9702/22/F/M/23 Q5

1.(a) A microphone and cathode-ray oscilloscope (CRO) are used to analyse a sound wave of frequency 5000 Hz. The trace that is displayed on the screen of the CRO is shown in Fig. 5.1.

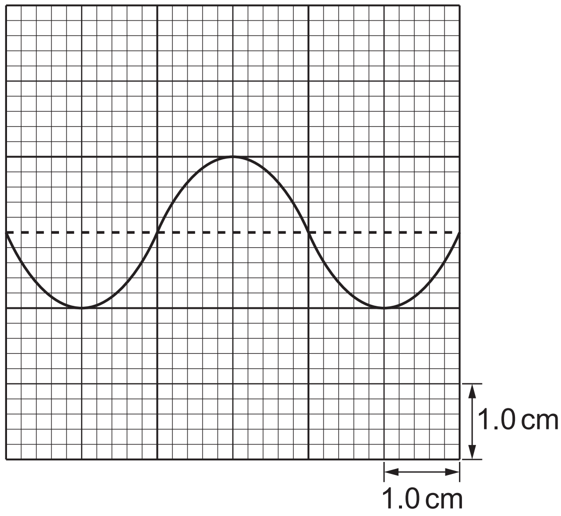

Fig. 5.1

(i) Determine the time-base setting, in s cm^{-1}, of the CRO.

time-base setting = ... s cm^{-1} [2]

(ii) The intensity of the sound detected by the microphone is now increased from its initial value of I to a new value of $3I$. The frequency of the sound is unchanged. Assume that the amplitude of the trace on the CRO screen is proportional to the amplitude of the sound wave.

On Fig. 5.1, sketch the new trace shown on the screen of the CRO. [3]

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

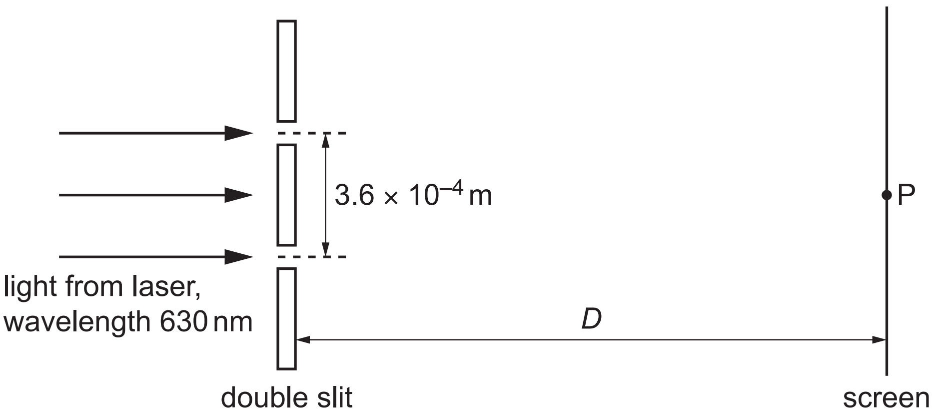

Fig. 5.2 (not to scale)

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.

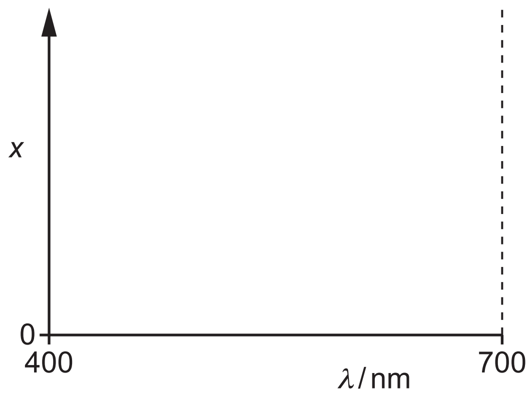

Fig. 5.3

[1]

[Total: 10]

9702/22/O/N/22 Q5

2.(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.

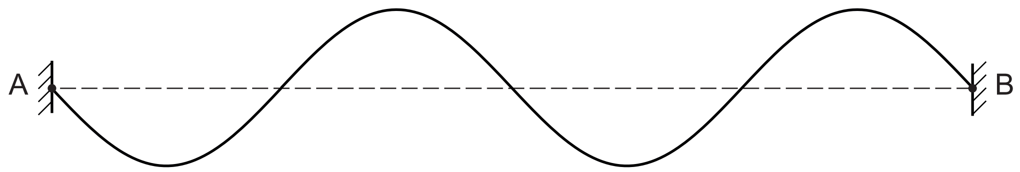

Fig. 5.1

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]

(c) A beam of vertically polarised light of intensity I_0 is incident normally on a polarising filter that has its transmission axis at 30° to the vertical, as shown in Fig. 5.2.

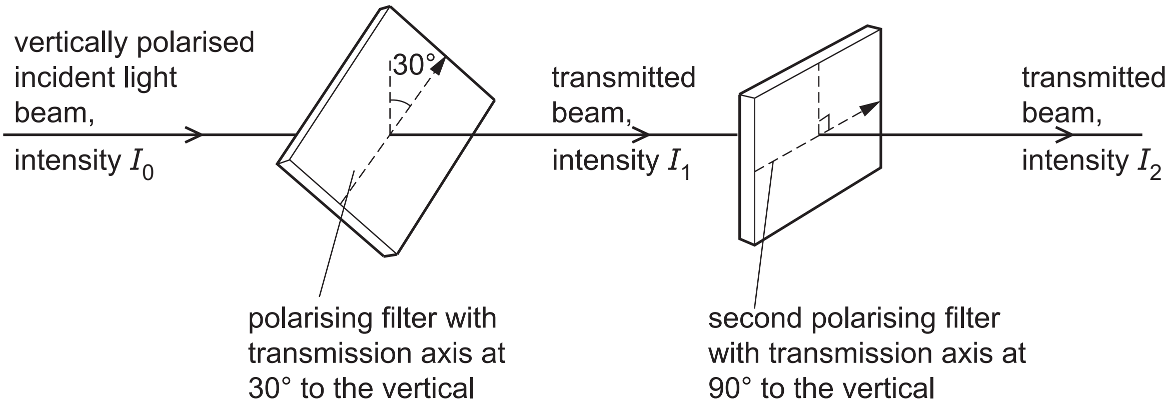

Fig. 5.2

The transmitted light from the first polarising filter has intensity I_1. This light is then incident normally on a second polarising filter that has its transmission axis at 90° to the vertical. The transmitted light from the second filter has intensity I_2.

Calculate:

(i) the ratio $\frac{I_1}{I_0}$

$\frac{I_1}{I_0}$ = ... [2]

(ii) the ratio $\frac{I_2}{I_0}$.

$\frac{I_2}{I_0}$ = ... [2]

[Total: 10]

9702/21/O/N/22 Q4

3.(a) Polarisation is a phenomenon associated with light waves but not with sound waves.

(i) State the meaning of polarisation.

....

....

.... [1]

(ii) State why light waves can be plane polarised but sound waves cannot.

....

....

.... [1]

(b) Two polarising filters A and B are positioned so that their planes are parallel to each other and perpendicular to a central axis line XY, as shown in Fig. 4.1.

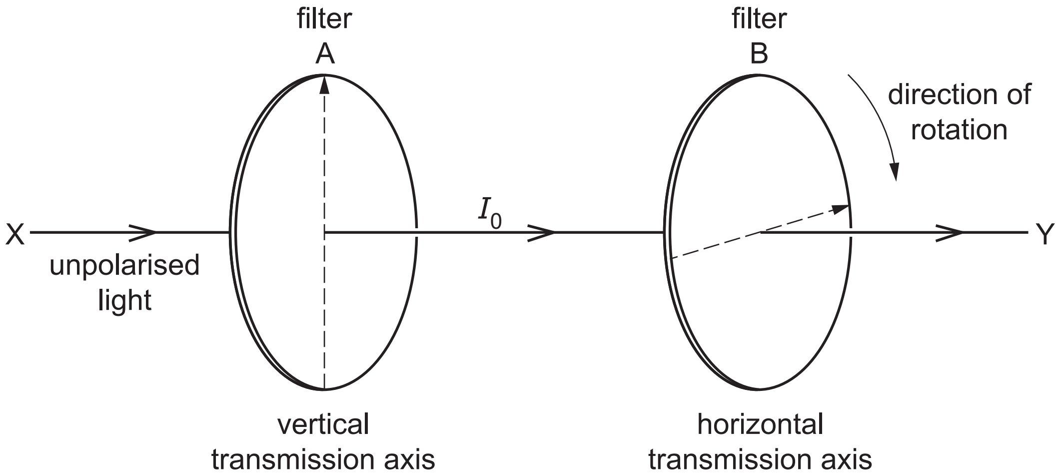

Fig. 4.1

The transmission axis of filter A is vertical and the transmission axis of filter B is horizontal.

Unpolarised light of a single frequency is directed along the line XY from a source positioned at X. The light emerging from filter A is vertically plane polarised and has intensity I_0.

Filter B is rotated from its starting position about the line XY, as shown in Fig. 4.1.

After rotation, the intensity of the light emerging from filter B is $\frac{1}{4}I_0$.

Calculate the angle of rotation of filter B from its starting position.

angle of rotation = ... ° [3]

(c) A microwave of intensity I_0 and amplitude A_0 meets another microwave of the same frequency and of intensity $\frac{1}{4}I_0$ travelling in the opposite direction. Both microwaves are vertically plane polarised and superpose where they meet.

(i) Explain, without calculation, why these two waves cannot form a stationary wave with zero amplitude at its nodes.

....

....

.... [2]

(ii) Determine, in terms of A_0, the maximum amplitude of the wave formed.

maximum amplitude = ... A_0 [3]

[Total: 10]

9702/23/M/J/22 Q5

4.(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.

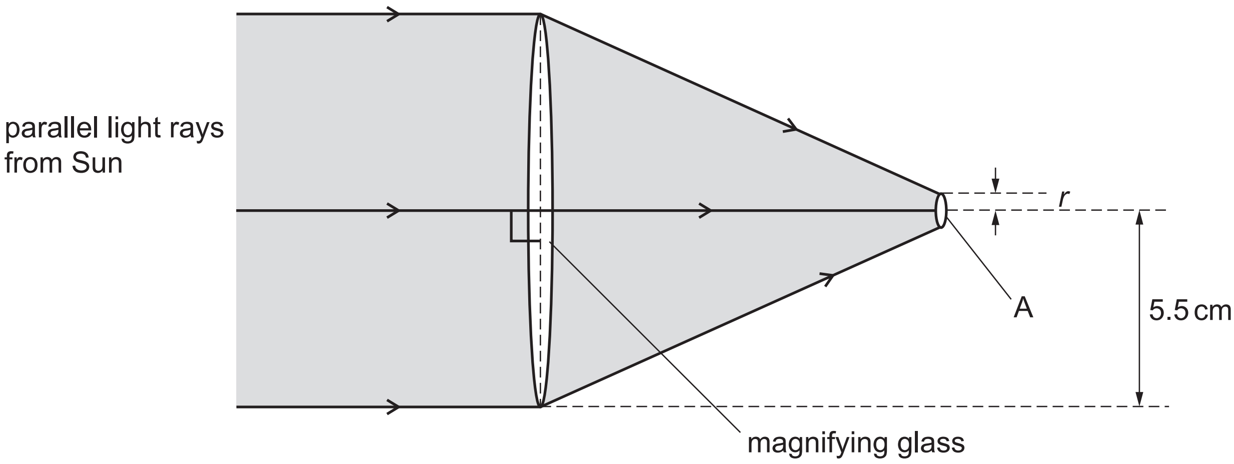

Fig. 5.1 (not to scale)

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]

(b) A laser emits a beam of electromagnetic waves of frequency 3.7×10^{15} Hz in a vacuum.

(i) Show that the wavelength of the waves is 8.1×10^{-8} m.

[2]

(ii) State the region of the electromagnetic spectrum to which these waves belong.

.... [1]

(iii) The beam from the laser now passes through a diffraction grating with 2400 lines per millimetre. A detector sensitive to the waves emitted by the laser is moved through an arc of 180° in order to detect the maxima produced by the waves passing through the grating, as shown in Fig. 5.2.

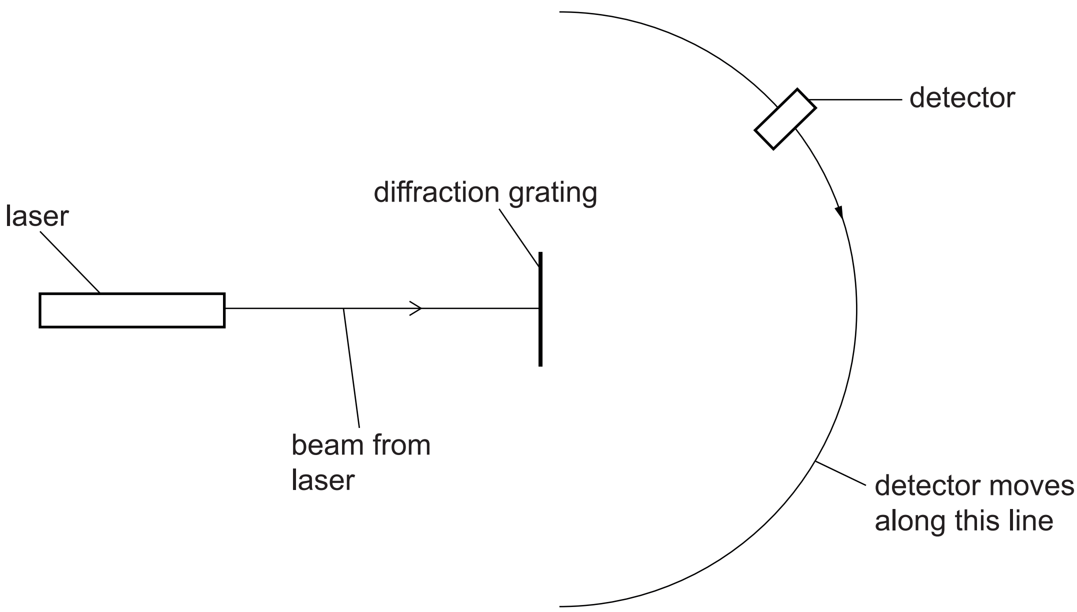

Fig. 5.2

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]

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

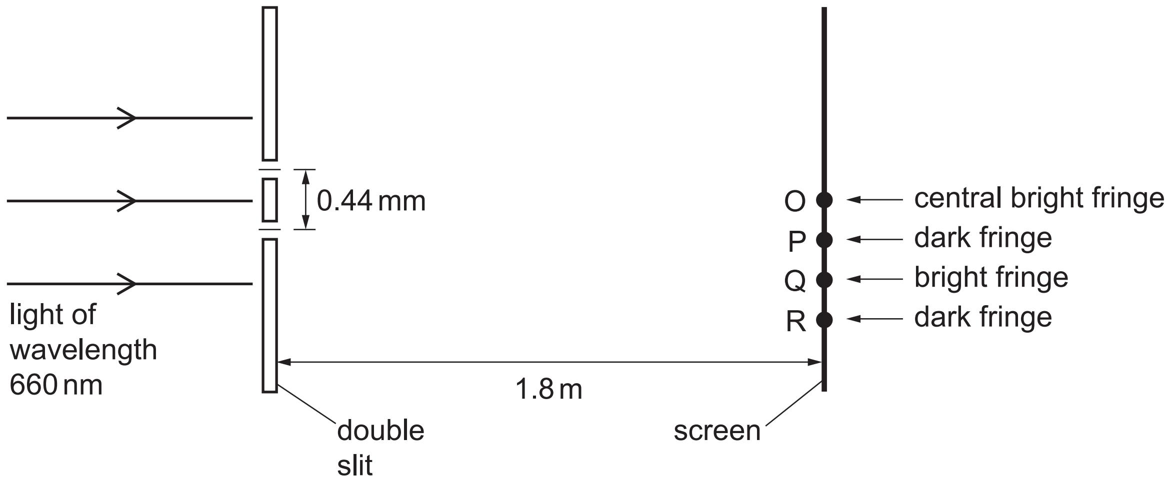

Fig. 5.1 (not to scale)

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.

....

....

....

.... [2]

[Total: 11]

9702/21/M/J/22 Q5

6. 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]

(d) A particle on the string has zero displacement at time $t = 0$. From time $t = 0$ to time $t = 0.060\,s$, the particle moves through a total distance of 72 mm.

Calculate the amplitude of oscillation of the particle.

amplitude = ... mm [2]

[Total: 8]

7. **(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]

(b) A motorcycle is travelling at $13.0\,\mathrm{m\,s^{-1}}$ along a straight road. The rider of the motorcycle sees a pedestrian standing in the road directly ahead and operates a horn to emit a warning sound. The pedestrian hears the warning sound from the horn at a frequency of 543 Hz. The speed of the sound in the air is $334\,\mathrm{m\,s^{-1}}$.

(i) Calculate the frequency, to three significant figures, of the sound emitted by the horn.

frequency = ... Hz [2]

(ii) The motorcycle rider passes the stationary pedestrian and then moves directly away from her. As the rider moves away, he operates the horn for a second time. The pedestrian now hears sound that is increasing in frequency.

State the variation, if any, in the speed of the motorcycle when the rider operates the horn for the second time.

.... [1]

(c) A beam of vertically polarised monochromatic light is incident normally on a polarising filter, as shown in Fig. 5.1.

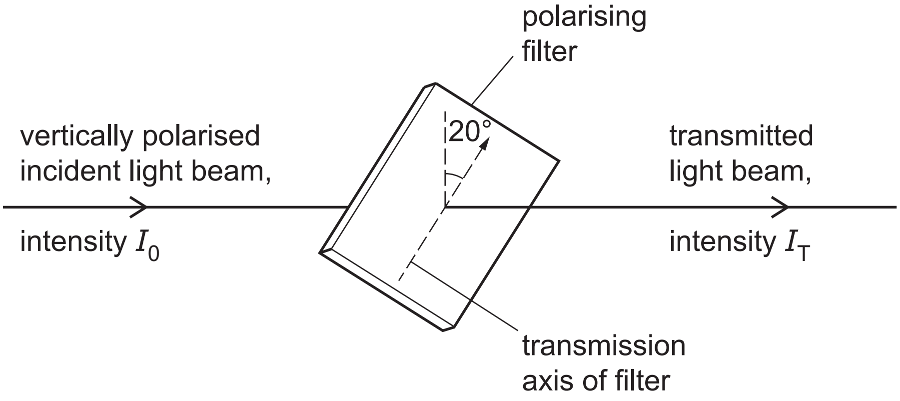

Fig. 5.1

The filter is positioned with its transmission axis at an angle of 20° to the vertical. The incident light has intensity I_0 and the transmitted light has intensity I_T.

(i) By considering the ratio $\frac{I_T}{I_0}$, calculate the ratio

$$\frac{\text{amplitude of transmitted light}}{\text{amplitude of incident light}}.$$

Show your working.

ratio = ... [3]

(ii) The filter is now rotated, about the direction of the light beam, from its starting position shown in Fig. 5.1. The direction of rotation is such that the angle of the transmission axis to the vertical initially increases.

Calculate the minimum angle through which the filter must be rotated so that the intensity of the transmitted light returns to the value that it had when the filter was at its starting position.

angle = ... ° [1]

[Total: 10]

9702/22/O/N/21 Q5

8. 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.

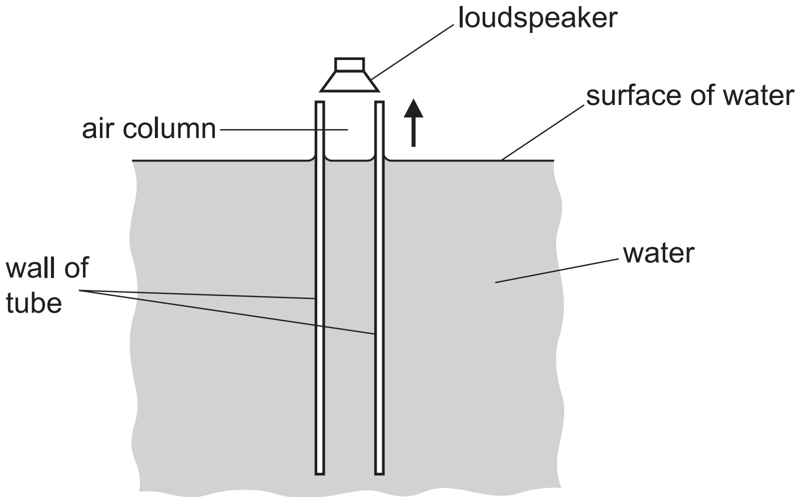

Fig. 5.1

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 $340\,\mathrm{m\,s^{-1}}$.

(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]

9702/21/O/N/21 Q4

9. (a) By reference to the direction of transfer of energy, state what is meant by a *longitudinal* wave.

....

.... [1]

(b) A vehicle travels at constant speed around a wide circular track. It continuously sounds its horn, which emits a single note of frequency 1.2 kHz. An observer is a large distance away from the track, as shown in the view from above in Fig. 4.1.

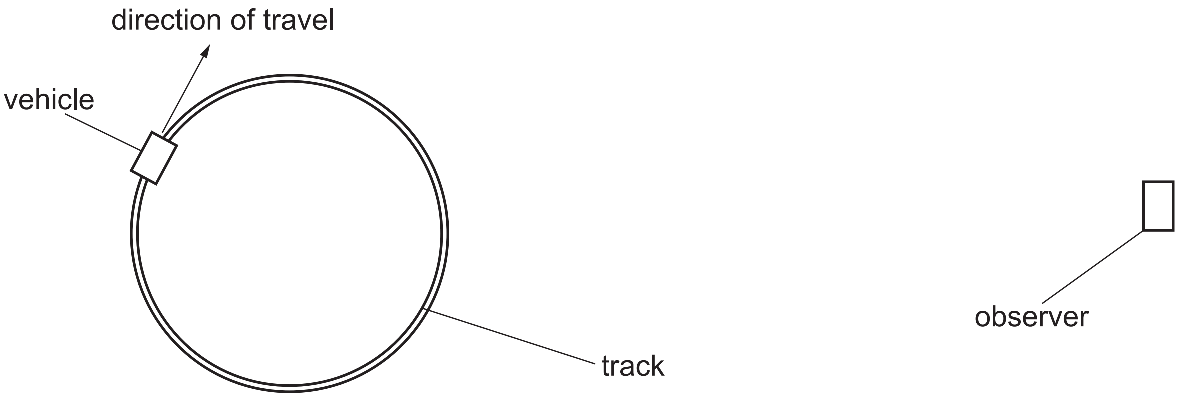

Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with time of the frequency f of the sound of the horn that is detected by the observer. The time taken for the vehicle to travel once around the track is T.

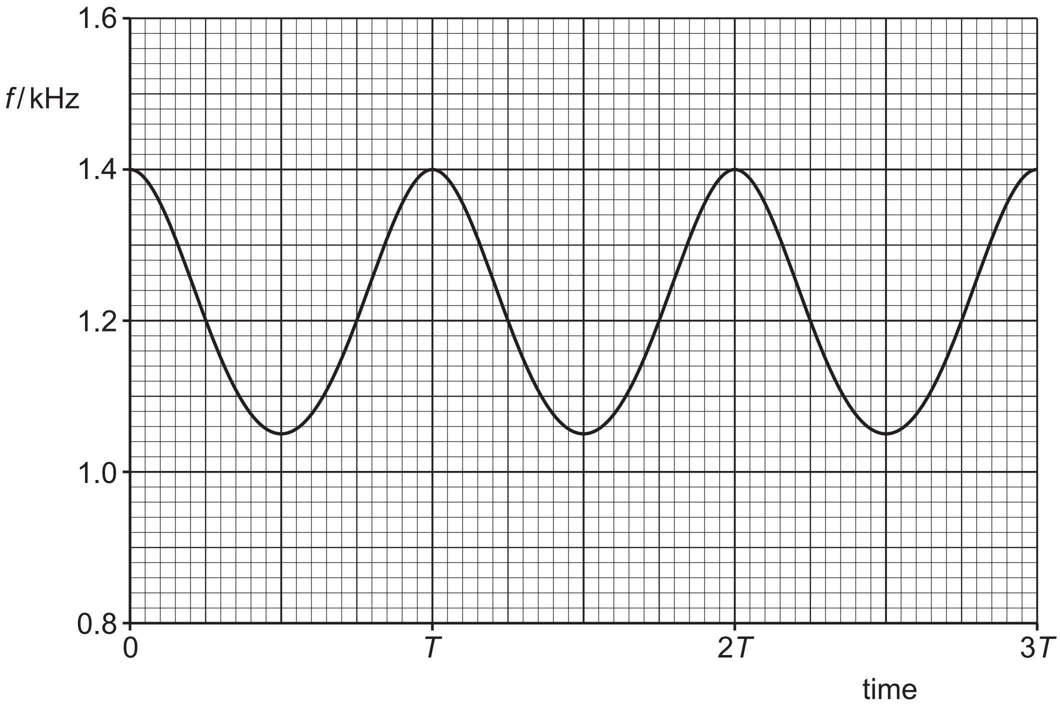

Fig. 4.2

(i) Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.

....

....

....

.... [2]

(ii) State the name of the phenomenon in **(b)(i)**.

.... [1]

(iii) On Fig. 4.1, mark with a letter X the position of the vehicle when it emitted the sound that is detected at time *T*. [1]

(iv) On Fig. 4.1, mark with a letter Y the position of the vehicle when it emitted the sound that is detected at time $\frac{9T}{4}$. [1]

(c) The speed of the sound in the air is $320\,\text{m}\,\text{s}^{-1}$.

Use Fig. 4.2 to determine the speed of the vehicle in **(b)**.

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

[Total: 9]

9702/23/M/J/21 Q4

10. **(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.

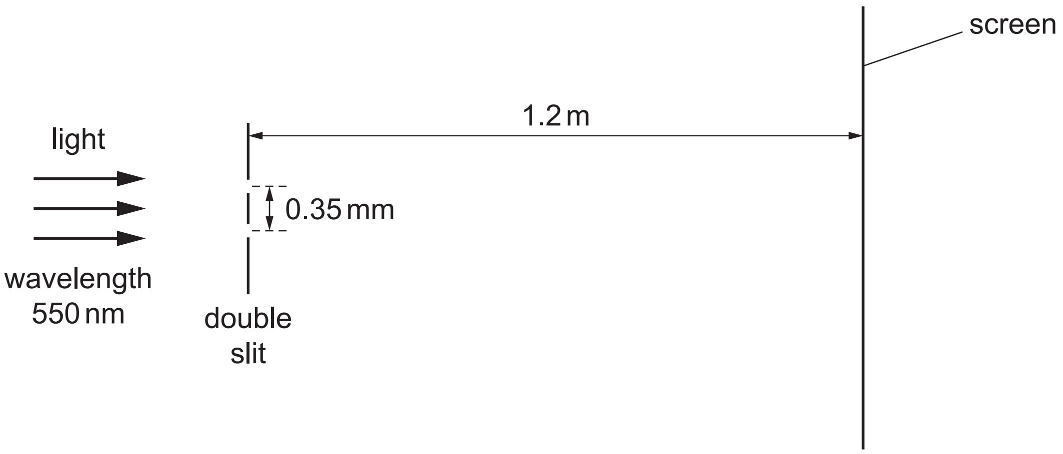

Fig. 4.1 (not to scale)

(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]

11. (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.

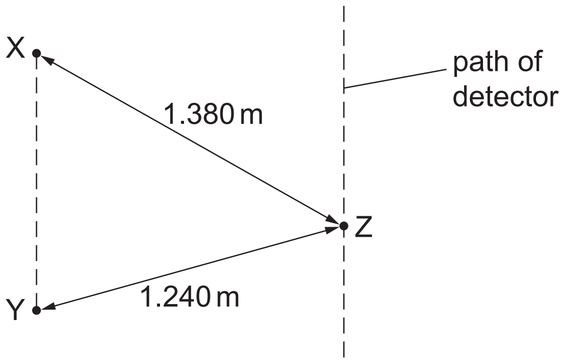

Fig. 4.1 (not to scale)

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.

(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]

9702/21/M/J/21 Q4

12. (a) For a progressive wave, state what is meant by *wavelength*.

....

.... [1]

(b) A light wave from a laser has a wavelength of 460 nm in a vacuum.

Calculate the period of the wave.

period = ... s [3]

(c) The light from the laser is incident normally on a diffraction grating.

Describe the diffraction of the light waves at the grating.

....

....

.... [2]

(d) A diffraction grating is used with different wavelengths of visible light. The angle θ of the **fourth**-order maximum from the zero-order (central) maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 4.1.

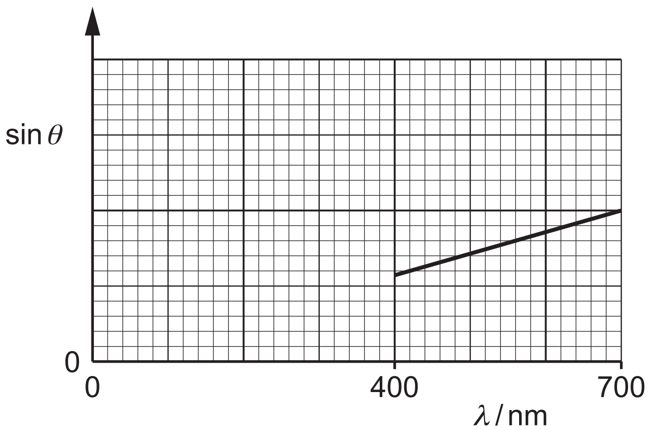

Fig. 4.1

(i) The gradient of the graph is *G*.

Determine an expression, in terms of *G*, for the distance *d* between the centres of two adjacent slits in the diffraction grating.

d = ... [2]

(ii) On Fig. 4.1, sketch a graph to show the results that would be obtained for the **second**-order maxima. [2]

[Total: 10]

9702/22/F/M/21 Q4

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

....

....

.... [2]

(b) A transmitter produces microwaves that travel in air towards a metal plate, as shown in Fig. 4.1.

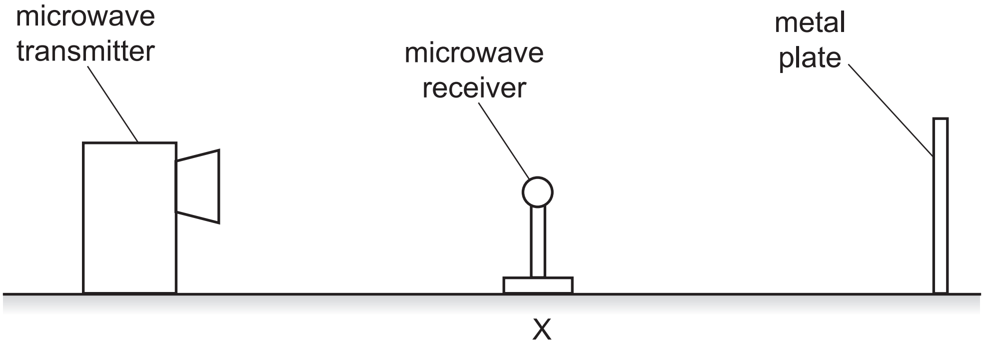

Fig. 4.1

The microwaves have a wavelength of 0.040 m. A stationary wave is formed between the transmitter and the plate.

(i) Explain the function of the metal plate.

....

.... [1]

(ii) Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

(iii) A microwave receiver is initially placed at position X where it detects an intensity minimum. The receiver is then slowly moved away from X directly towards the plate.

1. Determine the shortest distance from X of the receiver when it detects another intensity minimum.

distance = ... m

2. Determine the number of intensity maxima that are detected by the receiver as it moves from X to a position that is 9.1 cm away from X.

number = ...
[2]

[Total: 8]

9702/22/F/M/21 Q5

14. A source of sound is attached to a rope and then swung at a constant speed in a horizontal circle, as illustrated in Fig. 5.1.

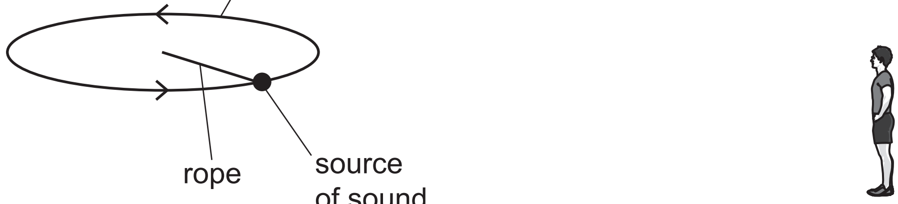

Fig. 5.1 (not to scale)

The source moves with a speed of $12.0\,\text{m}\,\text{s}^{-1}$ and emits sound of frequency 951 Hz. The speed of the sound in the air is $330\,\text{m}\,\text{s}^{-1}$. An observer, standing a very long distance away from the source, hears the sound.

(a) Calculate the minimum frequency, to three significant figures, of the sound heard by the observer.

minimum frequency = ... Hz [2]

(b) The circular path of the source has a radius of 2.4 m.

Determine the shortest time interval between the observer hearing sound of minimum frequency and the observer hearing sound of maximum frequency.

time interval = ... s [2]

[Total: 4]

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

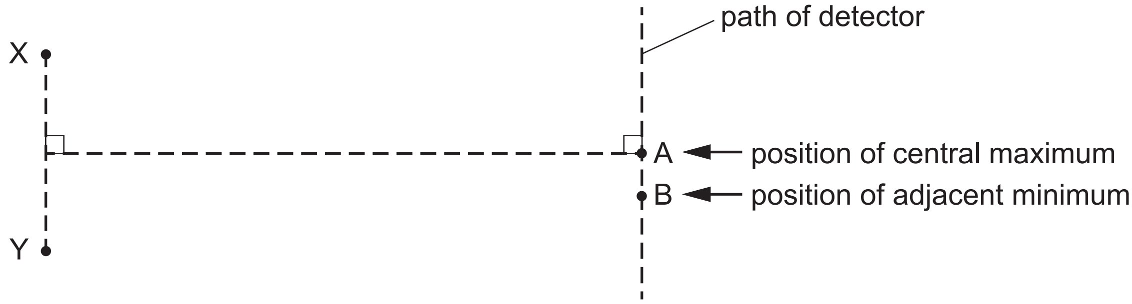

Fig. 5.1 (not to scale)

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]

(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]

16. A progressive wave Y passes a point P. The variation with time *t* of the displacement *x* for the wave at P is shown in Fig. 5.1.

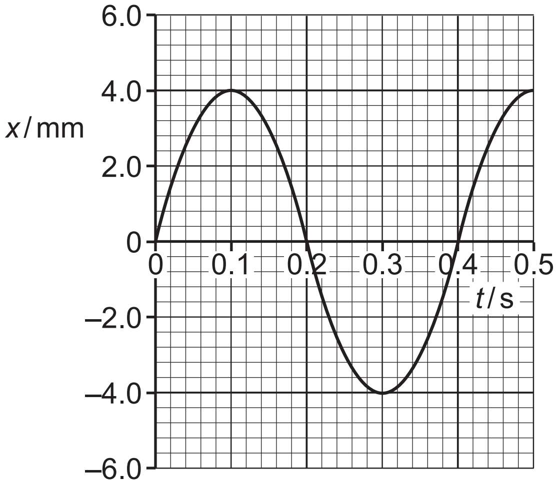

Fig. 5.1

The wave has a wavelength of 8.0 cm.

(a) Determine the speed of the wave.

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

(b) A second wave Z has wavelength 8.0 cm and amplitude 2.0 mm at point P. Waves Y and Z have the same speed.

For the waves at point P, calculate the ratio

$$\frac{\text{intensity of wave Z}}{\text{intensity of wave Y}}.$$

ratio = ... [3]

[Total: 5]

9702/21/O/N/20 Q6

17. **(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]

18. Two progressive sound waves Y and Z meet at a fixed point P. The variation with time *t* of the displacement *x* of each wave at point P is shown in Fig. 4.1.

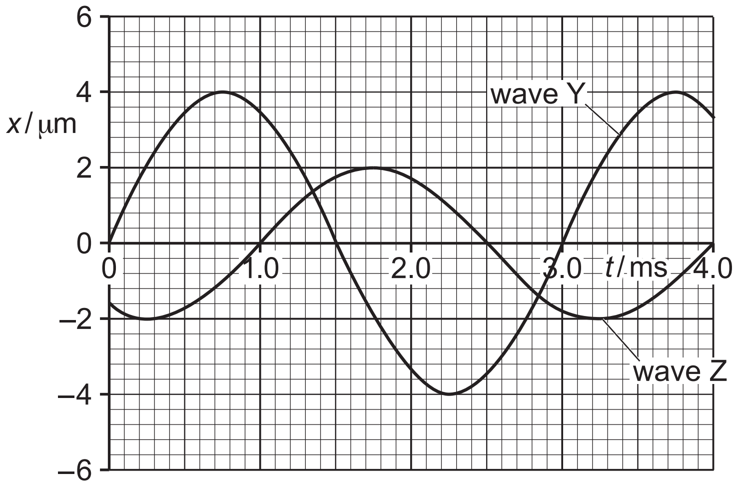

Fig. 4.1

(a) Use Fig. 4.1 to state **one** quantity of waves Y and Z that is:

(i) the same

.... [1]

(ii) different.

.... [1]

(b) State and explain whether waves Y and Z are coherent.

....

.... [1]

(c) Determine the phase difference between the waves.

phase difference = ... ° [1]

(d) The two waves superpose at P. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.75$ ms.

resultant displacement = ... μm [1]

(e) The intensity of wave Y at point P is I.

Determine, in terms of I, the intensity of wave Z.

intensity = ... [2]

(f) The speed of wave Z is $330\,m\,s^{-1}$.

Determine the wavelength of wave Z.

wavelength = ... m [3]

[Total: 10]

9702/22/M/J/20 Q4

19. **(a)** State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

....

.... [1]

(b) A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

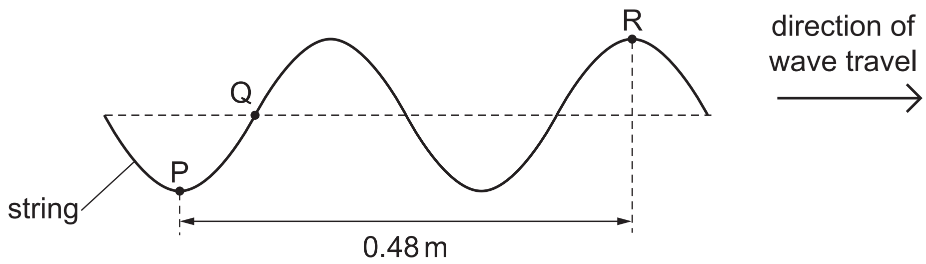

Fig. 4.1

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

(i) Use Fig. 4.1 to determine the wavelength of the wave.

wavelength = ... m [1]

(ii) Calculate the speed of the wave.

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

(iii) Determine the phase difference between points Q and R.

phase difference = ... ° [1]

(iv) Fig. 4.1 shows the position of the string at time t = 0. Describe how the displacement of point Q on the string varies with time from t = 0 to t = 0.010 s.

....

....

....

.... [2]

(c) A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

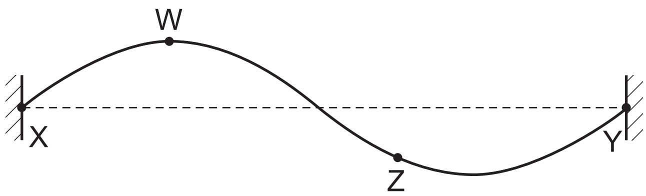

Fig. 4.2

(i) Explain what is meant by a *node* of a stationary wave.

.... [1]

(ii) State the number of antinodes of the wave shown in Fig. 4.2.

number = ... [1]

(iii) State the phase difference between points W and Z on the string.

phase difference = ...° [1]

(iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

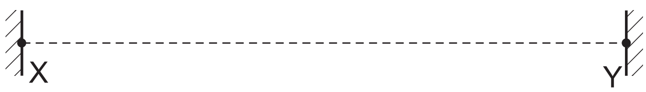

Fig. 4.3

[1]

[Total: 11]

9702/22/M/J/20 Q5

20. One end of a wire is attached to a fixed point. A force F is applied to the wire to cause extension x. The variation with F of x is shown in Fig. 5.1.

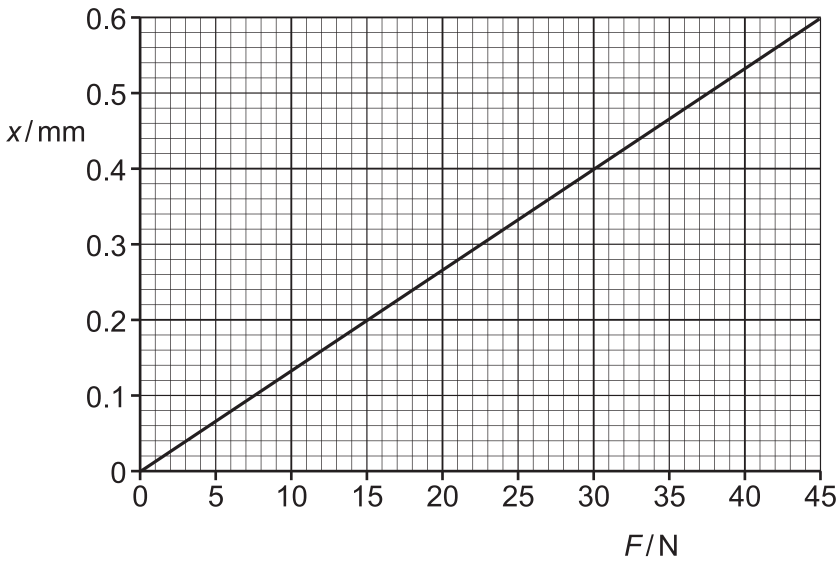

Fig. 5.1

The wire has a cross-sectional area of $4.1 \times 10^{-7}\,m^2$ and is made of metal of Young modulus 1.7×10^{11} Pa. Assume that the cross-sectional area of the wire remains constant as the wire extends.

(a) State the name of the law that describes the relationship between F and x shown in Fig. 5.1.

.... [1]

(b) The wire has an extension of 0.48 mm.

Determine:

(i) the stress

stress = ... Pa [2]

(ii) the strain.

strain = ... [2]

21. (a) (i) By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

....

.... [1]

(ii) State the principle of superposition.

....

....

.... [2]

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

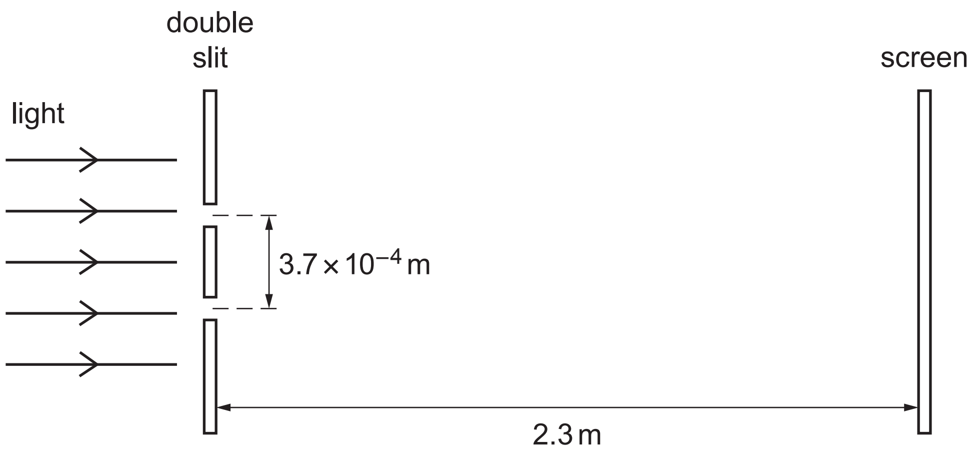

Fig. 4.1 (not to scale)

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.

....

....

....

.... [2]

[Total: 8]

22. **(a)** For a progressive wave, state what is meant by:

(i) the *wavelength*

....

.... [1]

(ii) the *amplitude*.

....

.... [1]

(b) A beam of red laser light is incident normally on a diffraction grating.

(i) Diffraction of the light waves occurs at each slit of the grating. The light waves emerging from the slits are coherent.

Explain what is meant by:

1. *diffraction*

....

.... [1]

2. *coherent*.

....

.... [1]

(ii) The wavelength of the laser light is 650 nm. The angle between the **third** order diffraction maxima is 68°, as illustrated in Fig. 4.1.

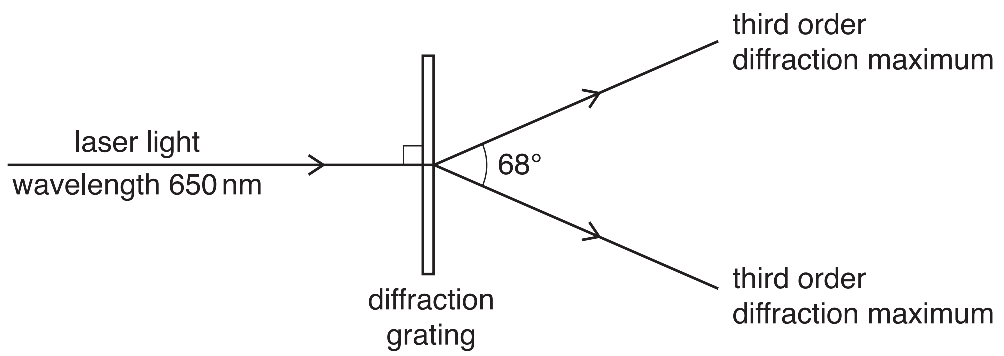

Fig. 4.1 (not to scale)

Calculate the separation d between the centres of adjacent slits of the grating.

d = ... m [3]

(iii) The red laser light is replaced with blue laser light.

State and explain the change, if any, to the angle between the third order diffraction maxima.

....

....

.... [2]

[Total: 9]

9702/22/O/N/19 Q5

23. (a) State what is meant by the *wavelength* of a progressive wave.

....

.... [1]

(b) A cathode-ray oscilloscope (CRO) is used to analyse a sound wave. The screen of the CRO is shown in Fig. 5.1.

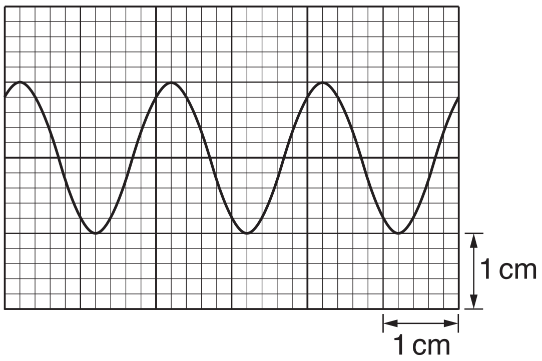

Fig. 5.1

The time-base setting of the CRO is 2.5 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ... Hz [2]

(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.

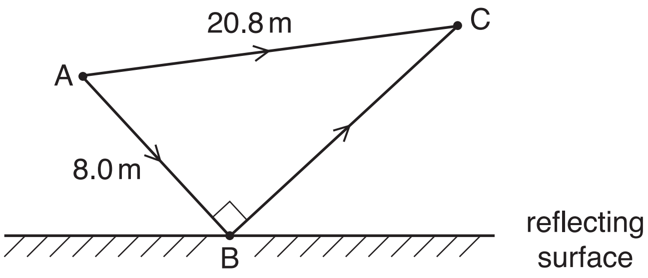

Fig. 5.2 (not to scale)

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]

(iii) Determine the difference between the times taken for the sound to travel from the source to point C along the two different paths.

time difference = ... s [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]

[Total: 9]

9702/21/O/N/19 Q5

24. 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.

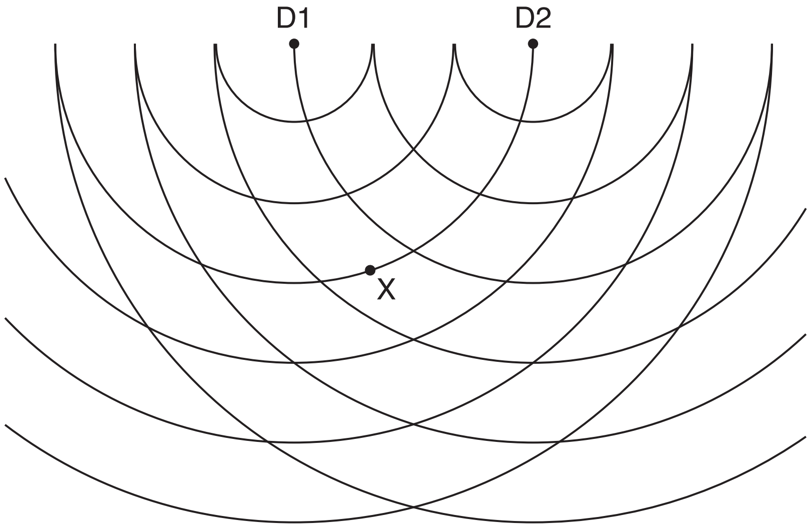

Fig. 5.1

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.

....

.... [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.

....

.... [1]

(c) The speed of the waves is 0.40 m s^{-1}. Calculate the period of the waves.

period = ... s [2]

(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]

[Total: 8]

9702/23/M/J/19 Q5

25. A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

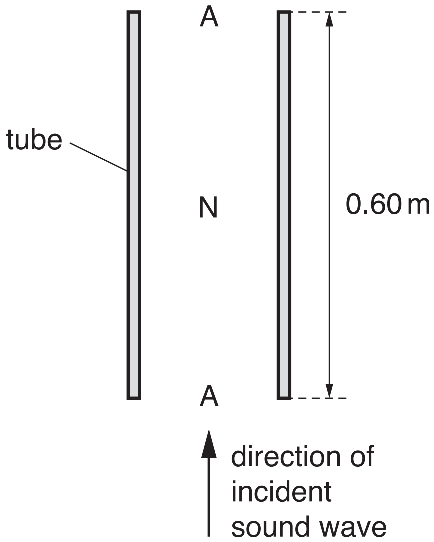

Fig. 5.1

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 at both ends and a node N at the midpoint.

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

....

....

....

....[2]

(b) 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.

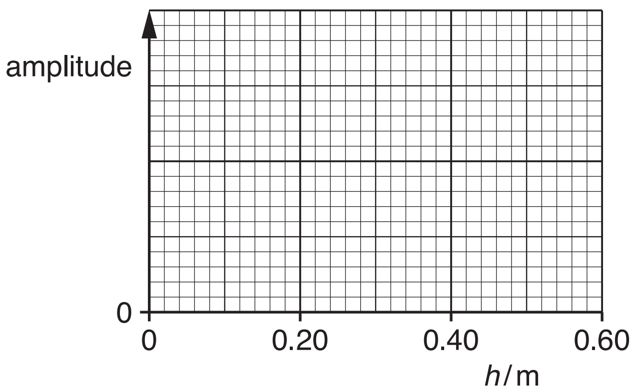

Fig. 5.2

[2]

(c) For the stationary wave, state:

(i) the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

....[1]

(ii) 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]

(d) The speed of the sound wave is 340 m s^{-1}.

Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(e) The frequency of the sound wave is gradually increased.

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

frequency = ... Hz [1]

[Total: 9]

26. **(a)** For a progressive water wave, state what is meant by:

(i) *displacement*

....

....[1]

(ii) *amplitude*.

....

....[1]

(b) Two coherent waves X and Y meet at a point and superpose. The phase difference between the waves at the point is 180°. Wave X has an amplitude of 1.2 cm and intensity I. Wave Y has an amplitude of 3.6 cm.

Calculate, in terms of I, the resultant intensity at the meeting point.

intensity = ... [2]

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

....

....

....[2]

(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 [3]

(iii) The beam of light in **(c)(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.

....

....

....[2]

[Total: 11]

9702/21/M/J/19 Q5

27. (a) A loudspeaker oscillates with frequency *f* to produce sound waves of wavelength λ. The loudspeaker makes *N* oscillations in time *t*.

(i) State expressions, in terms of some or all of the symbols *f*, λ and *N*, for:

1. the distance moved by a wavefront in time *t*

distance = ...

2. time *t*.

time *t* = ...
[2]

(ii) Use your answers in **(i)** to deduce the equation relating the speed *v* of the sound wave to *f* and λ.

[1]

(b) The waveform of a sound wave is displayed on the screen of a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

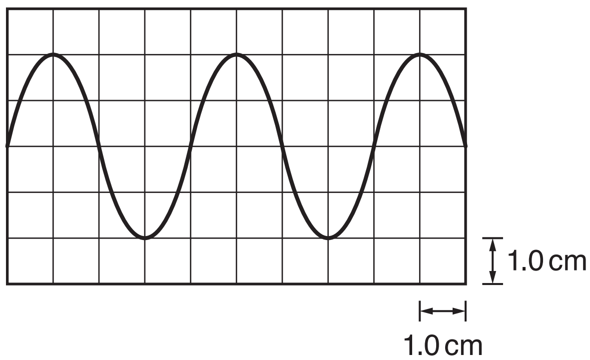

Fig. 5.1

The time-base setting is 0.20 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ... Hz [2]

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

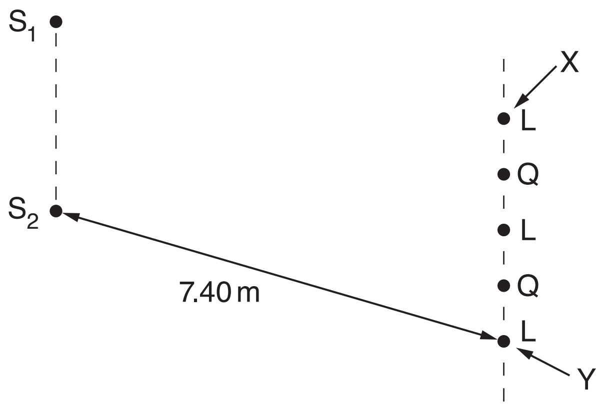

Fig. 5.2 (not to scale)

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]

[Total: 9]

9702/22/F/M/19 Q5

28. **(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.

amplitude = ... cm [2]

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

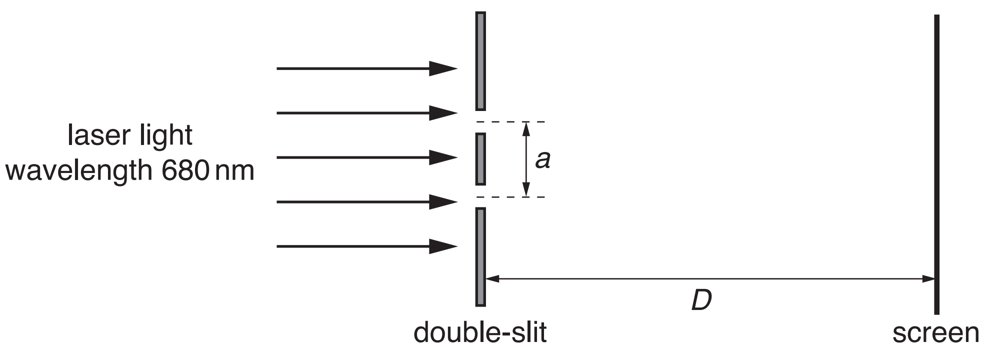

Fig. 5.1 (not to scale)

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.

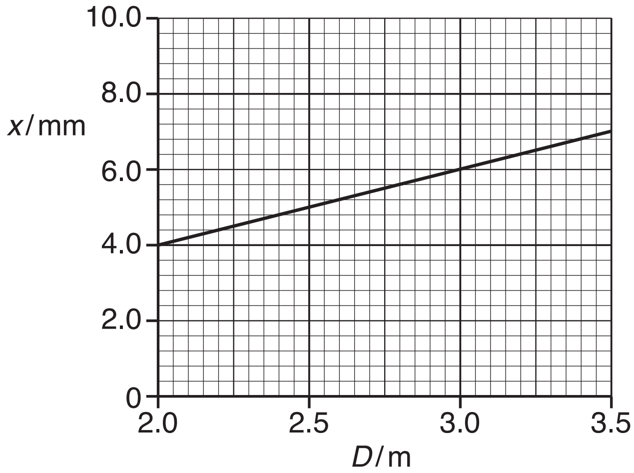

Fig. 5.2

(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]

29. **(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.

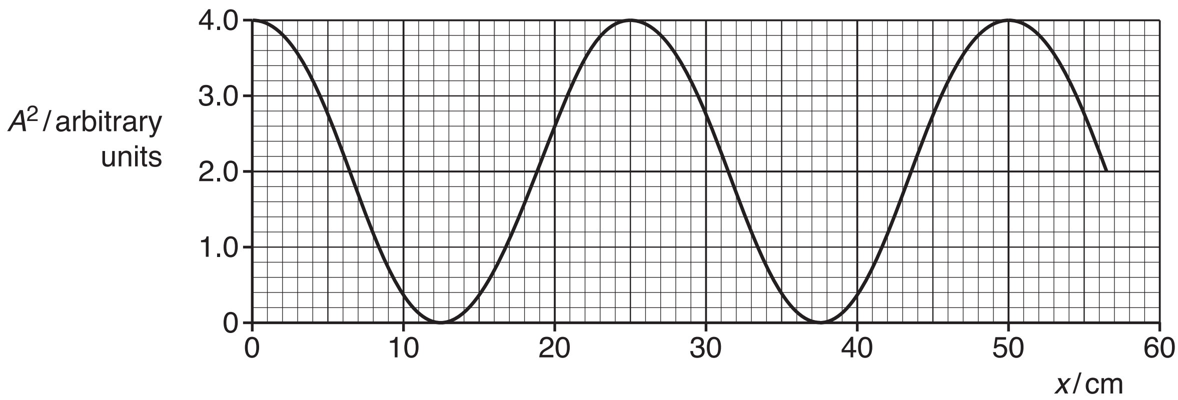

Fig. 4.1

(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 $330\,\text{m s}^{-1}$. 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]

30. 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.

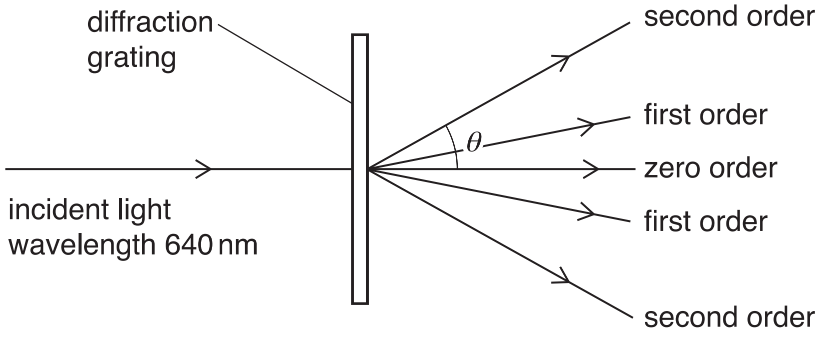

Fig. 5.1 (not to scale)

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]

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

....

....

.... [2]

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

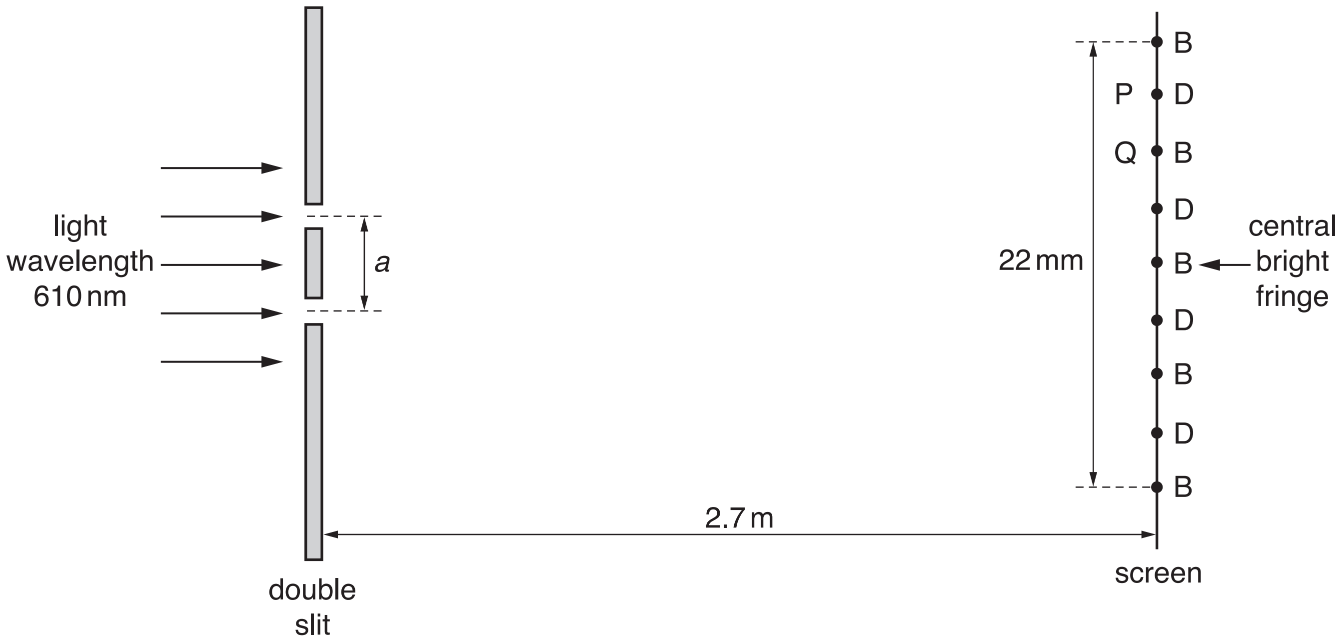

Fig. 4.1 (not to scale)

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]

32. (a) State the relationship between the intensity and the amplitude of a wave.

....

....[1]

(b) Microwaves of the same amplitude and wavelength are emitted in phase from two sources P and Q. The sources are arranged as shown in Fig. 5.1.

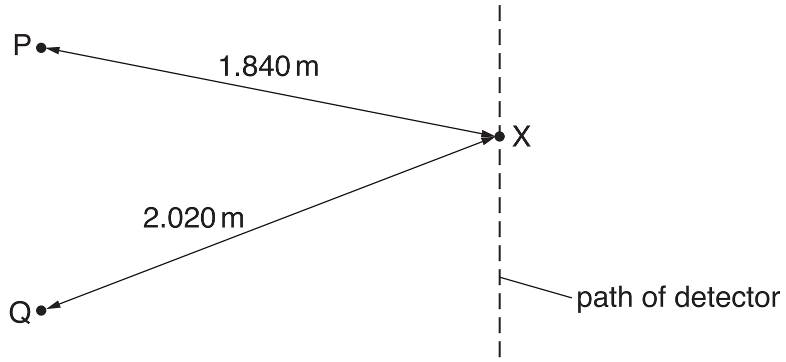

Fig. 5.1

A microwave detector is moved along a path that is parallel to the line joining P and Q. A series of intensity maxima and intensity minima are detected.

When the detector is at a point X, the distance PX is 1.840 m and the distance QX is 2.020 m. The microwaves have a wavelength of 6.0 cm.

(i) Calculate the frequency of the microwaves.

frequency = ... Hz [2]

(ii) Describe and explain the intensity of the microwaves detected at X.

....

....

....

....

....[3]

(iii) Describe the effect on the interference pattern along the path of the detector due to each of the following separate changes.

1. The wavelength of the microwaves decreases.

....

....

2. The phase difference between the microwaves emitted from the sources changes to 180°.

....

....
[2]

[Total: 8]

33. (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.

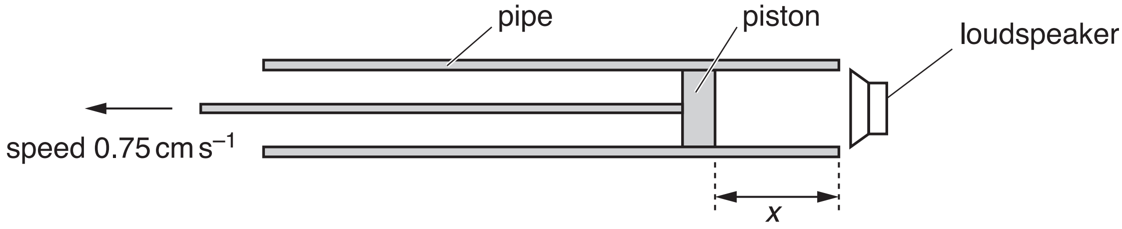

Fig. 4.1

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]

34. **(a)** For a progressive wave, state what is meant by

(i) the *period*,

....

....[1]

(ii) the *wavelength*.

....

....[1]

(b) Fig. 4.1 shows the variation with time t of the displacement x of two progressive waves P and Q passing the same point.

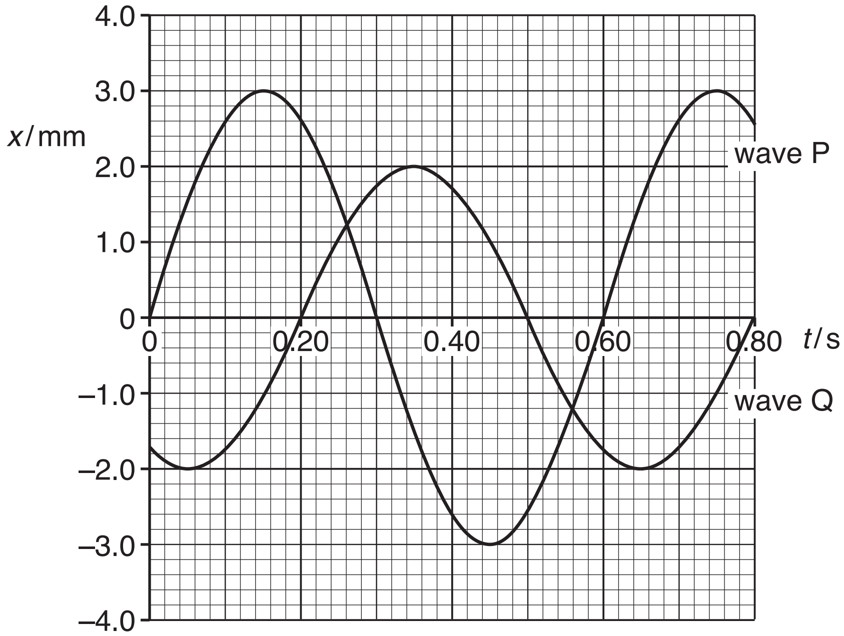

Fig. 4.1

The speed of the waves is $20\,cm\,s^{-1}$.

(i) Calculate the wavelength of the waves.

wavelength = ... cm [2]

(ii) Determine the phase difference between the two waves.

phase difference = ... ° [1]

(iii) Calculate the ratio

$$\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}.$$

ratio = ... [2]

(iv) The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45\,\text{s}$.

displacement = ... mm [1]

[Total: 8]

35. (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]

36. (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.

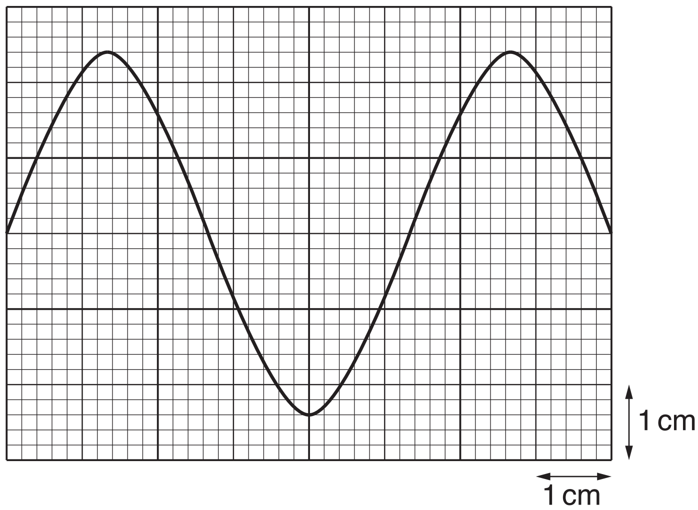

Fig. 4.1

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.

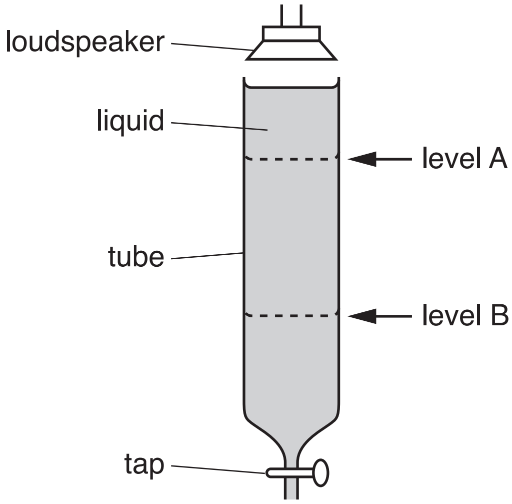

Fig. 4.2

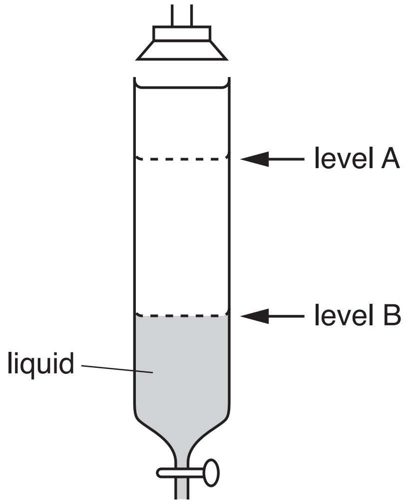

Fig. 4.3

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

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

time = ... s [2]

[Total: 12]

37. (a) State the conditions required for the formation of a stationary wave.

....

....

....

....[2]

(b) A horizontal string is stretched between two fixed points X and Y. The string is made to vibrate vertically so that a stationary wave is formed. At one instant, each particle of the string is at its maximum displacement, as shown in Fig. 4.1.

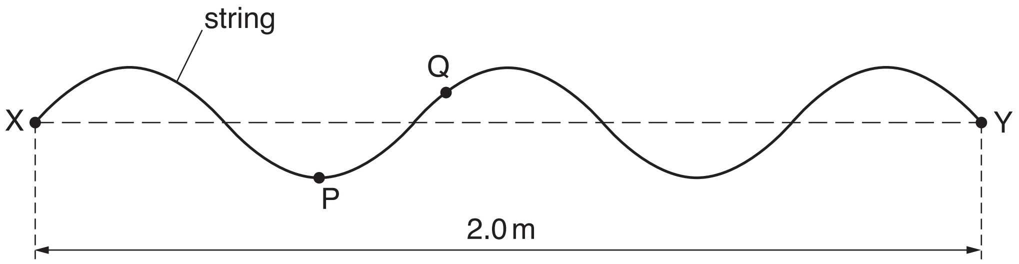

Fig. 4.1

P and Q are two particles of the string. The string vibrates with a frequency of 40 Hz. Distance XY is 2.0 m.

(i) State the number of antinodes in the stationary wave.

number = ...[1]

(ii) Determine the minimum time taken for the particle P to travel from its lowest point to its highest point.

time taken = ... s [2]

(iii) State the phase difference, with its unit, between the vibrations of particle P and of particle Q.

phase difference = ...[1]

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

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

[Total: 8]

9702/21/O/N/17 Q3

38. **(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.

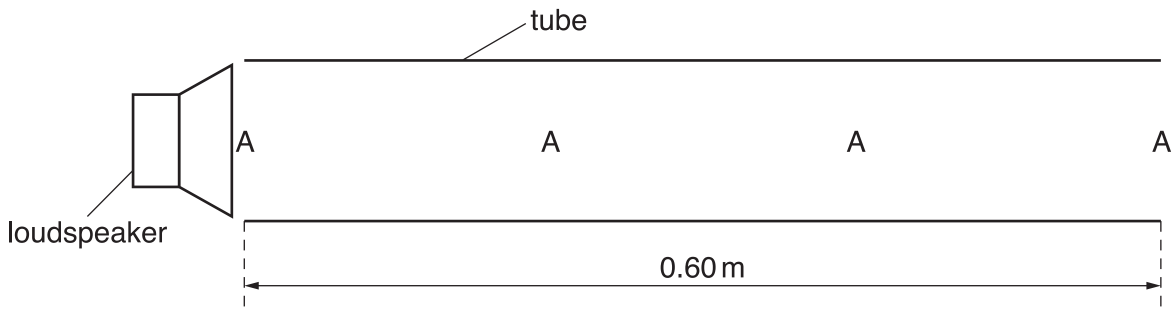

Fig. 3.1

The speed of the sound in the tube is $340\,\mathrm{m\,s^{-1}}$. 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]

39. **(a)** A diffraction grating is used to determine the wavelength of light.

(i) Describe the diffraction of light at a diffraction grating.

....

....

....[2]

(ii) By reference to interference, explain

1. the zero order maximum,

....

....

....

2. the first order maximum.

....

....

[3]

(b) A diffraction grating is used with different wavelengths of light. The angle θ of the second order maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 5.1.

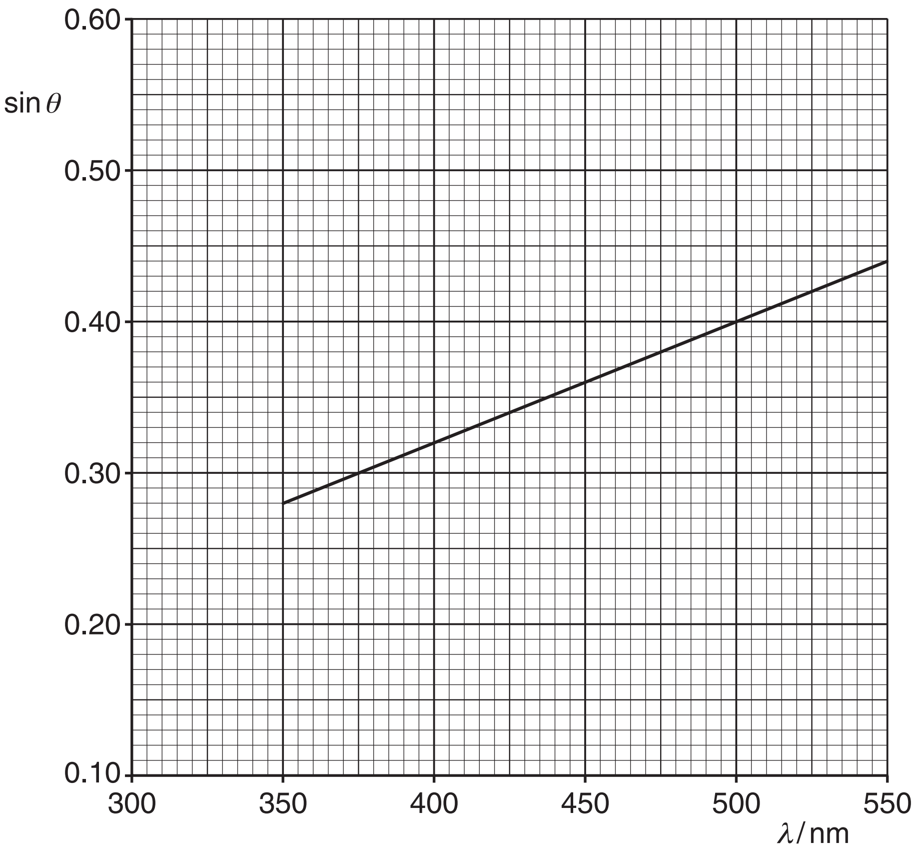

Fig. 5.1

(i) Determine the gradient of the line shown in Fig. 5.1.

gradient = ...[2]

(ii) Use the gradient determined in **(i)** to calculate the slit separation *d* of the diffraction grating.

d = ...m [2]

(iii) On Fig. 5.1, sketch a line to show the results that would be obtained for the first order maxima. [1]

[Total: 10]

9702/22/M/J/17 Q5

40. **(a)** Define the *frequency* of a sound wave.

....

....[1]

(b) A sound wave travels through air. Describe the motion of the air particles relative to the direction of travel of the sound wave.

....

....[1]

(c) The sound wave emitted from the horn of a stationary car is detected with a microphone and displayed on a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

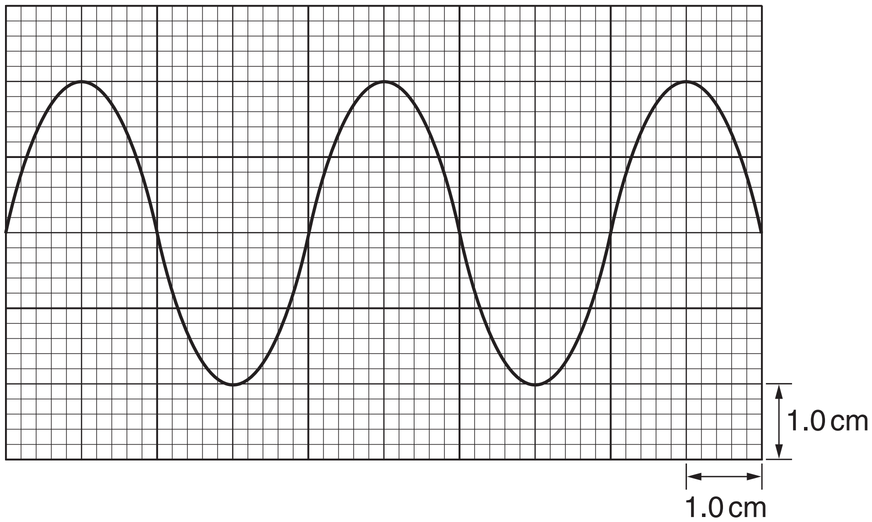

Fig. 5.1

The *y*-axis setting is 5.0 mV cm^{-1}.
The time-base setting is 0.50 ms cm^{-1}.

(i) Use Fig. 5.1 to determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The horn of the car sounds continuously. Describe the changes to the trace seen on the c.r.o. as the car travels at constant speed

1. directly towards the stationary microphone,

....

....

2. directly away from the stationary microphone.

....

....
[3]

[Total: 7]

41. (a) Interference fringes may be observed using a light-emitting laser to illuminate a double slit. The double slit acts as two sources of light.

Explain

(i) the part played by diffraction in the production of the fringes,

....

....

....[2]

(ii) the reason why a double slit is used rather than two separate sources of light.

....

....

....[1]

(b) A laser emitting light of a single wavelength is used to illuminate slits S_1 and S_2, as shown in Fig. 6.1.

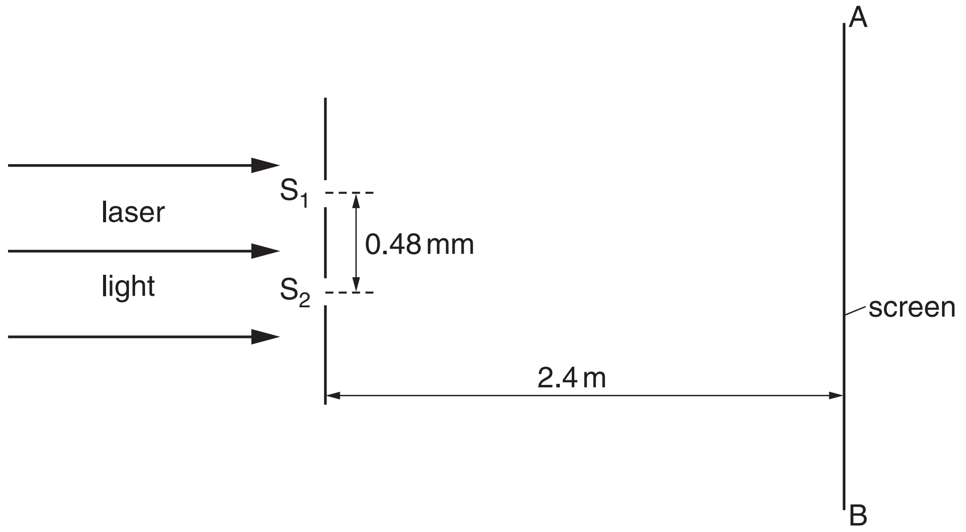

Fig. 6.1 (not to scale)

An interference pattern is observed on the screen AB. The separation of the slits is 0.48 mm. The slits are 2.4 m from AB. The distance on the screen across 16 fringes is 36 mm, as illustrated in Fig. 6.2.

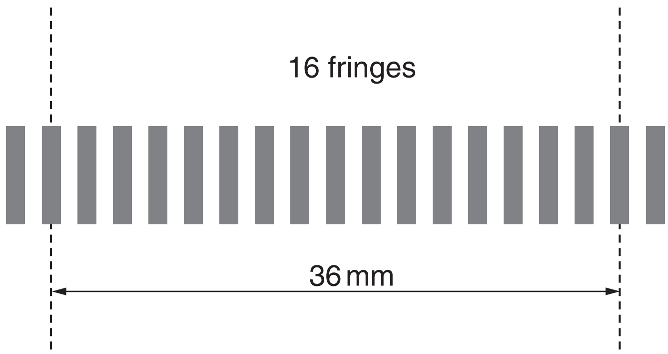

Fig. 6.2

Calculate the wavelength of the light emitted by the laser.

wavelength = ... m [3]

(c) Two dippers D_1 and D_2 are used to produce identical waves on the surface of water, as illustrated in Fig. 6.3.

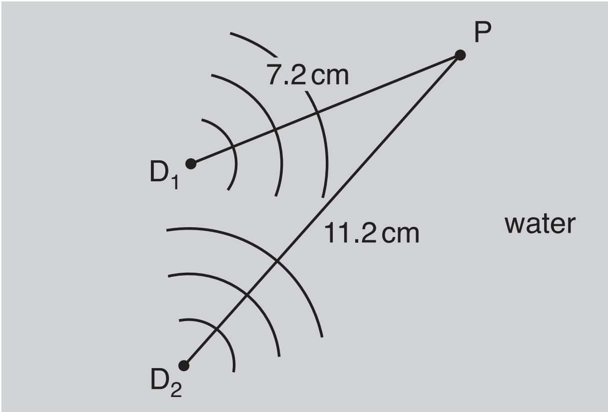

Fig. 6.3 (not to scale)

Point P is 7.2cm from D_1 and 11.2cm from D_2.

The wavelength of the waves is 1.6cm. The phase difference between the waves produced at D_1 and D_2 is zero.

(i) State and explain what is observed at P.

....

....

....[2]

(ii) State and explain the effect on the answer to **(c)(i)** if the apparatus is changed so that, separately,

1. the phase difference between the waves at D_1 and at D_2 is 180°,

....

....

....

2. the intensity of the wave from D_1 is less than the intensity of that from D_2.

....

....

....

[2]

[Total: 10]

42. (a) State the conditions required for the formation of stationary waves.

....

....

....[2]

(b) One end of a string is attached to a vibrator. The string is stretched by passing the other end over a pulley and attaching a load, as illustrated in Fig. 4.1.

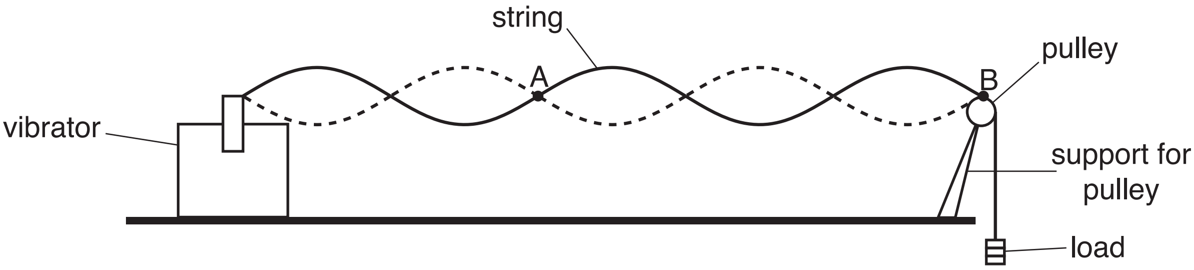

Fig. 4.1

The frequency of vibration of the vibrator is adjusted to 250 Hz and a transverse wave travels along the string with a speed of $12\,\mathrm{m\,s^{-1}}$. The wave is reflected at the pulley and a stationary wave forms on the string.

Fig. 4.2 shows the string between points A and B at time $t = t_1$.

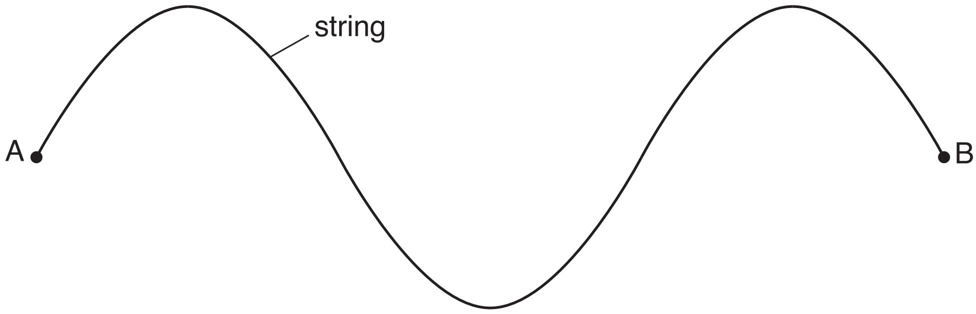

Fig. 4.2

At time $t = t_1$ the string has maximum displacement.

(i) Calculate the distance AB.

distance = ...m [2]

(ii) On Fig. 4.2, sketch the position of the string between A and B at times

1. $t = t_1 + 2.0\,\text{ms}$ (label this line P),

2. $t = t_1 + 5.0\,\text{ms}$ (label this line Q).

[3]

[Total: 7]

9702/21/M/J/17 Q5

43. **(a)** Describe the Doppler effect.

....

....

....[1]

(b) A car travels with a constant velocity along a straight road. The car horn with a frequency of 400 Hz is sounded continuously. A stationary observer on the roadside hears the sound from the horn at a frequency of 360 Hz.
The speed of sound is $340\,\mathrm{m\,s^{-1}}$.

Determine the magnitude *v*, and the direction, of the velocity of the car relative to the observer.

v = ... $\mathrm{m\,s^{-1}}$

direction ....
[3]

[Total: 4]

44. **(a)** State what is meant by the *Doppler effect*.

....

....

....[2]

(b) A child sits on a rotating horizontal platform in a playground. The child moves with a constant speed along a circular path, as illustrated in Fig. 4.1.

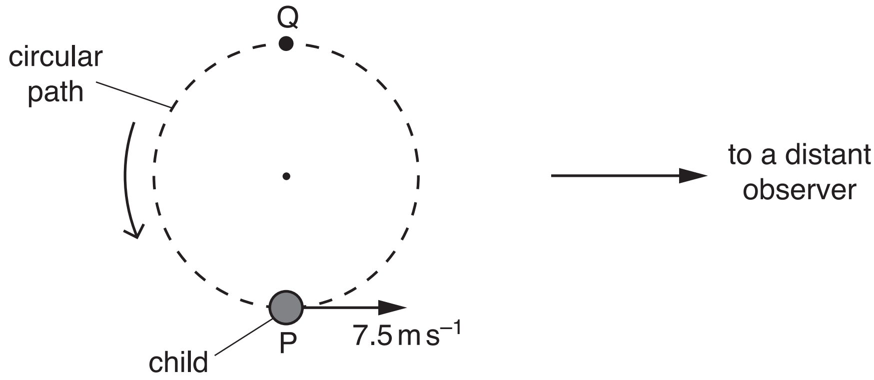

Fig. 4.1

An observer is standing a long distance away from the child. During one particular revolution, the child, moving at a speed of 7.5 m s^{-1}, starts blowing a whistle at point P and stops blowing it at point Q on the circular path.

The whistle emits sound of frequency 950 Hz. The speed of sound in air is 330 m s^{-1}.

(i) Determine the maximum frequency of the sound heard by the distant observer.

maximum frequency = ... Hz [2]

(ii) Describe the variation in the frequency of the sound heard by the distant observer.

....

....

....

....[2]

[Total: 6]

45. (a) State what is meant by the *diffraction* of a wave.

....

....[2]

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

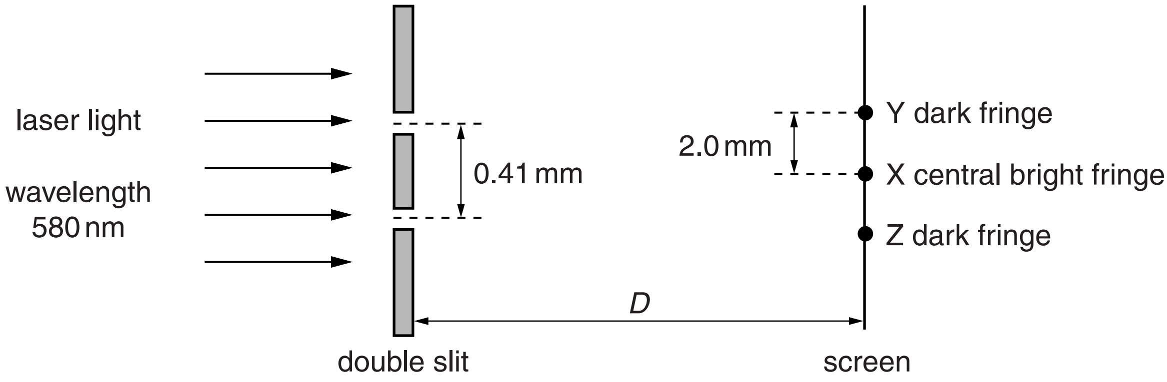

Fig. 4.1 (not to scale)

The wavelength of the light from the laser is 580 nm. The separation of the slits is 0.41 mm. The perpendicular distance between the double slit and the screen is *D*.

Coherent light emerges from the slits and an interference pattern is observed on the screen. The central bright fringe is produced at point X. The closest dark fringes to point X are produced at points Y and Z. The distance XY is 2.0 mm.

(i) Explain why a bright fringe is produced at point X.

....

....

....

....[2]

(ii) State the difference in the distances, in nm, from each slit to point Y.

distance = ... nm [1]

(iii) Calculate the distance *D*.

D = ... m [3]

(iv) The intensity of the light passing through the two slits 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.

....

....

....

....[2]

[Total: 10]

9702/21/O/N/16 Q4

46. (a) State what is meant by the *frequency* of a progressive wave.

....

....

....[2]

(b) A cathode-ray oscilloscope (c.r.o.) is used to determine the frequency of the sound emitted by a loudspeaker. The trace produced on the screen of the c.r.o. is shown in Fig. 4.1.

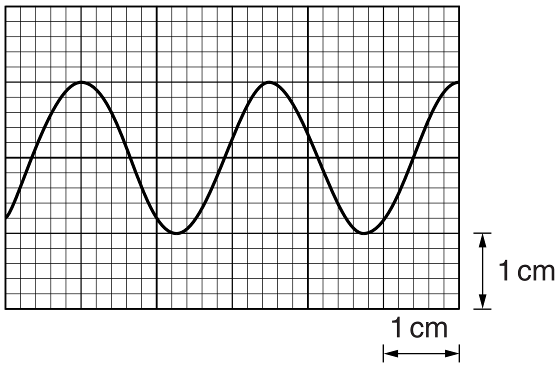

Fig. 4.1

The time-base setting of the c.r.o. is $250\,\mu s\,cm^{-1}$.

Show that the frequency of the sound wave is 1600 Hz.

[2]

(c) The loudspeaker in **(b)** emits the sound in all directions. A person attaches the loudspeaker to a string and then swings the loudspeaker at a constant speed in a horizontal circle above his head.

An observer, standing a large distance away from the loudspeaker, hears sound of maximum frequency 1640 Hz. The speed of sound in air is $330\,m\,s^{-1}$.

(i) Determine the speed of the loudspeaker.

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

(ii) Describe and explain, qualitatively, the variation in the frequency of the sound heard by the observer.

....

....

....

....

....[2]

[Total: 8]

9702/21/O/N/16 Q5

47. (a) State what is meant by the *diffraction* of a wave.

....

....[2]

(b) Laser light of wavelength 500 nm is incident normally on a diffraction grating. The resulting diffraction pattern has diffraction maxima up to and including the fourth-order maximum.

Calculate, for the diffraction grating, the minimum possible line spacing.

line spacing = ... m [3]

(c) The light in **(b)** is now replaced with red light. State and explain whether this is likely to result in the formation of a fifth-order diffraction maximum.

....

....

....

....[2]

[Total: 7]

9702/23/M/J/16 Q7

48. **(a)** Apparatus used to produce stationary waves on a stretched string is shown in Fig. 7.1.

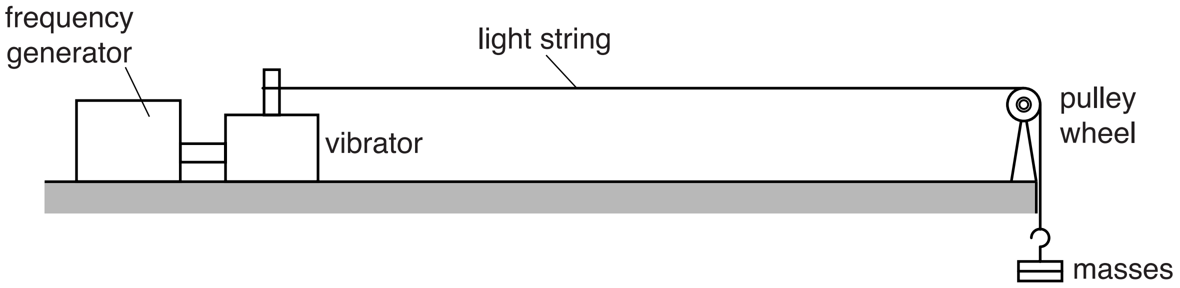

Fig. 7.1

The frequency generator is switched on.

(i) Describe two adjustments that can be made to the apparatus to produce stationary waves on the string.

1. ....

....

2. ....

....
[2]

(ii) Describe the features that are seen on the stretched string that indicate stationary waves have been produced.

.... [1]

(b) The variation with time *t* of the displacement *x* of a particle caused by a progressive wave R is shown in Fig. 7.2. For the same particle, the variation with time *t* of the displacement *x* caused by a second wave S is also shown in Fig. 7.2.

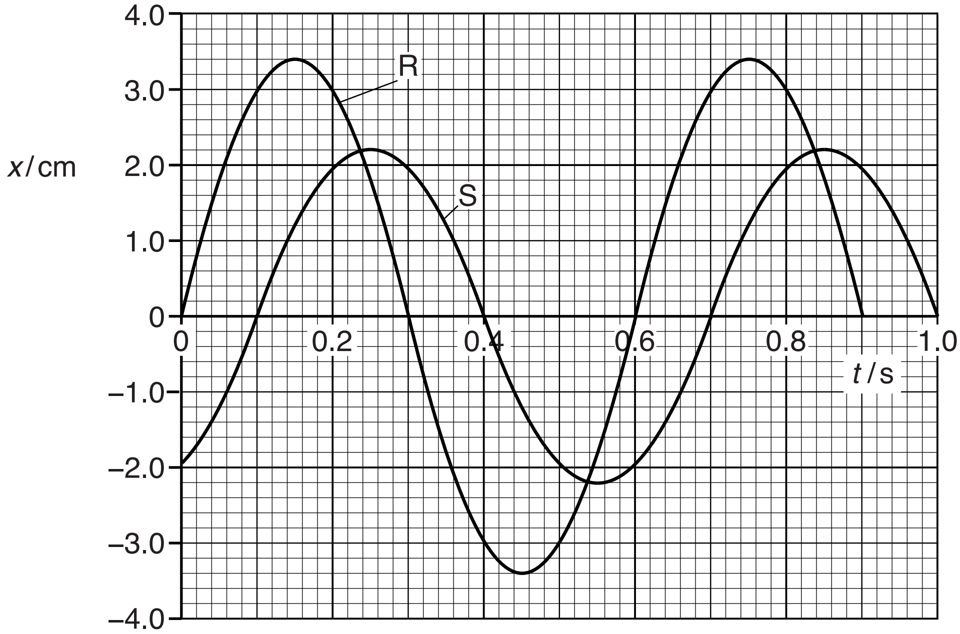

Fig. 7.2

(i) Determine the phase difference between wave R and wave S. Include an appropriate unit.

phase difference = ... [1]

(ii) Calculate the ratio

$$\frac{\text{intensity of wave R}}{\text{intensity of wave S}}.$$

ratio = ... [2]

[Total: 6]

49. **(a)** By reference to the direction of the propagation of energy, state what is meant by a *longitudinal* wave and by a *transverse* wave.

longitudinal: ....

....

....

transverse: ....

....

.... [2]

(b) The intensity of a sound wave passing through air is given by

$$I = Kv\rho f^2 A^2$$

where I is the intensity (power per unit area),
K is a constant without units,
v is the speed of sound,
ρ is the density of air,
f is the frequency of the wave
and A is the amplitude of the wave.

Show that both sides of the equation have the same SI base units.

[3]

(c) **(i)** Describe the *Doppler effect*.

....

....[1]

(ii) A distant star is moving away from a stationary observer.

State the effect of the motion on the light observed from the star.

....

....

....[1]

(d) A car travels at a constant speed towards a stationary observer. The horn of the car sounds at a frequency of 510 Hz and the observer hears a frequency of 550 Hz. The speed of sound in air is $340\,\text{m}\,\text{s}^{-1}$.

Calculate the speed of the car.

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

[Total: 10]

50. **(a)** Light of a single wavelength is incident on a diffraction grating. Explain the part played by *diffraction* and *interference* in the production of the first order maximum by the diffraction grating.

diffraction: ....

....

interference: ....

....

....

.... [3]

(b) The diffraction grating illustrated in Fig. 5.1 is used with light of wavelength 486 nm.

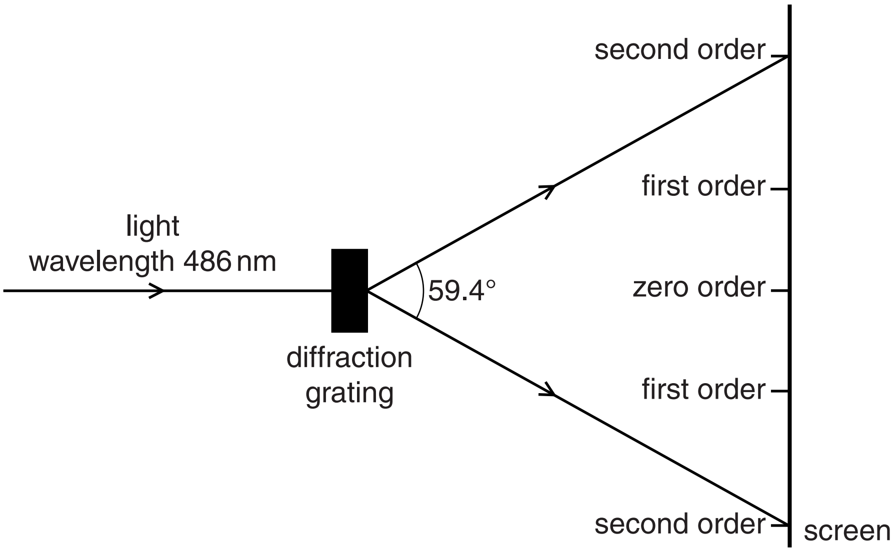

Fig. 5.1 (not to scale)

The orders of the maxima produced are shown on the screen in Fig. 5.1. The angle between the two second order maxima is 59.4°.

Calculate the number of lines per millimetre of the grating.

number of lines per millimetre = ... mm^{-1} [3]

[Total: 6]

51. The variation with time *t* of the displacement *y* of a wave X, as it passes a point P, is shown in Fig. 5.1.

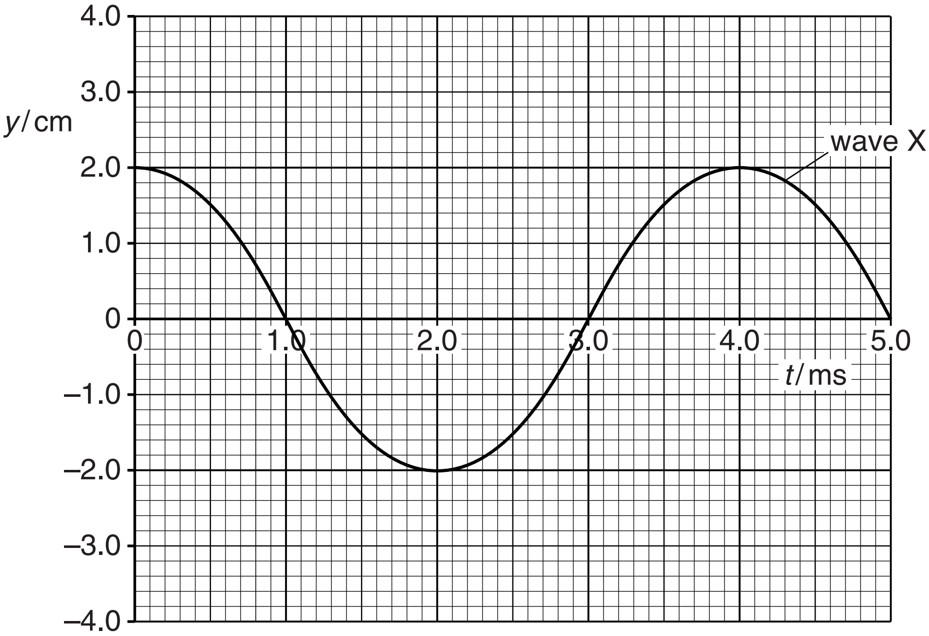

Fig. 5.1

The intensity of wave X is I.

(a) Use Fig. 5.1 to determine the frequency of wave X.

frequency = ... Hz [2]

(b) A second wave Z with the same frequency as wave X also passes point P.
Wave Z has intensity $2I$. The phase difference between the two waves is 90°.

On Fig. 5.1, sketch the variation with time *t* of the displacement *y* of wave Z.

Show your working.

[3]

(c) A double-slit interference experiment is used to determine the wavelength of light emitted from a laser, as shown in Fig. 5.2.

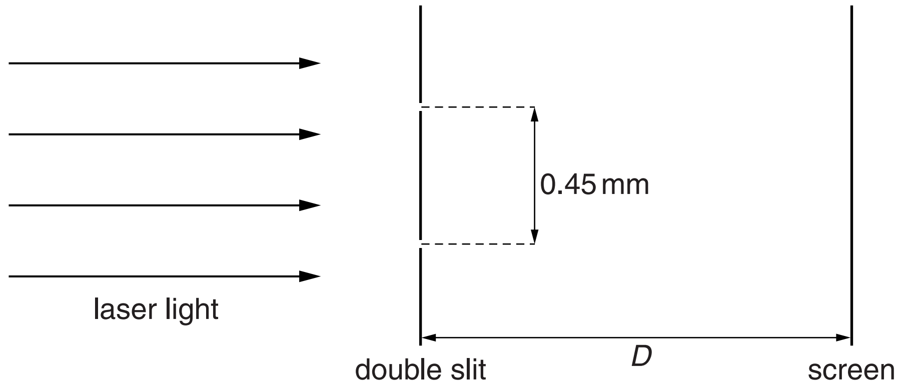

Fig. 5.2 (not to scale)

The separation of the slits is 0.45 mm. The fringes are viewed on a screen at a distance *D* from the double slit.

The fringe width *x* is measured for different distances *D*. The variation with *D* of *x* is shown in Fig. 5.3.

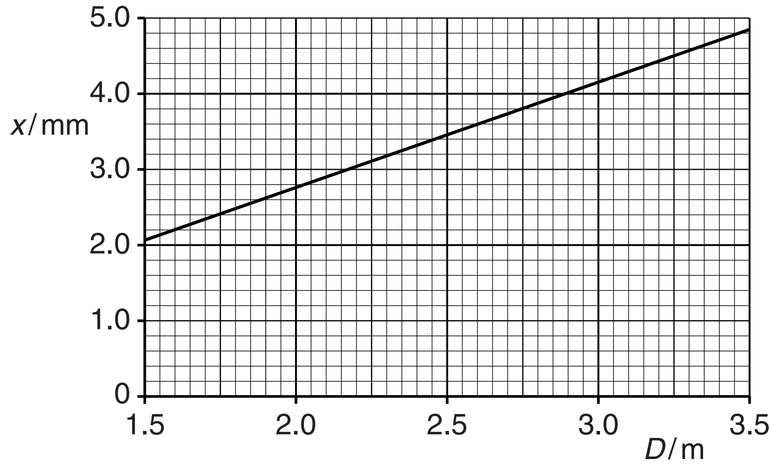

Fig. 5.3

(i) Use the gradient of the line in Fig. 5.3 to determine the wavelength, in nm, of the laser light.

wavelength = ... nm [4]

(ii) The separation of the slits is increased. State and explain the effects, if any, on the graph of Fig. 5.3.

....

....

....[2]

[Total: 11]

52. **(a)** **(i)** By reference to the direction of propagation of energy, state what is meant by a *transverse* wave.

....

.... [1]

(ii) State the principle of superposition.

....

....

.... [2]

(b) Circular water waves may be produced by vibrating dippers at points P and Q, as illustrated in Fig. 4.1.

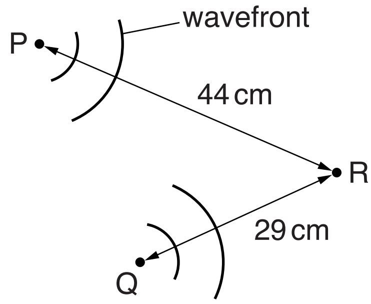

Fig. 4.1 (not to scale)

The waves from P alone have the same amplitude at point R as the waves from Q alone. Distance PR is 44 cm and distance QR is 29 cm.

The dippers vibrate in phase with a period of 1.5 s to produce waves of speed $4.0\,\text{cm}\,\text{s}^{-1}$.

(i) Determine the wavelength of the waves.

wavelength = ... cm [2]

(ii) By reference to the distances PR and QR, explain why the water particles are at rest at point R.

....

....

....

....

.... [3]

(c) A wave is produced on the surface of a different liquid. At one particular time, the variation of the vertical displacement *y* with distance *x* along the surface of the liquid is shown in Fig. 4.2.

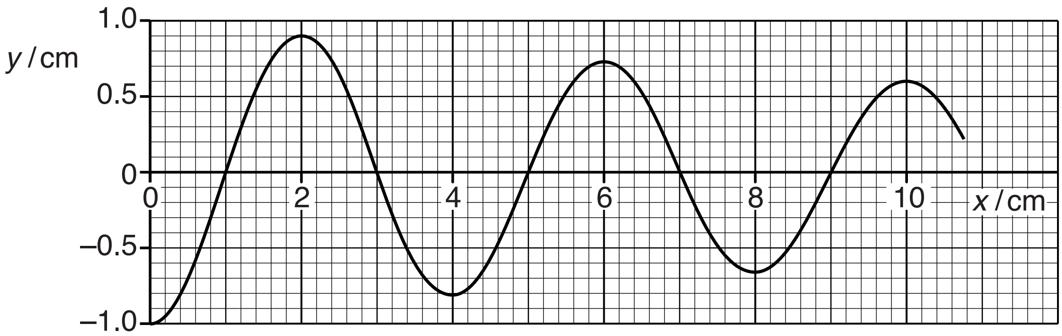

Fig. 4.2

(i) The wave has intensity I_1 at distance $x = 2.0\,\text{cm}$ and intensity I_2 at $x = 10.0\,\text{cm}$.

Determine the ratio

$$\frac{\text{intensity } I_2}{\text{intensity } I_1}.$$

ratio = ... [2]

(ii) State the phase difference, with its unit, between the oscillations of the liquid particles at distances $x = 3.0\,\text{cm}$ and $x = 4.0\,\text{cm}$.

phase difference = ... [1]

[Total: 11]