

1.

1. (a) State the difference between transverse and longitudinal waves.

[2]

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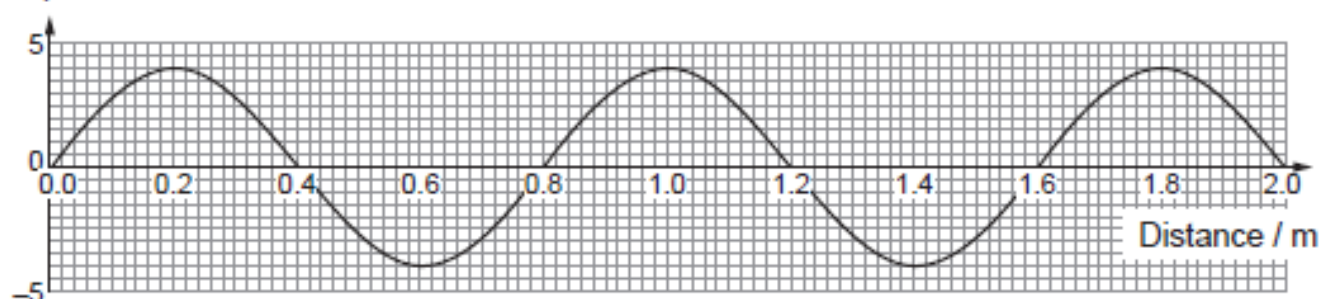
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- (b) The variation of displacement with respect to position and time is shown in the following two graphs for the same surface wave on water.

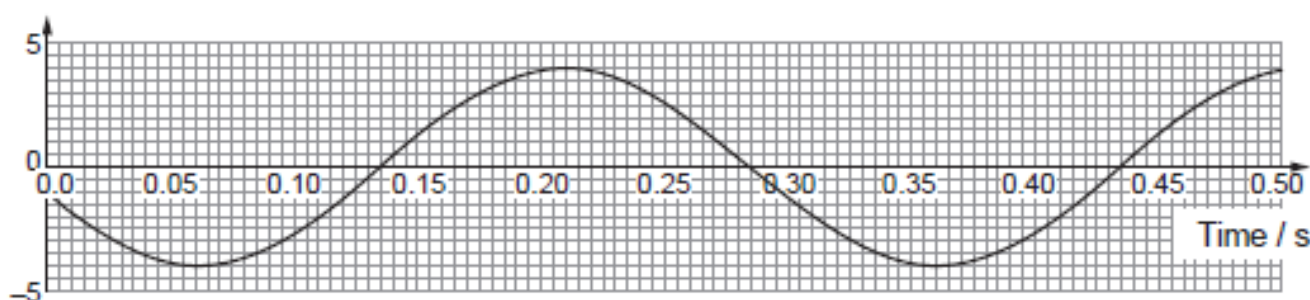
Graph of displacement against distance (at a given time)

Displacement / cm



Graph of displacement against time (at a given distance)

Displacement / cm



- (i) State the amplitude of the wave.

[1]

- (ii) State the wavelength of the wave.

[1]

(iii) Calculate the speed of the wave.

[3]

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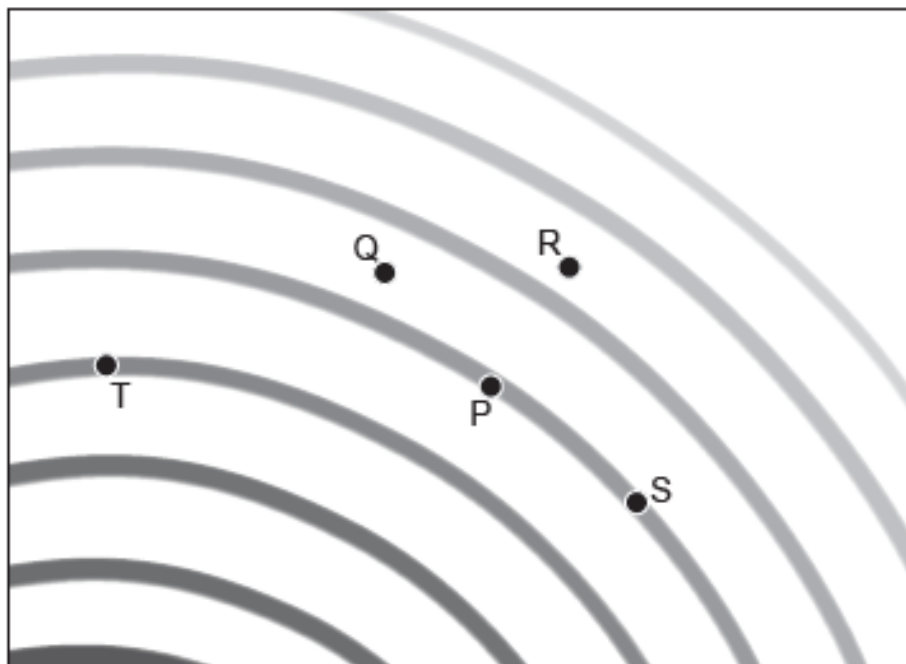
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(c) A wavefront diagram for waves on the surface of water is shown.



(i) Draw an arrow to indicate the direction of motion of the wavefront at point **S**. [1]

(ii) State the point(s) oscillating in phase with point **P**. [1]

1. (a) Explain what is meant by a progressive wave.

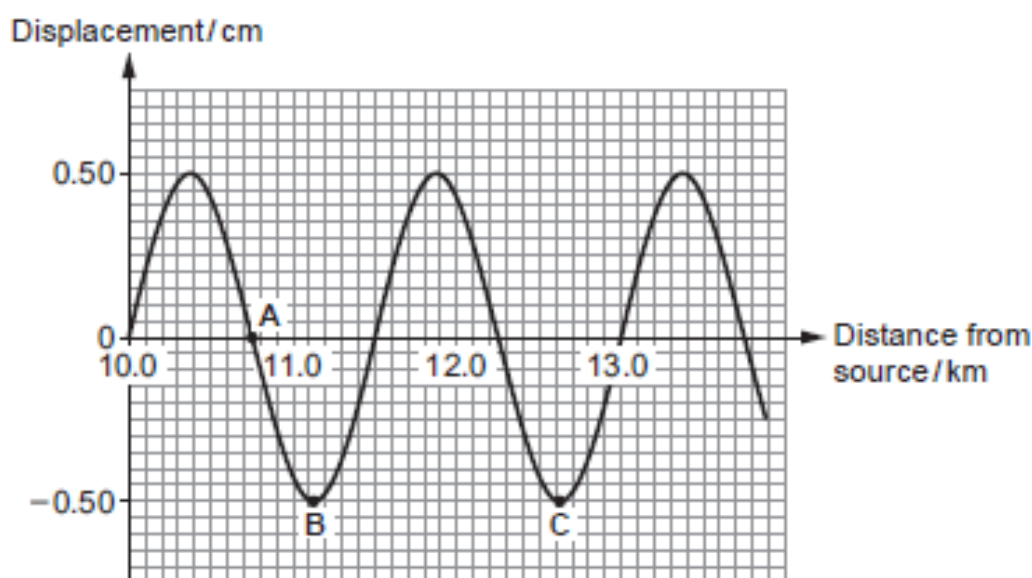
[2]

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- (b) Earthquakes produce seismic waves that travel through rock. The following graph shows the displacement at a given instant for a seismic wave.



- (i) Determine the phase difference between:

[2]

A and B

B and C

- (ii) A geologist at a monitoring station notes that there are 50 complete cycles of the wave in a time interval of 20 s. Calculate the speed of the wave.

[4]

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- (c) A section of rock undergoes a tensile stress of 900 MPa during an earthquake. Calculate the tensile strain if the Young modulus is 70 GPa for rock. [3]

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- (d) Explain how data obtained by geologists about earthquakes from various monitoring stations can benefit society. [2]

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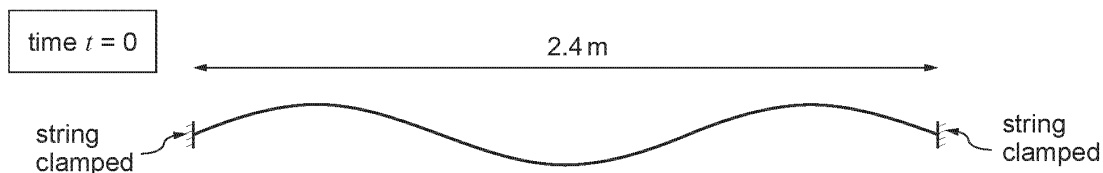
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3.

- (a) The diagram shows a **stationary** wave on a stretched string at a time of maximum displacement ($t = 0$).



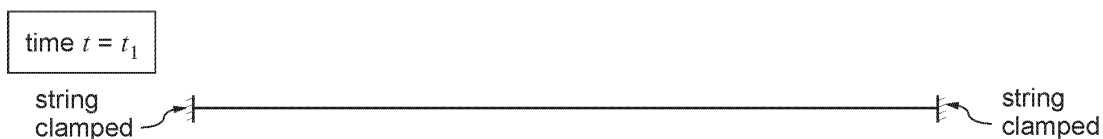
- (i) Determine the wavelength. [1]

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- (ii) Determine the distances of all the **antinodes** from the left hand end of the string. [1]

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- (iii) Time $t = t_1$ is the first time after $t = 0$ that the string is as shown below.



- (i) The frequency is 50 Hz. Determine t_1 . [2]

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- (ii) **On the diagram** for time $t = t_1$, draw vertical arrows at the approximate positions of the antinodes, to show the directions of motion of the string. [1]

- (b) Complete the diagram below to show the lowest frequency (fundamental) stationary wave on the string, at a time of maximum displacement, and **calculate its frequency**. [3]



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4.

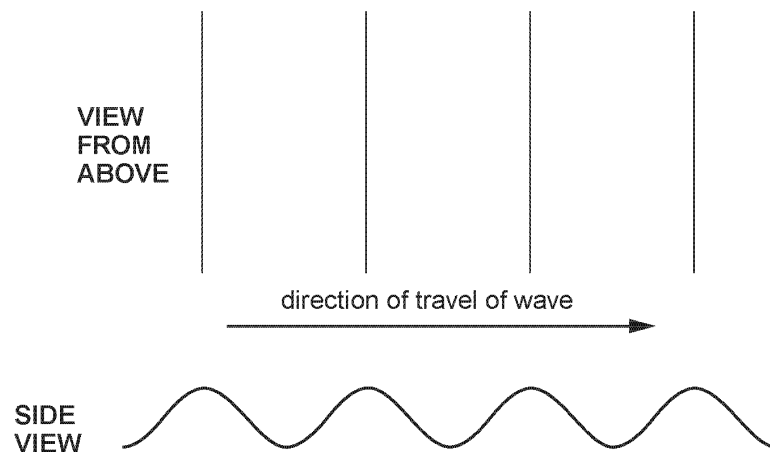
- (a) A student gives the following **wrong** definition of wavelength.

"The wavelength of a progressive wave is the distance between two successive points which are oscillating *with the same amplitude*."

- (i) Write down the words which should replace the words in italics. [1]

- (ii) Explain why the student's original version does not make sense. [1]

- (b) The top diagram is a plan (view from above) showing the positions of the crests of a progressive water wave at time $t = 0$. Underneath is a vertical section (side view) of the water surface at time $t = 0$.



- (i) By the time $t = 0.12\text{ s}$ the wave has travelled 60 mm. The wavelength is 15 mm. Calculate the frequency. [3]

- (ii) On the **top** diagram carefully draw in the positions of the crests at $t = 0.010\text{ s}$. [2]
Space for calculations if needed.

- (c) A barrier with two narrow slits is placed as shown in the path of water waves of wavelength 15 mm. An interference pattern is observed. *Diagram not to scale.*



- (i) Making use of the equation for double slit interference, determine whether there is constructive or destructive interference at point P. Give your reasoning. [3]

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- (ii) Explain why *diffraction* is essential for the formation of the interference pattern. [2]

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5.

2. (a) Explain what properties of light from a laser can be determined using polarisation and interference. Give practical details. [6 QER]

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- (b) The polarisation of light is used in Liquid Crystal Display TVs. These have been developed from research into new organic materials. Discuss the importance of research and development into new materials, in general, by giving a benefit and an issue that may arise from using new materials. [3]

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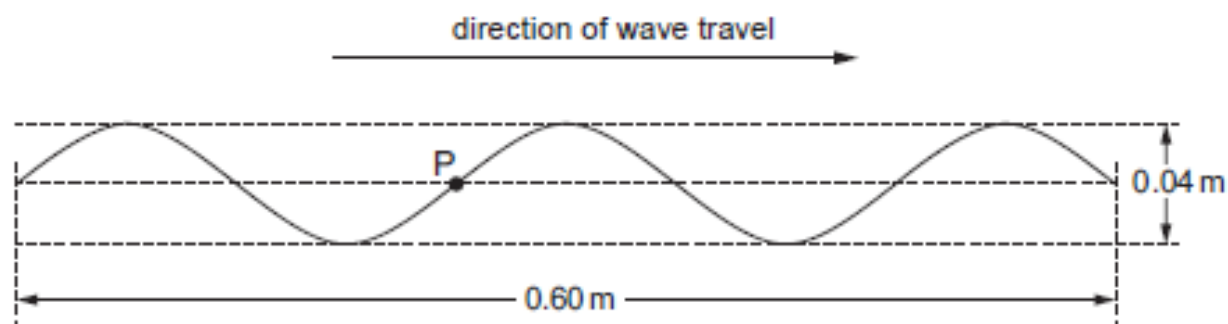
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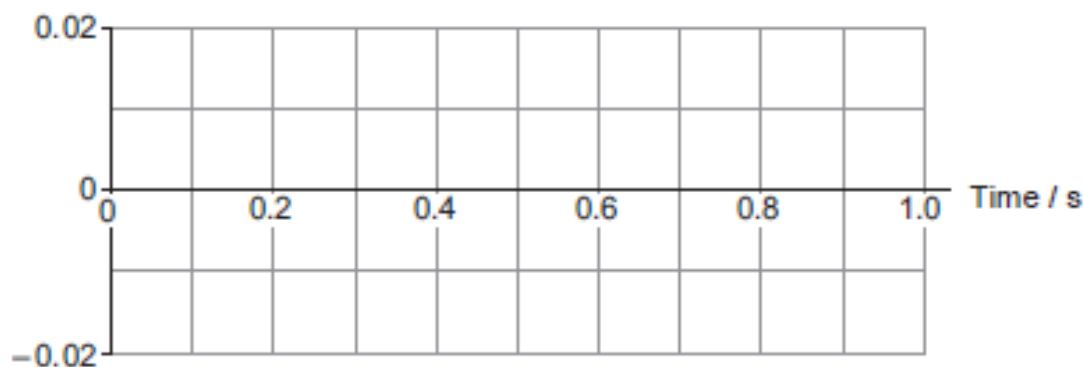
6.

4. (a) A progressive wave is travelling from left to right along a stretched string at a speed of 0.40 m s^{-1} . The diagram shows the string at time $t = 0$.



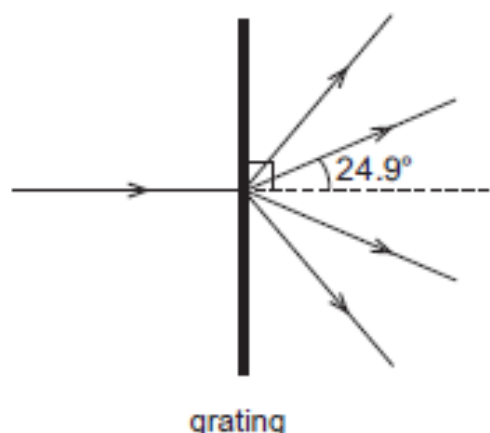
Carefully sketch, on the grid below, a displacement–time graph for point P on the string between $t = 0$ and $t = 1 \text{ s}$. The space below the grid is for your working. [3]

Displacement / m



Space for working:

- (b) The distance between the centres of the slits in a diffraction grating is 1500 nm. Monochromatic light is shone normally on to the grating.



- (i) First order beams emerge at angles of 24.9° to the normal (see diagram). Calculate the wavelength of the light. [2]

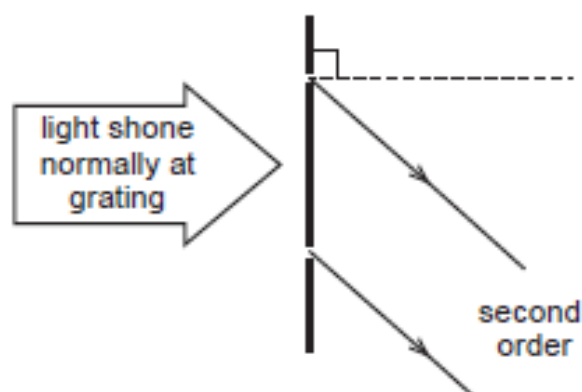
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- (ii) Explain in terms of path difference why the second order beams emerge from the diffraction grating at 57.4° to the normal. You will need to add to the diagram (which shows two adjacent slits in the grating). [3]



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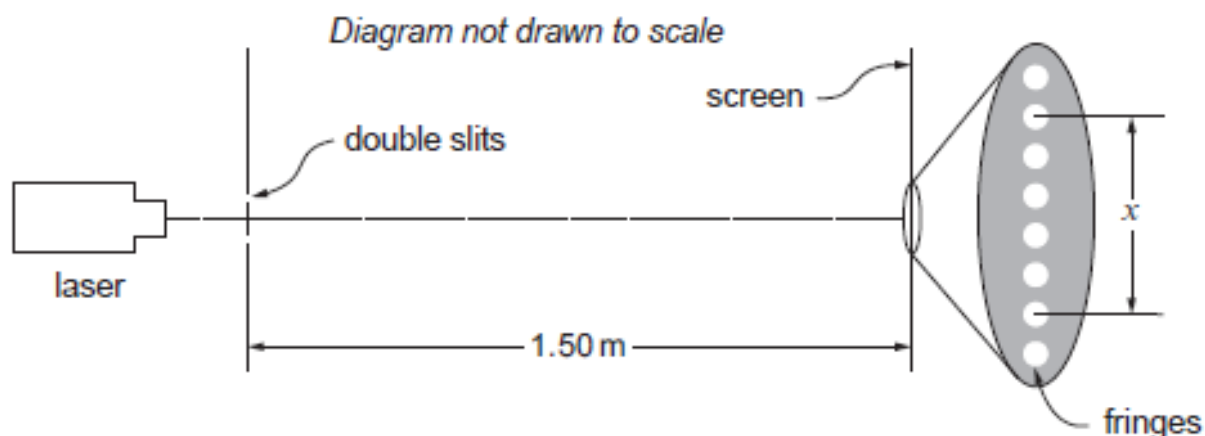
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7.

4. (a) Explain the conditions that are required of the light sources, for a two-source interference pattern to be observed. Include examples of when the requirements would and would not be met. [6 QER]

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(b) A Young's fringes experiment is set up as shown.



(i) Six students measure the distance x , obtaining these results:

6.5 mm 6.3 mm 6.9 mm 6.9 mm 6.7 mm 6.4 mm

Calculate the mean value for fringe separation (the separation of the centres of neighbouring bright fringes), together with its percentage uncertainty. [4]

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(ii) The uncertainty in the distance of 1.50 m shown in the diagram is negligible. The separation between the centres of the slits is given by the makers of the double slit as $0.60 \text{ mm} \pm 5\%$. Calculate a value for the wavelength of the light from the laser, along with its percentage uncertainty. [3]

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- (c) The laser beam is now shone normally on to a diffraction grating with centres of slits separated by 1500 nm . Second order beams emerge at angles of 45° to the normal.

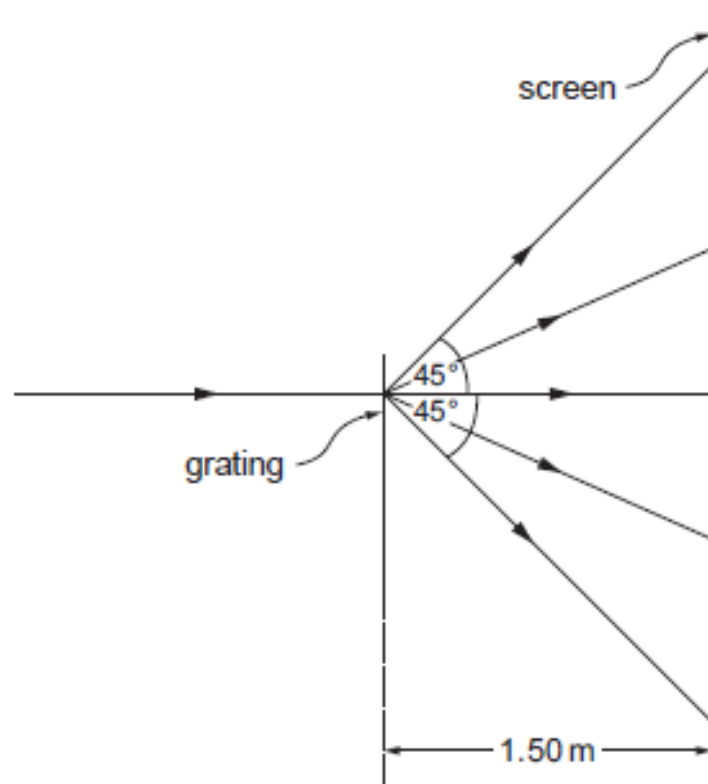


Diagram not drawn to scale

- (i) Determine a value for the wavelength of the laser light from the data. [2]

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- (ii) The beams from the grating strike the screen as shown opposite. The pattern on the screen may be compared with the pattern of fringes in part (b) (Young's experiment). There are fewer bright spots in the case of the grating. State two other differences between the patterns and state briefly why each difference occurs. [4]

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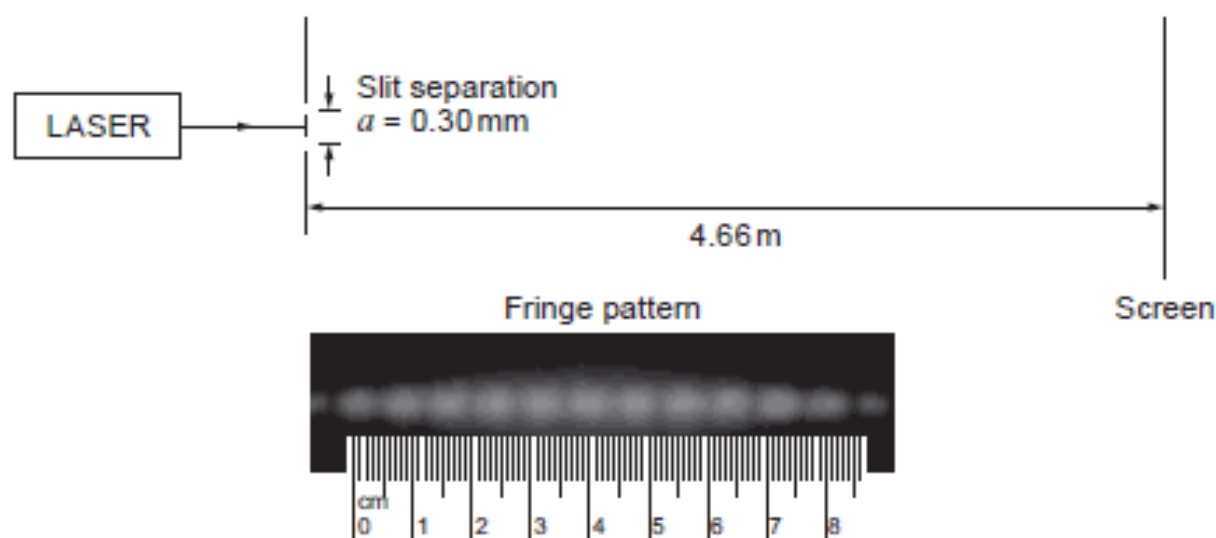
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8. 1. (a) State what is meant by two coherent sources. [1]

- (b) In the 1700s, light was thought to consist of a stream of particles. In the 1800s, it was said to be a wave but since the early 1900s it has been accepted that light behaves both like a wave and like a particle (wave particle duality). Explain briefly the part that Young's double slit experiment played in this history. [2]

- (c) Young's double slit experiment is carried out using laser light.



- (i) Calculate the fringe separation from the above diagram. [2]

- (ii) The distance between the slits and the screen is 4.66 m. Calculate the wavelength of the laser light. [2]

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- (iii) State one advantage and one disadvantage of using a large slit-to-screen distance. [2]

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2. (a) Single slit diffraction of light is demonstrated by using a red laser and the results are shown below. The two different diffraction patterns are obtained by varying the slit width only.

Figure 2a



Figure 2b



- (i) Explain whether Figure 2a or Figure 2b has the wider slit. [2]

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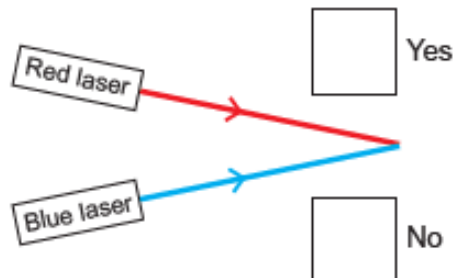
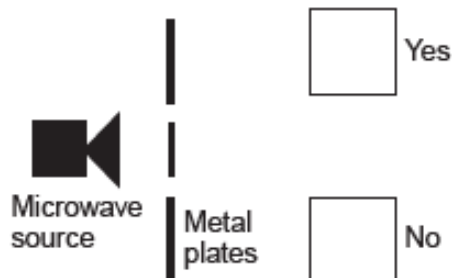
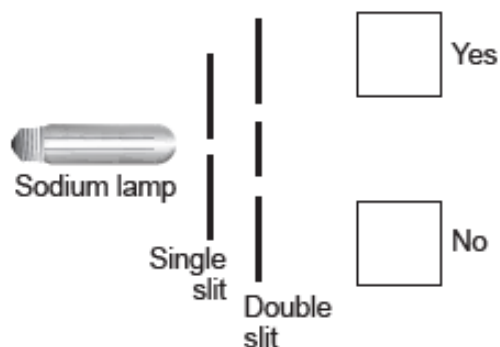
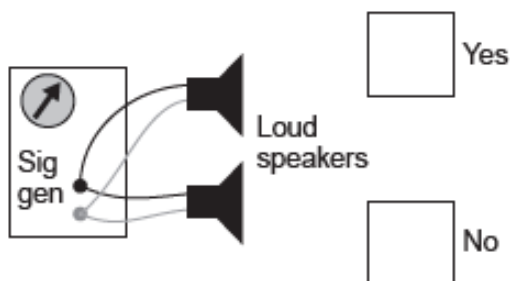
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- (ii) State what can be done to the single slit to obtain the greatest amount of diffraction. [1]

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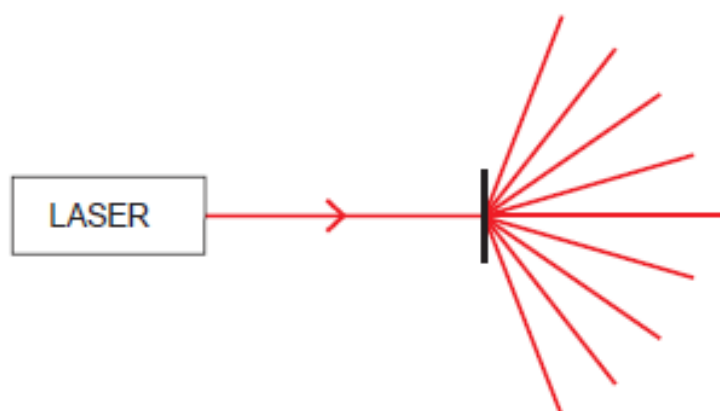
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- (b) Tick (✓) the appropriate boxes to show which of the following arrangements allow an interference pattern to be observed/heard. [2]



- (c) Laser light is shone at a diffraction grating with slit separation $2.4\mu\text{m}$ and a total of nine bright beams are produced (see below). Determine the maximum and minimum possible wavelengths for the laser light. [4]

Diagram not to scale



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10.

- (a) The label indicating slit separation on a *diffraction grating* has been removed. A student decides to determine the slit separation (the separation between the centres of its slits) by shining a laser normally at the grating. The wavelength of the laser light is $5.32 \times 10^{-7} \text{ m}$.

He measures the angle between a **second order** emerging beam and the central (*zero order*) beam to be 28.9° .

- (i) Show clearly that the slit separation is approximately $2 \times 10^{-6} \text{ m}$. [3]

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- (ii) Suggest an advantage of choosing a second order, rather than a first order, beam. [1]

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- (b) The student now uses the grating to determine the wavelength of the light from another laser. He measures the second order beam to be at an angle of 35.1° .

- (i) Calculate the wavelength of the light. [2]

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- (ii) Determine the highest order that the grating will produce with this wavelength. Show your working. [2]

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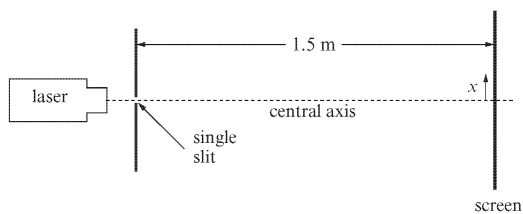
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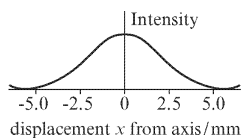
11.

(a) Apparatus is set up as shown.



The graph shows how the intensity of light on the screen varies with displacement x from the central axis.

[Note the expanded displacement scale.]



(i) Name the wave property being demonstrated. [1]

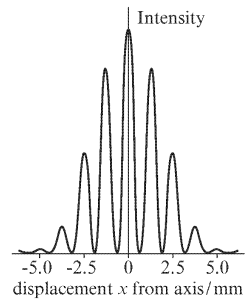
(ii) What can be deduced about the width of the slit compared with the wavelength of the light from the laser? Give your reasoning. Calculations are not needed. [2]

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(iii) What would happen to the graph if the width of the slit were to be increased? [2]

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- (b) The single slit is now replaced by two parallel slits, each of the same width as the single slit in (a). The centres of the slits are 0.75 mm apart. The intensity of light on the screen near the central axis now varies as shown.



- (i) Determine from the graph the separation of the bright interference fringes. [1]

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- (ii) Hence find the wavelength of the light. [2]

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- (iii) Explain in terms of *interference*, *phase*, and *path difference* how the **bright** fringes arise. Assume that the slits act as in-phase sources. [3]

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- (iv) Suggest why the brightness of the bright fringes decreases with displacement x from the central axis, in the region shown on the graph. [1]

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- (c) It is easier to obtain clear fringes in the experiment of part (b) using a laser rather than an ordinary light source. Give two reasons for this. [2]

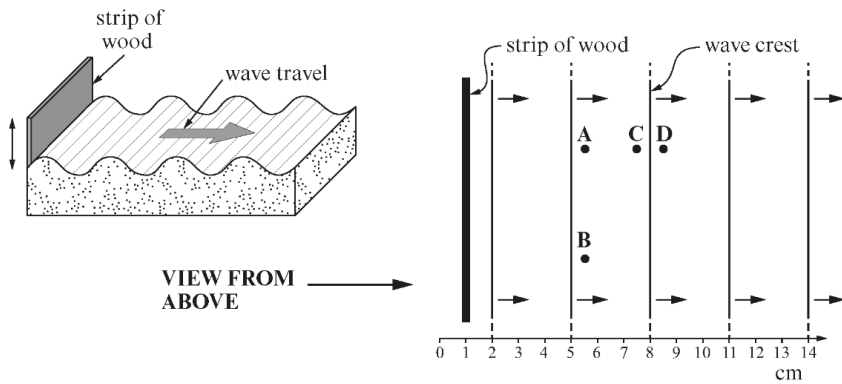
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12. (a) A strip of wood, in contact with the surface of water in a tank, oscillates up and down at a frequency of 5.0 Hz. The view from above shows the positions of wave crests (where the water height is a maximum) at one instant.



- (i) Determine the wavelength of the wave. [1]

- (ii) Calculate the time it takes for a wave crest to travel a distance of 10.5 cm. [3]

- (iii) State whether or not the oscillations at points **B**, **C** and **D** are *in phase* with the oscillations at **A**. Justify your answers. [3]

Point **B**.....

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Point **C**.....

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Point **D**.....

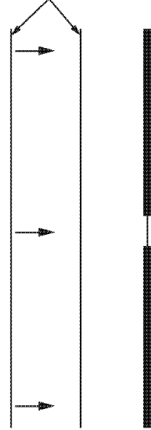
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(b) The waves of frequency 5.0 Hz approach a barrier with a gap in it (see diagram below). The waves that pass through the gap spread out.

(i) What name is given to the spreading of the waves? [1]

(ii) Carefully sketch the **two** wave crests to the right of, and nearest to, the gap. [2]

wave crests



(iii) What changes would occur to the diagram above if the **frequency** of the wave were increased by a factor of 4? No calculations are needed. [2]

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3. (a) Describe a diffraction grating. [2]

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- (b) A diffraction grating has 400 000 slits per metre of its width.

- (i) Show that the distance between the centres of neighbouring slits is $2.5\text{ }\mu\text{m}$. [1]

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- (ii) A laser beam is shone normally at the grating. The **second** order beams leave the grating at angles of 25.2° either side of the grating normal. Calculate the wavelength of the laser light. [3]

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- (iii) Calculate the angle (to the grating normal) of the **third** order beams. [2]

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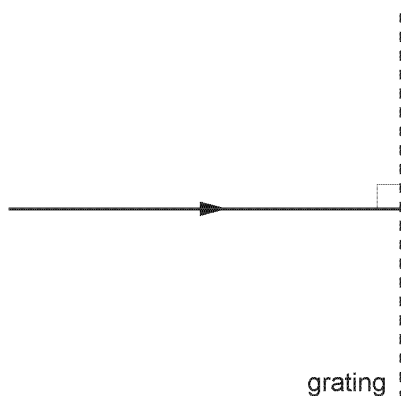
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- (iv) The beams of different orders are spaced much further apart than the fringes in a typical Young's slits set-up using the same laser. Why is this so? [1]

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- (a) A beam of light of wavelength 532 nm is shone normally (in the direction shown) on to a diffraction grating with slit spacing 1200 nm (between centres of adjacent slits).



- (i) Calculate all the angles at which bright beams emerge from the grating. [3]

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- (ii) Draw all the emerging beams (representing each as a single line) **on the diagram above**. [You are not expected to use a protractor.] [2]

- (b) Light of wavelength 650 nm is now used instead of the light of wavelength 532 nm . State the ways in which the pattern of emerging beams will change. [You may wish to make further calculations.] [2]

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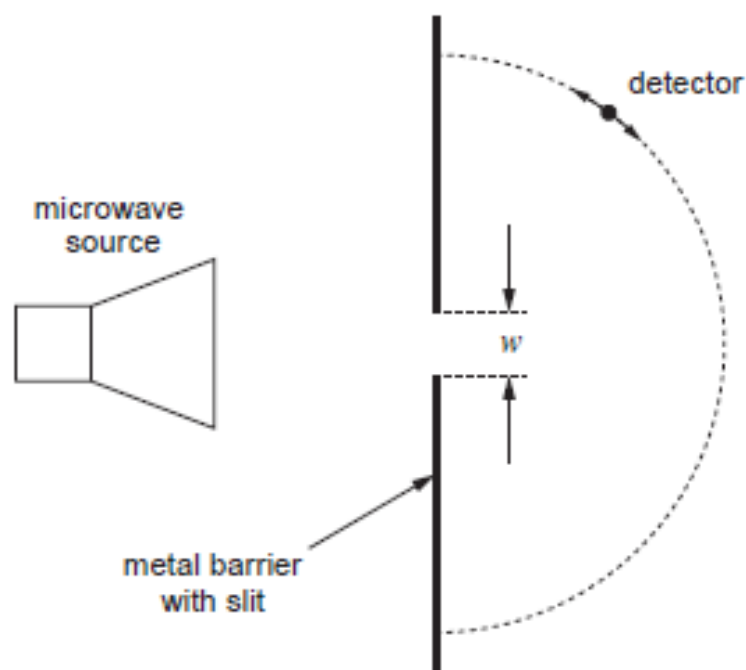
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5. (a) In the set-up shown, a microwave detector moved along the semi-circular path detects diffracted waves at all points around the semicircle.



- (i) The width, w , of the gap is 25 mm. What can be deduced about the wavelength of the microwaves? [1]

- (ii) Rhian suggests that making the gap wider will increase the intensity of the microwaves detected. Discuss to what extent she is correct. [2]

- (b) In the set-up shown, slits S_1 and S_2 act as in-phase sources. Rhian detects minima of wave intensity at P and Q, and a single maximum between P and Q.

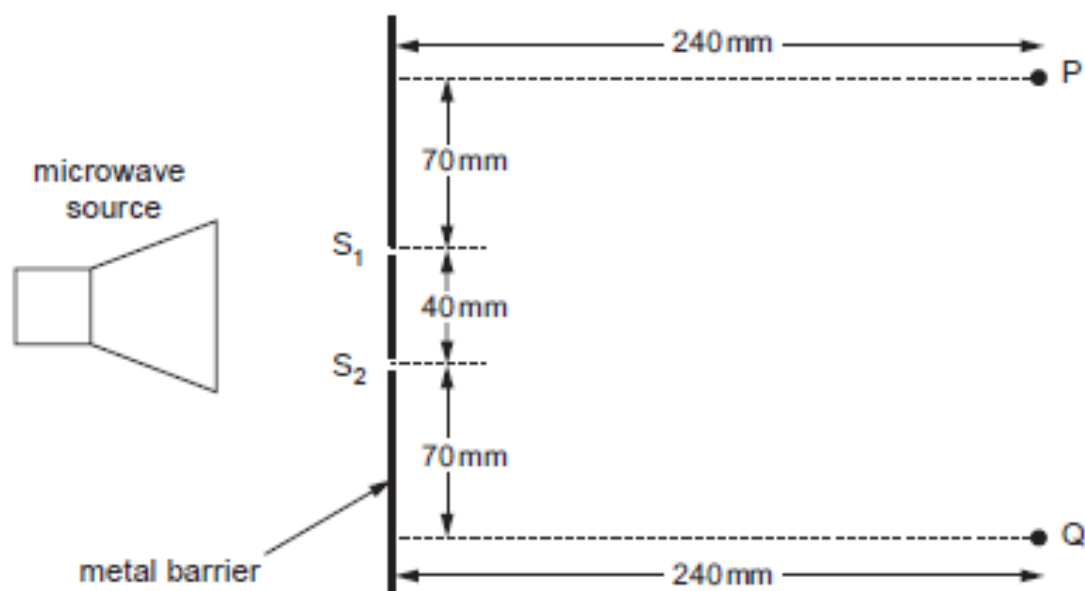


Diagram not to scale

Calculate the path lengths S_1P and S_2P , and hence the wavelength of the microwaves.

[4]

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