distance *y* = ………………… m [3]

(ii) Calculate the next higher frequency of operation of the speakers such that the point **B** will be a position of maximum intensity.

frequency = ………………… kHz [2]

7 **(iii)** With the speakers emitting the original signal of frequency 1000 Hz, the voltages across S_1 and S_2 are adjusted to 3.0 V and 9.0 V respectively.

Given that the amplitude of the output of each speaker is proportional to the voltage across its terminals, find the new intensity at **A**, expressing your answer in terms of I_{max}.

new intensity at **A** = ………………… [4]

(b) A *diffraction* grating is to be calibrated by a spectrometer experiment with a source emitting a spectral series of lines of known wavelengths.

(i) Explain what is meant by *diffraction*.

………………………………………………………………………………………

…………………………………………………………………………… [1]

7

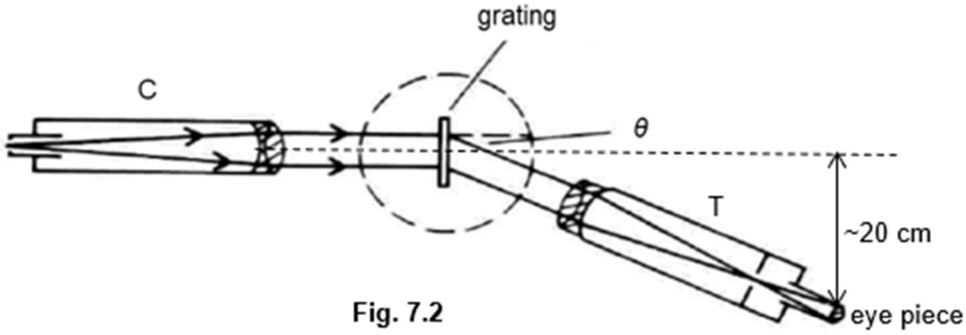

Fig. 7.2

The grating in Fig. 7.2 is set up with light incident normally from a collimator C, with θ, the angle of first order of angular deflections.

(ii) The light from a hydrogen discharge tube contains electromagnetic radiations of wavelengths 660 nm (red) and 490 nm (blue). This light is passed through the grating and observed through a telescope T. The grating has a slit density of 359 lines per mm.

1. The position of the first order blue fringe is observed to be approximately 20 cm from the central maxima.

Estimate the normal distance of the eyepiece in T from the diffraction grating.

normal distance = ………………… m [3]

2. Determine the angular separation of the red and blue light for hydrogen for the second order diffraction pattern.

angular separation = ………………… ° [3]

7

3. Determine the highest order observable for blue light.

highest observable order = ………………… [2]

4. The diffraction grating may also be used to investigate wavelengths of an unknown source.

Suggest one advantage and one disadvantage of obtaining the wavelength by using observations of the higher order of the diffracted light rather than the first-order diffraction light.

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…………………………………………………………………… [2]

8 **(a)** Sound waves travel from a source S to a point X along two paths SX and SPX, as shown in Fig. 6.1.

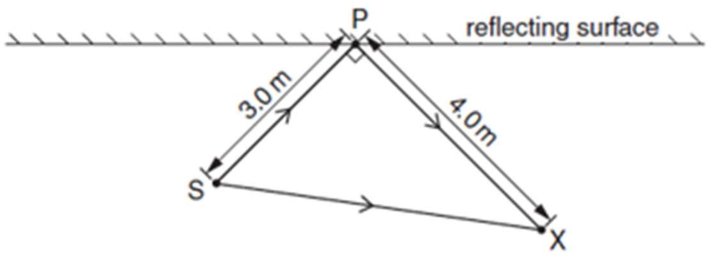

Fig. 6.1

(i) The frequency of the sound from S is 400 Hz and the speed of sound in air is 320 m s^{-1}. Calculate the wavelength of the sound waves.

wavelength = ... m [1]

(ii) The distance SP is 3.0 m and the distance PX is 4.0 m. The angle SPX is 90°.

Suggest whether a maximum or a minimum is detected at point X if there is a phase change of π of the sound wave upon reflection on the surface. Explain your answer.

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.... [2]

8

(b) A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating, as shown in Fig. 6.2.

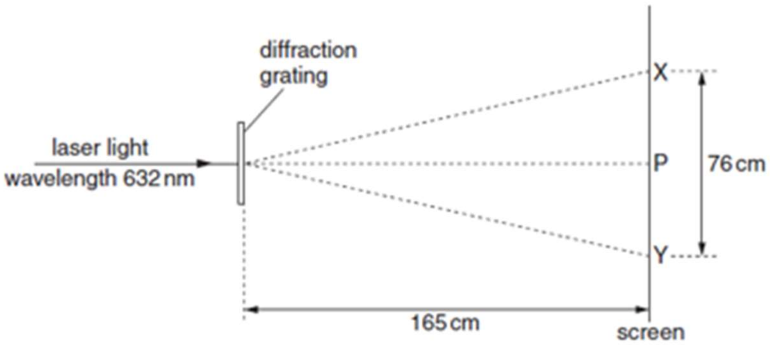

Fig. 6.2

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.

The brightest spot is P. The spots formed closest to P and on each side of P are X and Y. X and Y are separated by a distance of 76 cm.

(i) Calculate the number of lines per metre on the grating.

number per metre = ... [2]

8

(ii) The grating is now rotated about an axis parallel to the incident laser beam, as shown in Fig. 6.3.

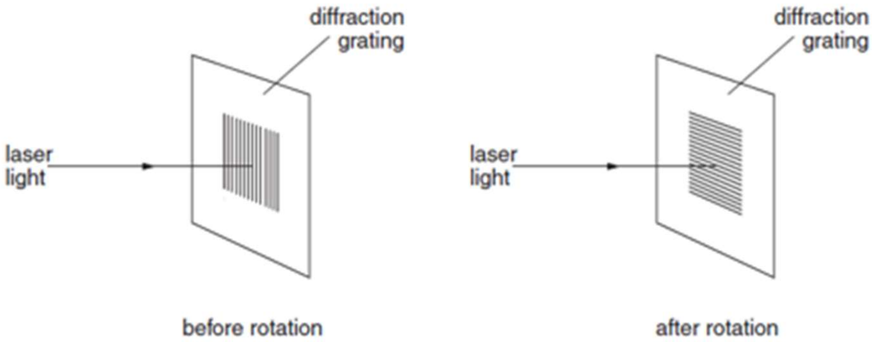

Fig. 6.3

State what effect, if any, this rotation will have on the positions of the spots P, X and Y.

....

....

.... [2]

(c) In another experiment using the apparatus in **(b)**, a student notices that the distances XP and PY, as shown in Fig. 6.1, are not equal.

Suggest a reason for this difference.

....

.... [1]

9 A helium-neon laser produces light of wavelength 633nm. The laser is placed behind a glass microscope slide that has been painted black. A single vertical slit of width 0.0800mm has been produced by scratching through the paint with a razor blade.

Light from the laser passes through the slit and hits a white wall at a distance of 5.12m from the slit. A patch of red light is formed on the screen. On both sides of this central patch there are smaller, less intense patches.

A light sensor connected to a data logger is moved across the screen and the distance moved by the light sensor and the intensity of the light is recorded. Fig. 7.1 is the intensity-distance graph generated.

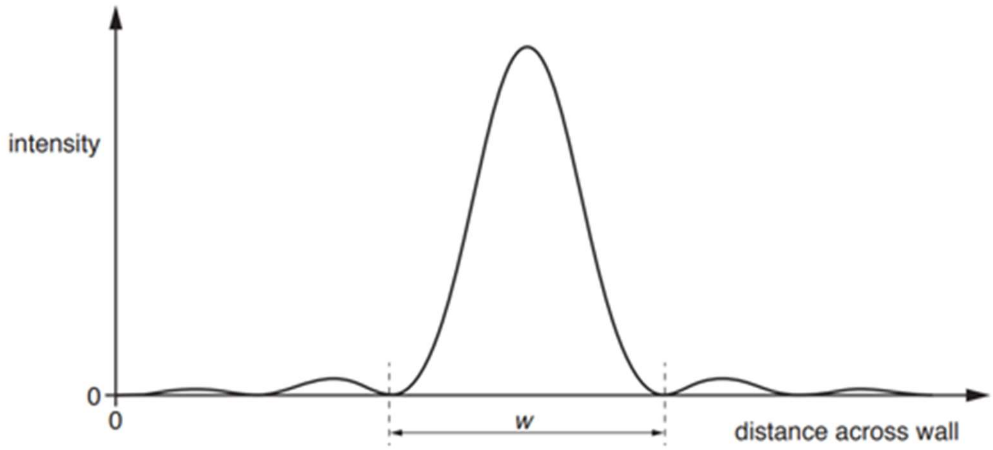

Fig. 7.1

The width *w* of the central patch is equal to the distance between the two minimum points on either side of the central patch where the intensity of red light is equal to zero.

(a) Show that *w* is 0.0810 m wide.

[2]

9 **(b)** A second vertical slit of width 0.0800mm is scratched across the slide. The second slit is parallel to the first and its centre is a horizontal distance of 0.240mm away from the centre of the first slit.

The microscope slide now acts as a double slit. At the centre of the double-slit interference pattern on the wall, there are bright and dark fringes which are uniformly spaced.

(i) Some parts of the screen that were brightly lit when only the first slit was present are now dark, even though light is still passing through the first slit in the same way.

Explain what causes this to happen.

....

....

.... [1]

(ii) Determine the separation *x* of the bright fringes.

x = ... m [1]

(iii) Most of the bright fringes are separated from adjacent bright fringes by a distance x. In a few places, away from the centre, however, there is no light in a position where a bright fringe is expected.

Using the results from **(a)** and **(b)(ii)**, explain why there is no light at such places.

....

....

....

.... [2]

10 **Fig. 4.1** shows two similar small loudspeakers driven in phase from a common audio-frequency source.

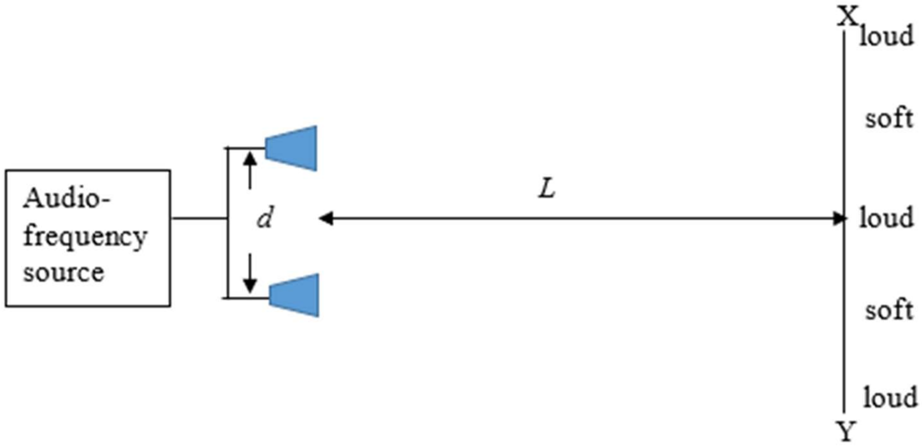

Fig. 4.1

The distance L is much larger than the distance d. When a student walks with a constant speed from X to Y, the intensity of the note he hears is alternately loud and soft at equally spaced intervals.

(a) **(i)** Explain the origin of the loud and soft regions.

....

....

....

.... [2]

(ii) The distance between the two loudspeakers is 75 cm while L is 10.0 m. The sound has a wavelength of 4.8 cm. Calculate the distance between adjacent loud and soft regions.

[2]

10

(iii) While walking from X to Y, the student notices that the intensity of the maxima is not the same. It gets stronger when he walks from X towards the midpoint and then becomes weaker again as he walks towards Y. Explain his observations.

....

....

....

.... [2]

(b) **(i)** When a recording is played through one of the loudspeakers, it is desirable that the speaker should have a diameter d smaller than the wavelength. State the reason why.

....

....[1]

(ii) Estimate the maximum diameter of the speaker that would ensure adequate spreading of sound waves from a recording of a piano. Explain your reasoning. [Speed of sound in air = 340 m s^{-1}, the notes of a piano range from 34 Hz to 3.4 kHz.]

Maximum diameter = ... m [3]