IB · SL · Physics

3 hours 21 questions

Structured Questions

Wave Phenomena

Wavefronts & Rays / Reflection, Refraction & Transmission / Diffraction of Waves / Refraction of Waves / Superposition of Waves / Interference of Waves / Young's Double-Slit Experiment

Easy (8 questions)	/75
Medium (8 questions)	/83
Hard (5 questions)	/44
Total Marks	**/202**

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Easy Questions

1 (a) Outline what is meant by the terms

(i) Wavefront

[2]

(ii) Ray

[1]

.....

.....

.....

(3 marks)

(b) Complete the following sentence by placing a tick (✓) next to the correct answer:

The distance between two consecutive wavefronts is equal to the:

	wavelength
	frequency
	amplitude

.....

(1 mark)

(c) On the grid below, draw scale diagrams showing the wavefronts for

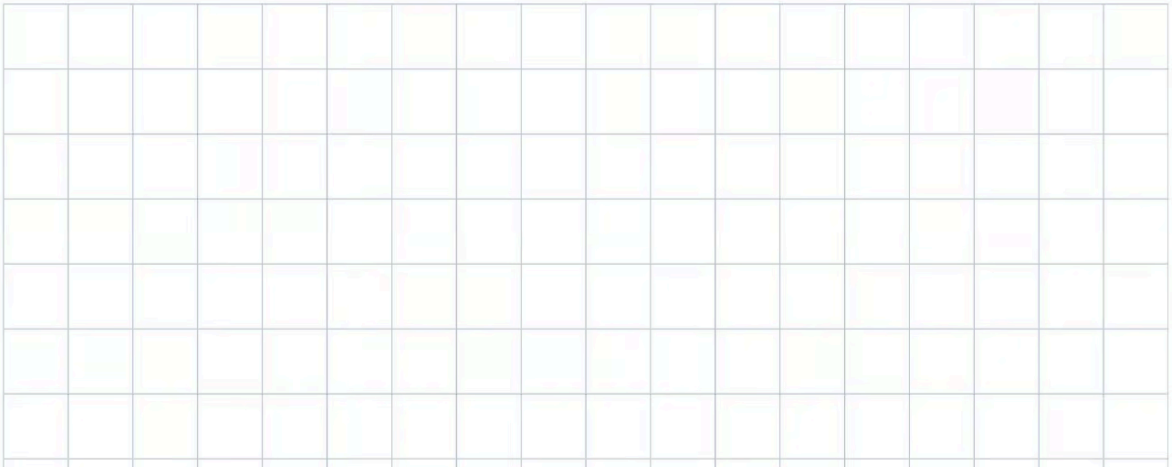
(i) A plane wave with a wavelength of 1 cm.

[2]

(ii) A circular wave with a wavelength of 1 cm.

[2]

On both diagrams, show with arrows, the direction of propagation.



(4 marks)

(d) Complete the following sentences by circling the correct word:

The higher the frequency of an oscillation, the **longer / shorter** the wavelength and the **closer / further apart** the wavefronts are **to / from** one another.

The lower the frequency of the oscillation, the **longer / shorter** the wavelength and the **closer / further apart** the wavefronts are **to / from** one another.

(2 marks)

2 (a) Outline what is meant by the principle of superposition.

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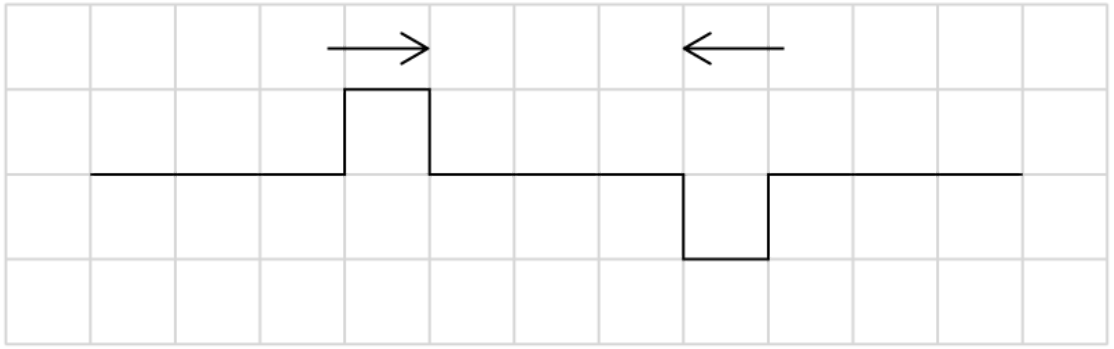
(2 marks)

(b) Two pulses travel toward one another as shown in the diagram.



Sketch the resultant displacement as the pulses superpose.

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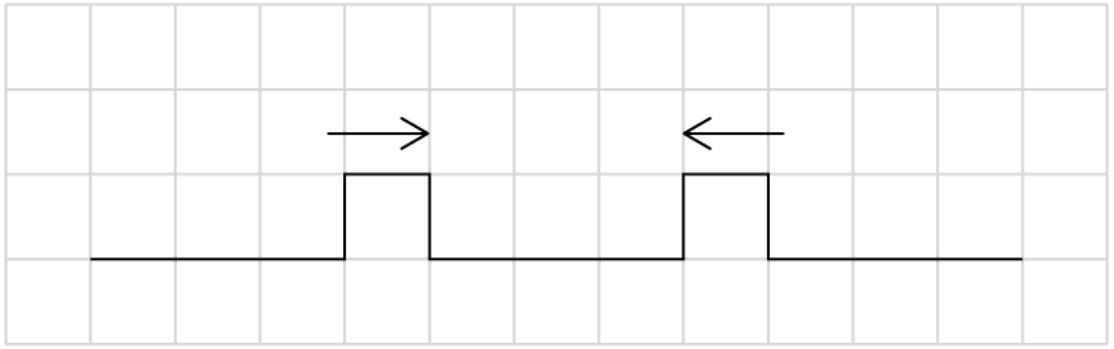
(1 mark)

(c) Two pulses travel in opposing directions as shown in the diagram. When the pulses meet, they superpose.



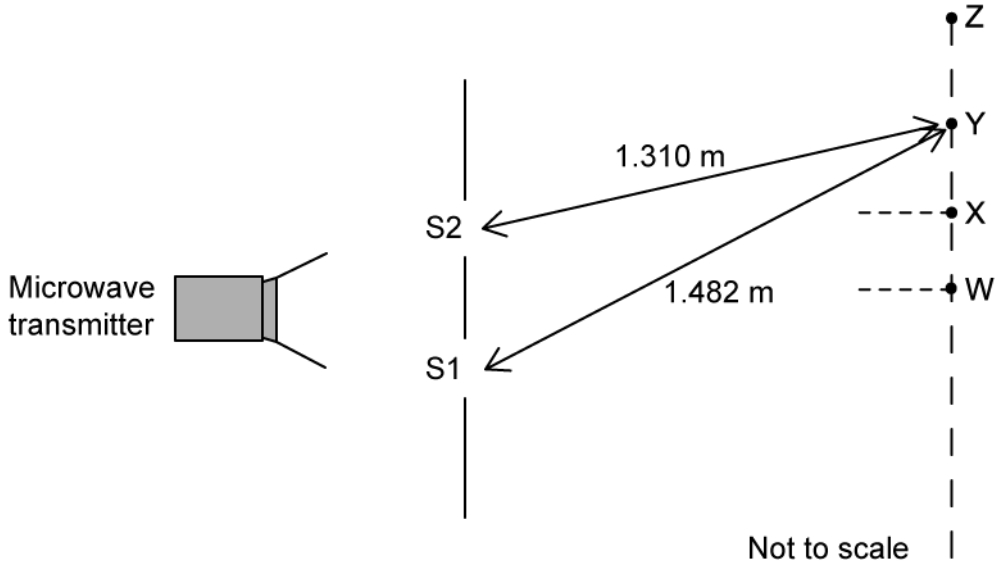
Draw the resultant peak as the pulses superpose.

(1 mark)

(d) Distinguish between the terms constructive interference and destructive interference.

(4 marks)

A beam of microwaves is incident normally on a pair of identical narrow slits S1 and S2.



3 (a) When a microwave receiver is initially placed at W which is equidistant from the slits, a maximum intensity is observed. The receiver is then moved towards Z along a line parallel to the slits. Intensity maxima are also observed at X and Y with one minimum between them. W, X and Y are consecutive maxima.

The distance from S1 to Y is 1.482 m and the distance from S2 to Y is 1.310 m.

(i) Calculate the path difference at Y.

[1]

(ii) Sketch the path difference on the diagram. Label this P.

[2]

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.....

.....

(3 marks)

(b) State the condition for intensity maxima to be observed at X and Y.

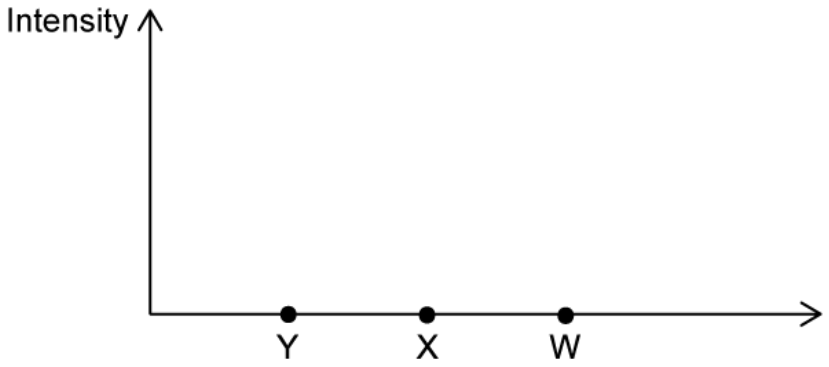
.....

(1 mark)

(c) State what the intensity maxima and intensity minima represent.

(2 marks)

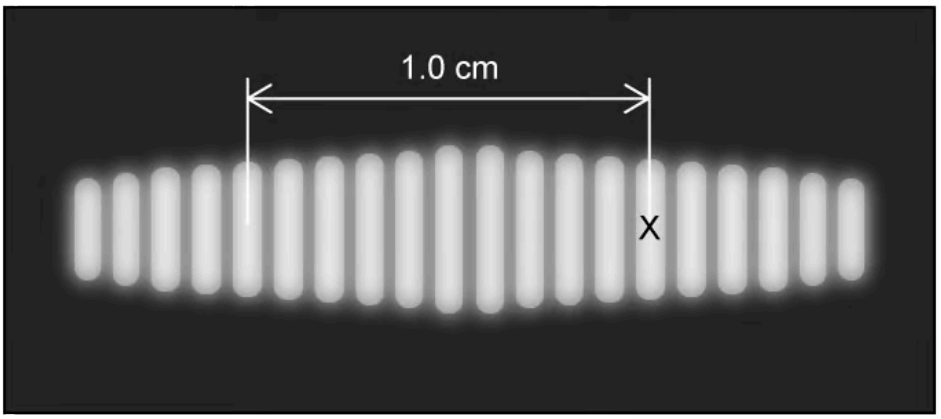
(d) A microwave receiver can be used to detect the interference pattern. This can be visually represented by an intensity graph.



Sketch the intensity graph for the points W, X and Y.

(3 marks)

4 (a) In an investigation into interference, monochromatic light of wavelength 600 nm is incident normally on a double slit. The fringes seen on a screen positioned at a distance D = 1.5 m from the slits are shown.



Determine the order, n of the bright fringe at X.

(1 mark)

(b) For the observation in part (a), sketch a diagram to show the triangle formed by the slits, the screen and the bright fringes.

Include the following information, along with any numerical values, on your diagram:

- Maxima, n
- Distance from double slits to screen, D
- Screen width, S
- Angle of diffraction, θ

(4 marks)

(c) Without using the angle of diffraction, calculate the separation between the slits.

(5 marks)

(d) Using the diagram from part (b), hence calculate the angle subtended between the slits, the central maxima and the fifth order maxima.

(2 marks)

5 (a) State what is meant by:

(i) The law of reflection.

[1]

(ii) Refraction.

[1]

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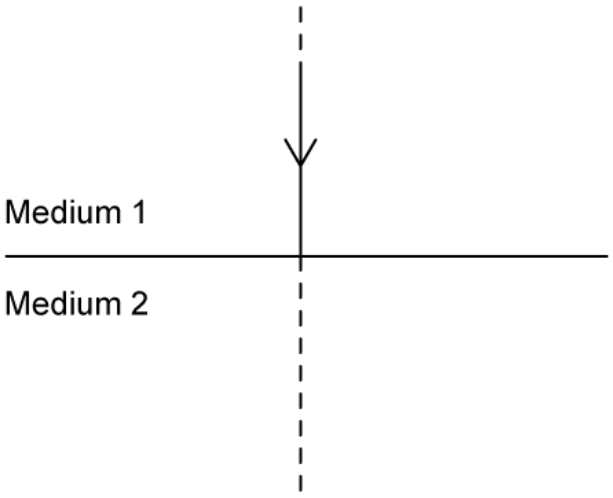
.....

(2 marks)

(b) The following diagram shows an incident ray perpendicular to the boundary between two media.



Complete the ray diagram by drawing the transmitted ray.

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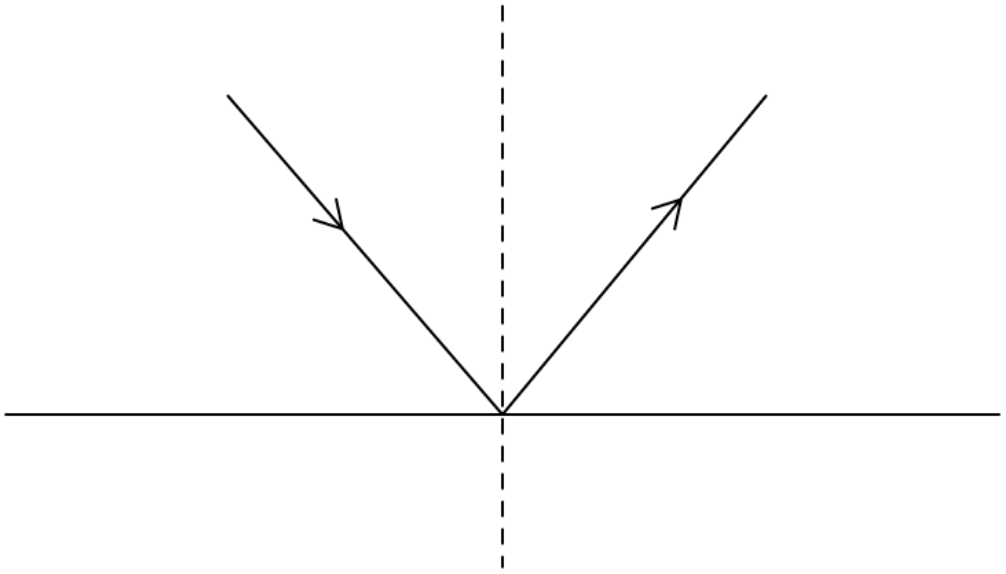
(2 marks)

(c) Ray diagrams can be used to show reflection and refraction. The following diagram shows the reflection of light on a smooth surface.



On the ray diagram label:

(i) The incident ray.

[1]

(ii) The reflected ray.

[1]

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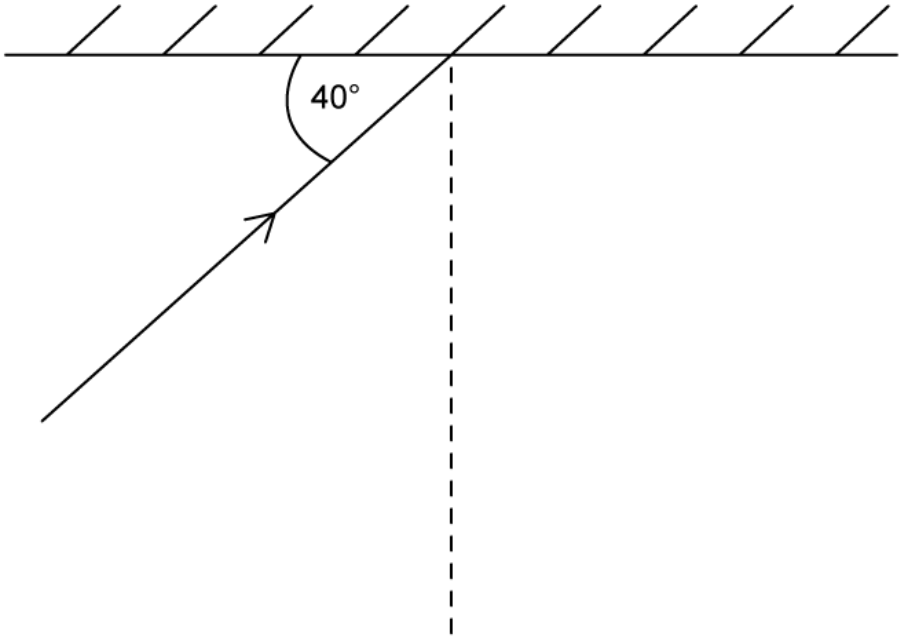
(2 marks)

(d) The ray diagram shows an incident ray on a plane mirror.



Calculate the angle of reflection.

(3 marks)

6 (a) Refraction occurs when light travels between media with different optical densities.

Describe what happens when light passes from a less dense medium into a more dense medium in terms of:

(i) The relative sizes of the angles of incidence and refraction.

[1]

(ii) The direction of the refracted light ray in relation to the normal.

[1]

.....

.....

(2 marks)

(b) The refractive index is calculated using the equation:

$$n = \frac{c}{v}$$

Write in the missing information to complete the following table:

Quantity	Symbol	Units
	n	No units
	c	
Speed of light in medium	v	

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.....

.....

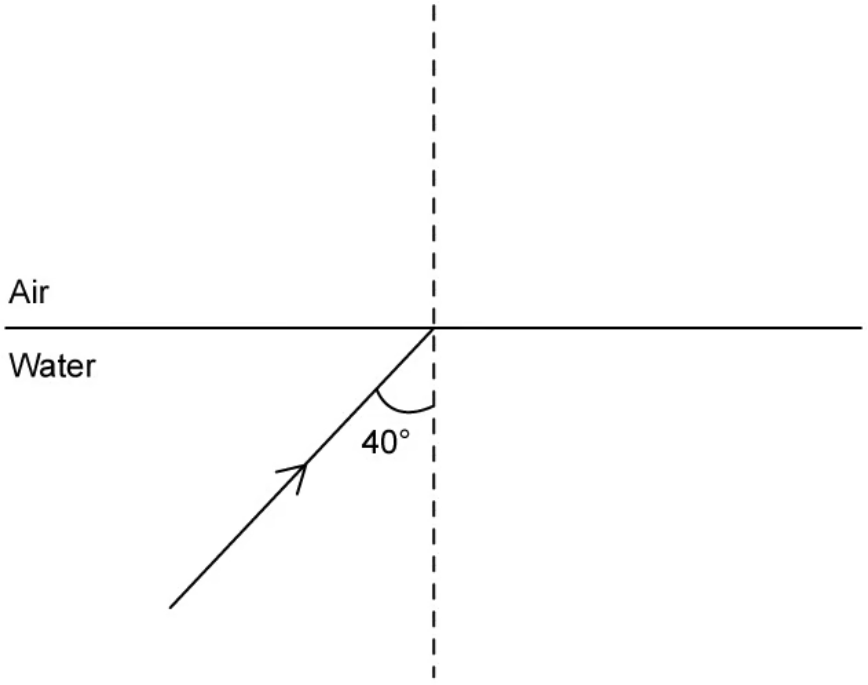
(3 marks)

(c) Define the term critical angle.

.....

(1 mark)

(d) Incident light travelling through water approaches the surface of the water and meets the boundary with air. The incident ray has an angle of incidence = 40°.



The refractive index of air is 1.00 and the refractive index of water is 1.33.

Calculate the angle of refraction for the refracted ray.

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(2 marks)

7 (a) Outline the conditions for destructive interference.

.....

(1 mark)

(b) Some light can be described as monochromatic.

State what is meant by the term monochromatic.

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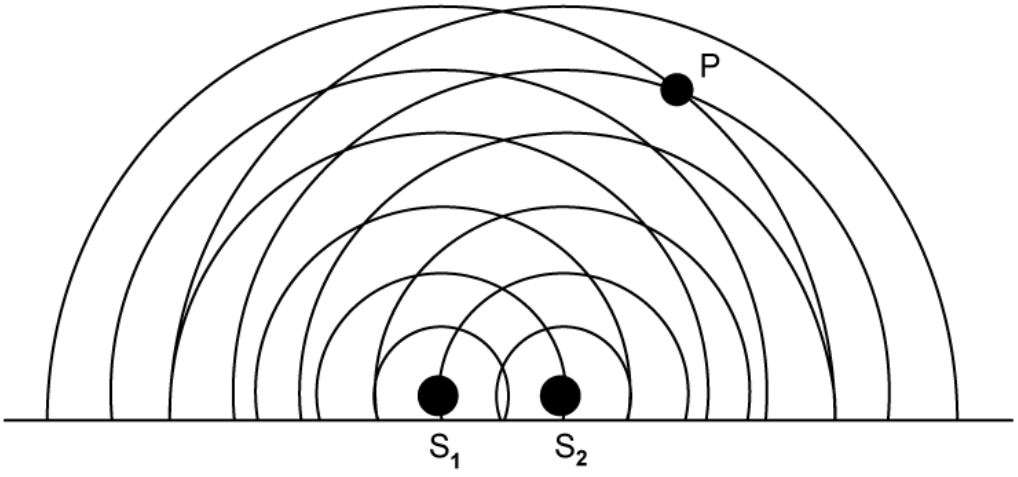
(1 mark)

(c) The diagram shows the wave fronts emitted from two point sources s_1 and s_2.



The waves meet at point P.

(i) By considering the number of waves, determine the path difference.

[3]

(ii) State whether constructive or destructive interference would occur at point P.

[1]

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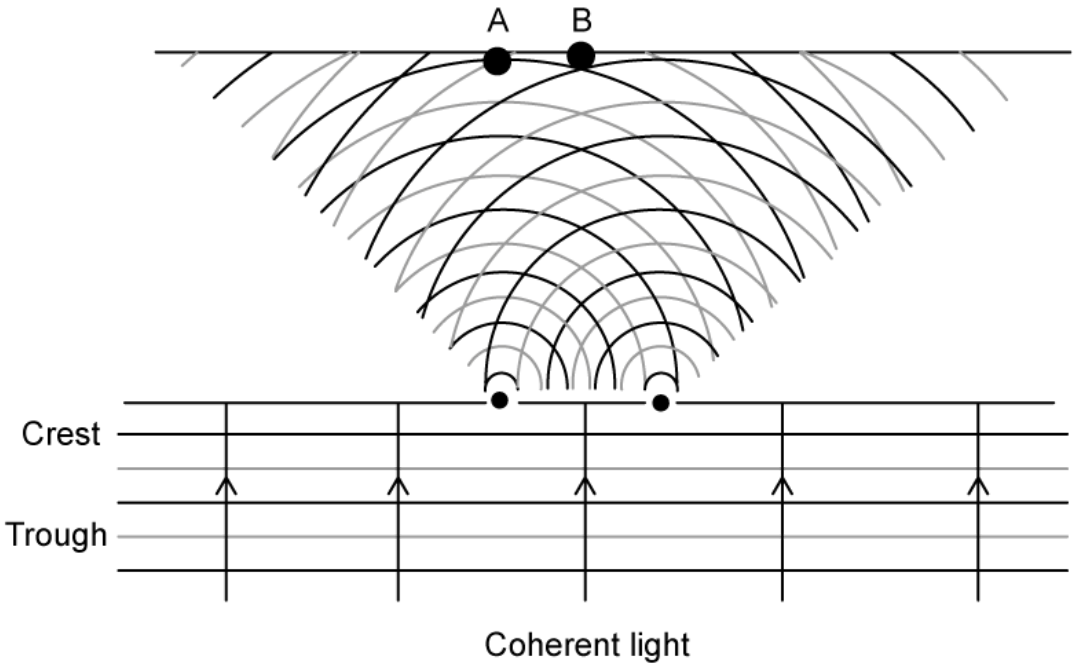
(4 marks)

(d) The diagram shows two sources of coherent light producing a double-slit interference pattern.



State whether the interference is constructive or destructive at point:

(i) A.

[1]

(ii) B.

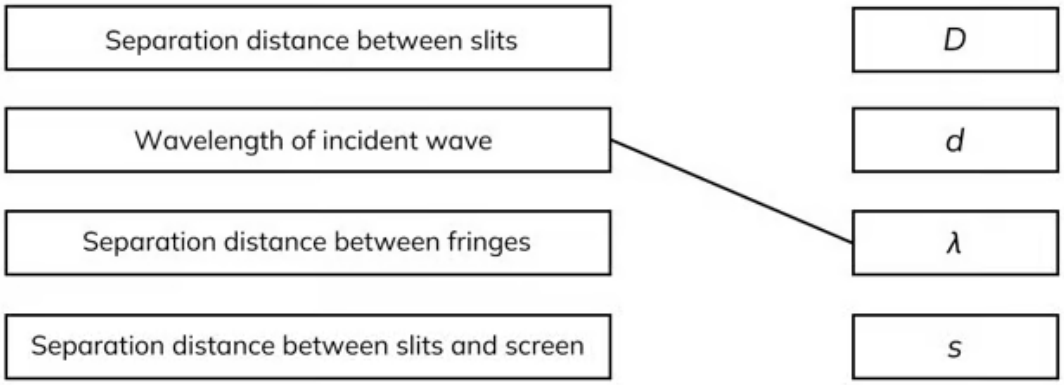
[1]

(2 marks)

8 (a) The distance between the bright fringes in a double-slit interference pattern can be determined by the double-slit equation

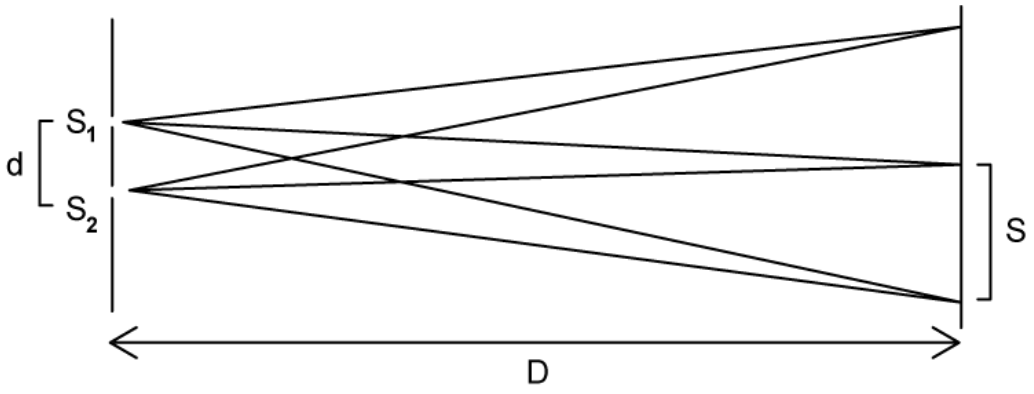
$$s = \frac{\lambda D}{d}$$

Draw a line to match the quantity to the correct symbol.



(3 marks)

(b) Red laser light is used to form a double-slit interference pattern on a screen.

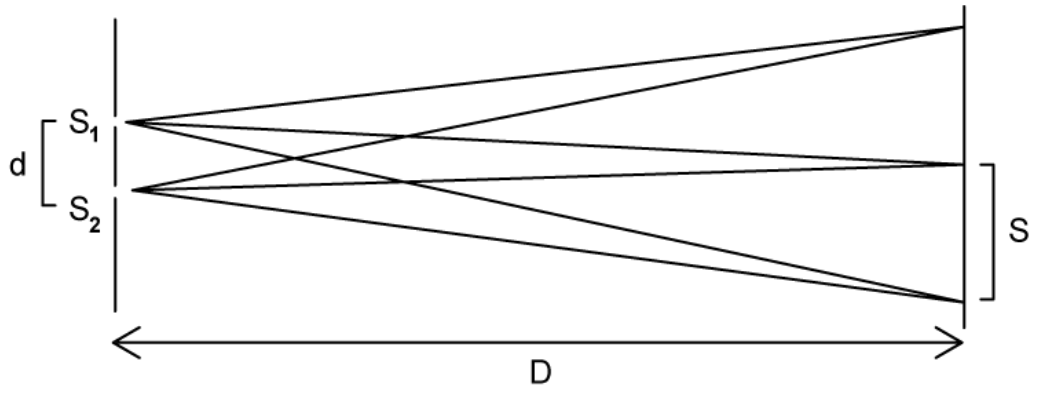


The distance between the bright fringes depends on the wavelength of the incident light.

Outline how the interference pattern would be affected if blue laser light were used instead.

(2 marks)

(c) Red laser light of wavelength λ = 650 nm is used to form a double-slit interference pattern on the screen as shown.

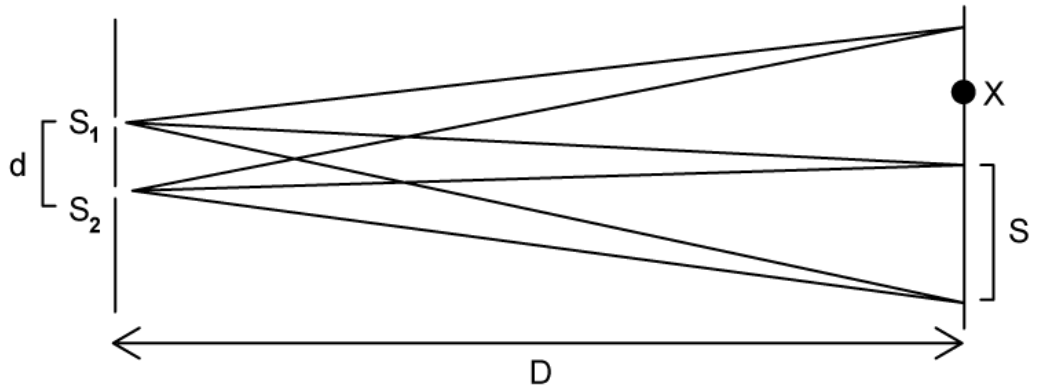


The separation distance of the slits d = 0.2 mm, and the distance between the slits and the screen D = 1.2 m.

Calculate the separation distance between the fringes on the screen s.

(4 marks)

(d) For the interference pattern shown in part (c):



Explain why there is no bright fringe at point X.

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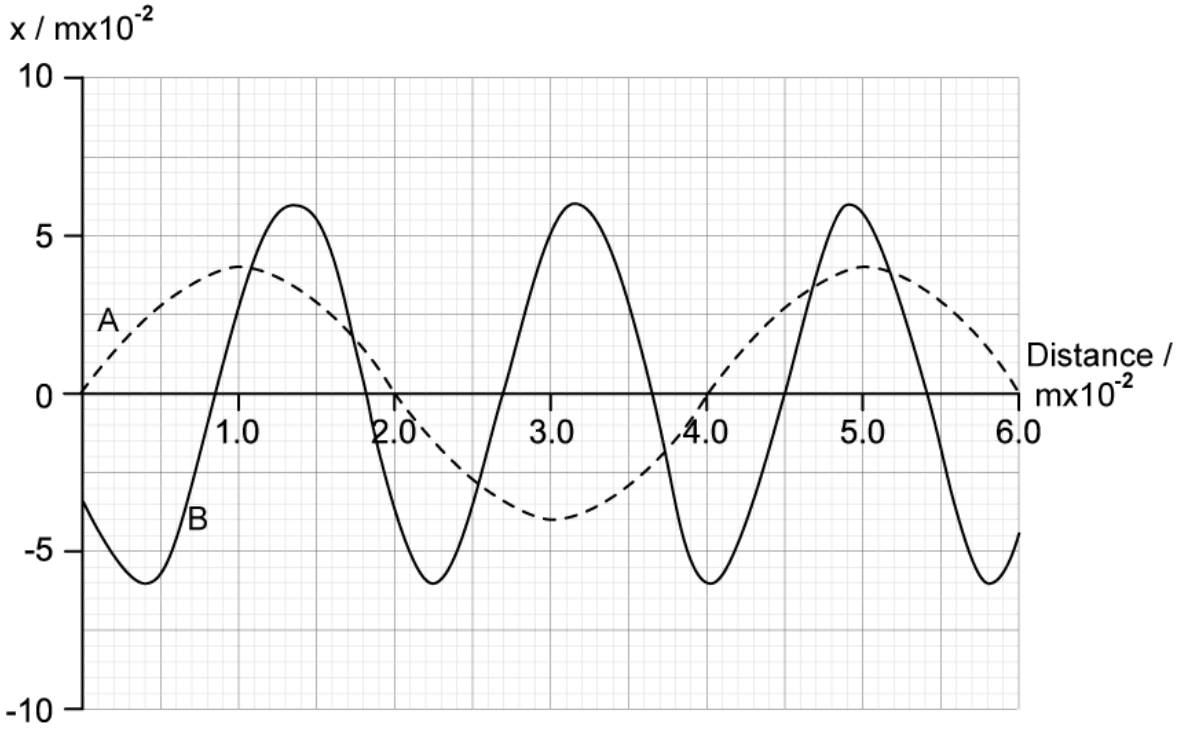
(2 marks)

Medium Questions

1 (a) A large water tank is set up so that a wave can be generated at each end of the tank. The two waves, A and B, travel towards each other at the same speed.

The graph shows the variation of displacement of the water surface with distance travelled at a particular instant.



Deduce how many times greater the amplitude of B is to the amplitude of A.

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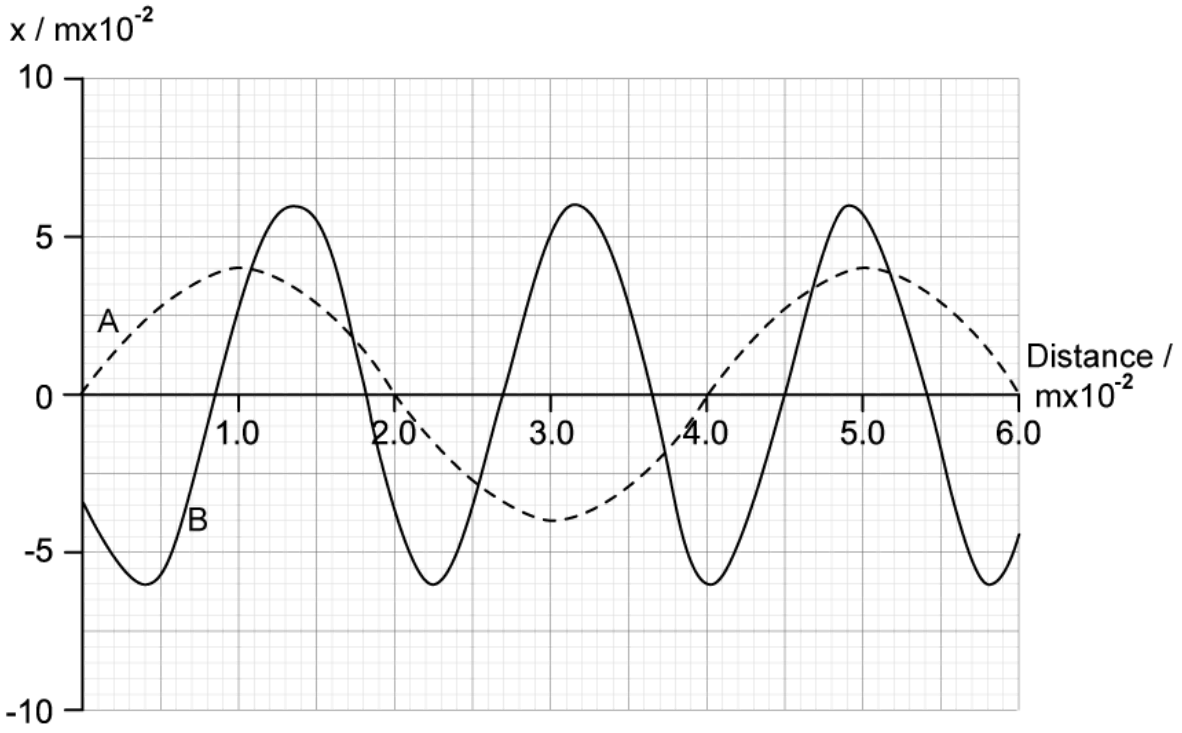
(2 marks)

(b) Wave A has a frequency of 9.0 Hz.



(i) Calculate the velocity of wave A

[2]

(ii) Determine the frequency of wave B

[2]

(4 marks)

(c) Explain how the stationary wave is generated in the tank.

(3 marks)

(d) Sketch a graph to represent the wave which would result from the superposition of wave A and wave B.

(4 marks)

2 (a) Superposition occurs when two or more waves interfere with each other.

(i) Explain the conditions required for a consistent stationary interference pattern to form during superposition.

[2]

(ii) Sketch a diagram to support your answer to part (i).

[2]

(4 marks)

(b) Superposition is often demonstrated using water waves which are transverse and clearly show increases and decreases in amplitude.

Describe how sound waves can also undergo superposition.

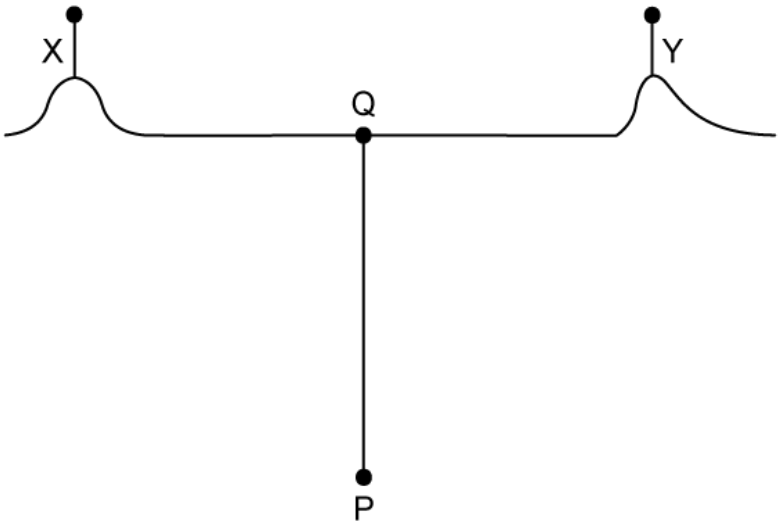
(3 marks)

(c) Two microwave transmitters are placed 15 cm apart and connected to the same source. A receiver is placed 70 cm away and moved along a line parallel to the transmitters. The receiver detects and alternating pattern of maxima and minima.

Explain how the maxima and minima are formed.

(3 marks)

3 (a) A group of hikers are exactly equidistant between two radio transmitters, X and Y. The transmitters are set to an operating wavelength of 200 m and have the same power outputs.



The hikers at point P receive a signal with zero amplitude. Outline what information about the signal you can assume from this.

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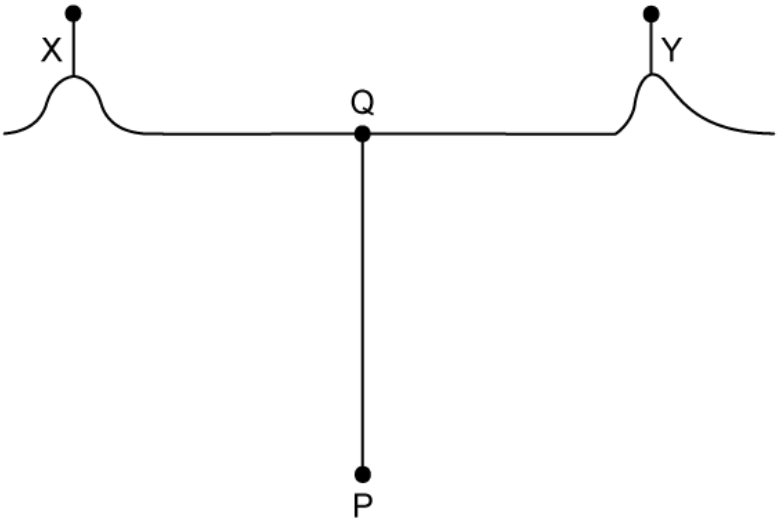
(3 marks)

(b) The hikers walk towards point Q on the line shown and continue to receive a signal of zero amplitude.

Once at Q they turn and walk towards Y, continuing until they receive a signal with amplitude double that emitted from either transmitter.



(i) Explain why there is no increase in amplitude detected on the walk from P to Q

[2]

(ii) Calculate the distance they walked along the line from Q to Y

[2]

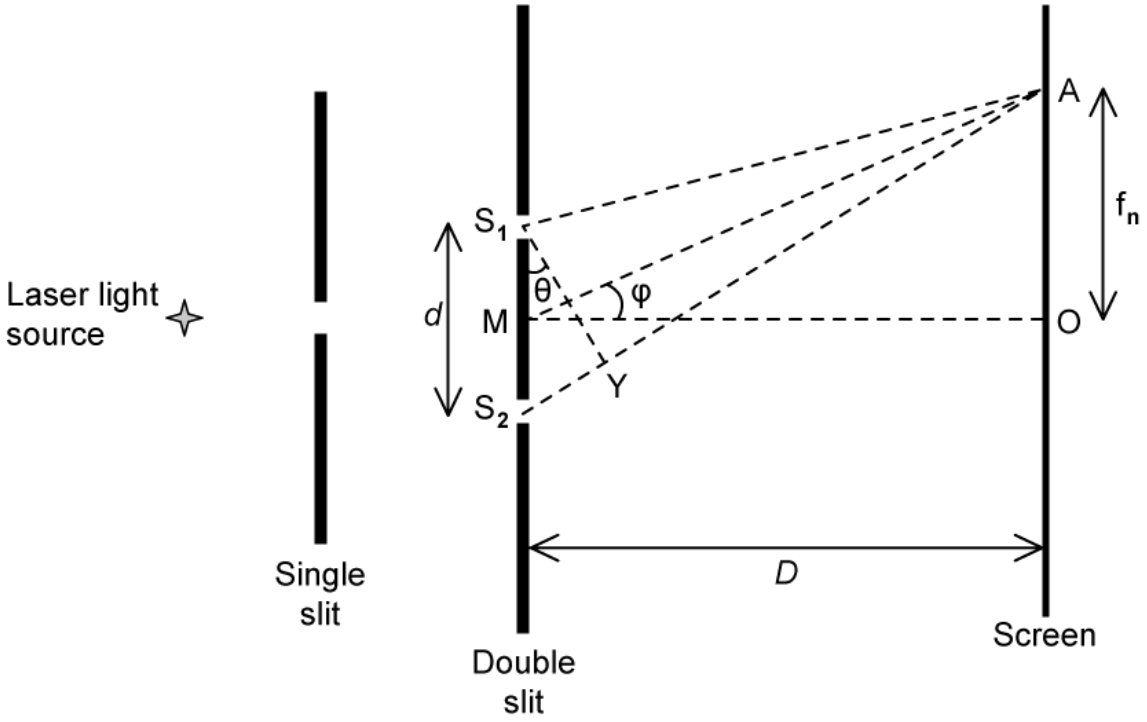
(4 marks)

(c) The hikers continue moving from Q towards the transmitter at Y where the distance QY is 20 km. The signal continues to rise and fall as they walk.

Calculate how many times they will hear the signal fall in intensity as they walk.

(2 marks)

4 (a) The diagram below shows an arrangement for observing the interference pattern produced by laser light passing through two narrow slits S_1 and S_2.



The distance S_1S_2 is d, and the distance between the double slit and the screen is D where $D \gg d$, so angles θ and ϕ are small. M is the midpoint of S_1S_2 and it is observed that there is a bright fringe at point A on the screen, a distance f_n from point O on the screen. Light from S_1 travels a distance S_2Y further to point A than light from S_1.

The wavelength of light from the laser is 650 nm and the angular separation of the bright fringes on the screen is 5.00×10^{-4} rad. Calculate the distance between the two slits.

(3 marks)

(b) A bright fringe is observed at A.

(i) Explain the conditions required in the paths of the rays coming from S_1 and S_2 to obtain this bright fringe.

[2]

(ii) State an equation in terms of wavelength for the distance S_2Y.

[1]

(3 marks)

(c) Deduce expressions for the following angles in the double-slit arrangement shown in part a:

(i) θ in terms of S_2Y and d

[2]

(ii) ϕ in terms of D and f_n

[2]

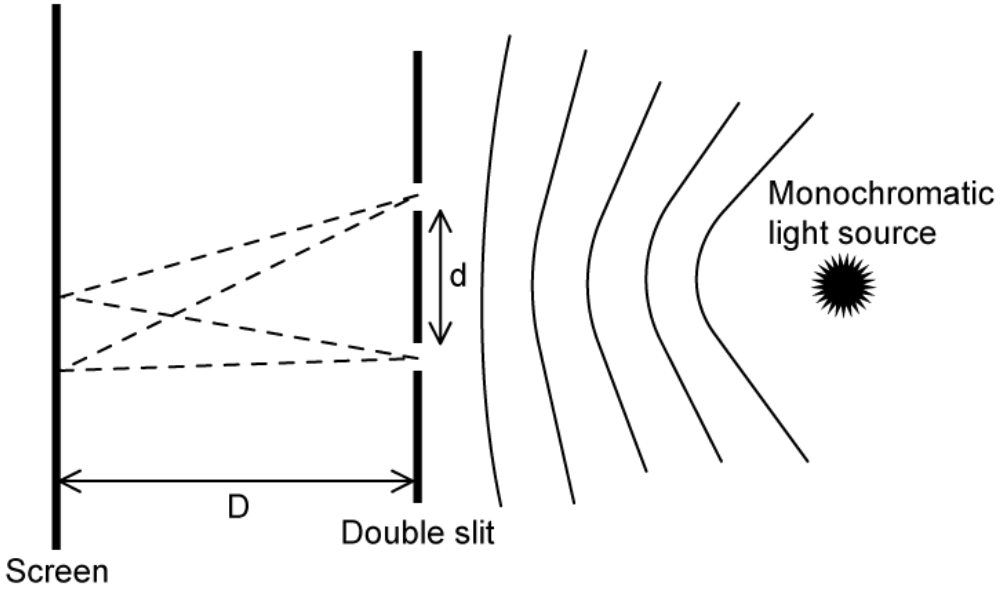
(4 marks)

(d) The separation of the slits S_1 and S_2 is 1.30 mm. The distance MO is 1.40 m. The distance f_n is the distance of the ninth bright fringe from O and the angle θ is 3.70×10^{-3} radians.

Calculate the wavelength of the laser light.

(2 marks)

5 (a) A beam of monochromatic light is incident upon two slits. The distance between the slits is 0.4 mm.



A series of bright and dark fringes appear on the screen. Explain how a bright fringe is formed.

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(2 marks)

(b) Monochromatic light is incident on the double-slits and the distance from the screen is 0.64 m. The distance between the bright fringes is 9.3×10^{-4} m. Determine the wavelength of the incident light.

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(2 marks)

(c) If the wavelength of the incident light is halved and the distance between the slits is doubled, outline the effect on the separation of the fringes of the interference pattern.

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(2 marks)

(d) One of the slits is covered so it emits no light.

Describe how this changes the pattern's appearance and the intensities observed on the screen.

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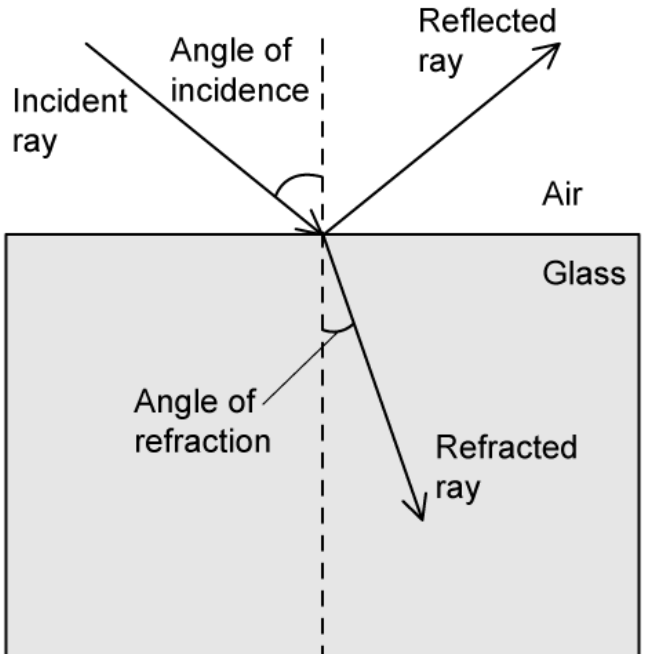
(2 marks)

6 (a) Light is incident upon a piece of glass.



The angle of incidence is less than that of the critical angle. The refractive index of the glass is 1.50.

Explain what is meant by the 'critical angle' and what will occur at angles that are above and below the critical angle.

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(3 marks)

(b) The angle of incidence for this situation is 34°.

Determine the angle of refraction to the nearest degree.

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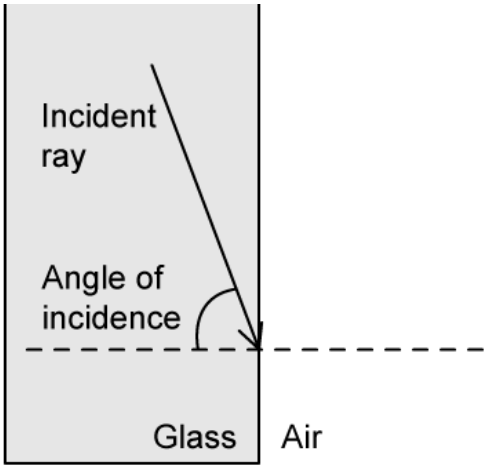
(2 marks)

(c) The refracted light travels within the glass for 5 m.

Determine the time that the light will take to travel this distance in the glass.

(2 marks)

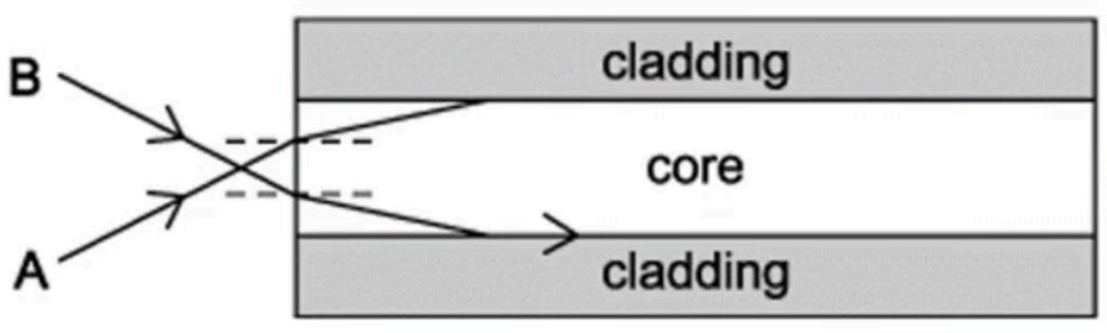
(d) The light continues within the glass until it strikes the side perpendicular to the original side of entry.



Show that the light will not emerge from the side of the glass.

(3 marks)

7 (a) The diagram shows a cross-section through a step-index optical fibre.



Beam A is incident at the end of the optical fibre at an angle of 12.6° to the normal and refracts into the core at 6.89° to the normal.

Calculate the refractive index of the core.

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(2 marks)

(b) Beam A travels through the air-core boundary and experiences total internal reflection.

On the diagram, show the path of this ray down the fibre and label the angle of reflection.

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(2 marks)

(c) Beam **B** is incident at the same end of the fibre. It refracts through the air-core boundary and then refracts again when it hits the core-cladding boundary at an angle of 51.8°, traveling along the boundary.

Calculate the refractive index of the cladding.

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(2 marks)

(d) A different step-index optical fibre is built with the same core as that in part (a) but with a different material used for the cladding.

The speed of light in the new cladding material is 1.54×10^8 m s^{-1}.

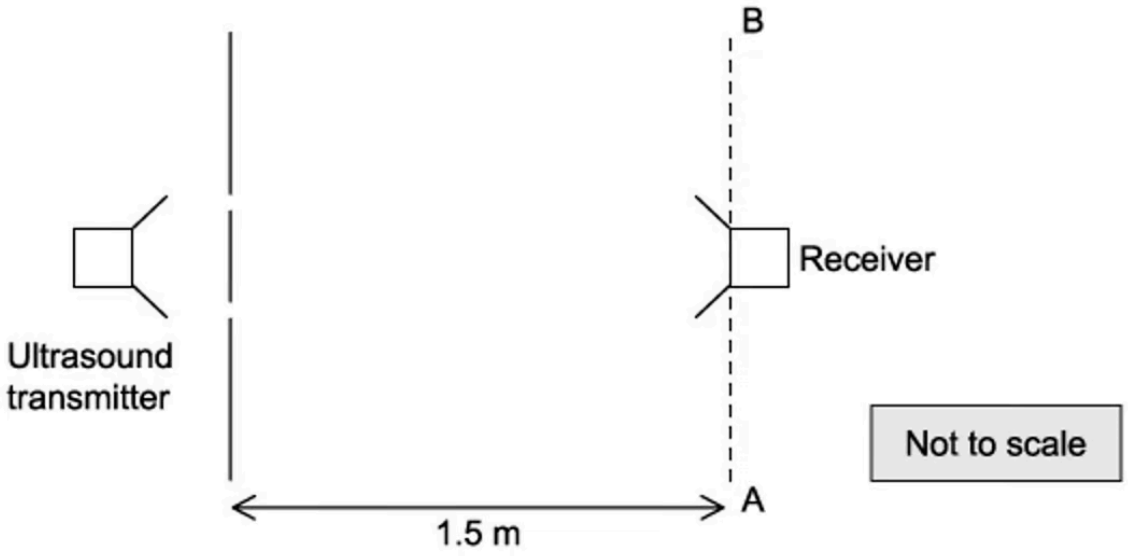
Explain why this new cladding material would not be suitable for sending signals through the step-index optical fibre. Use a calculation to support your answer.

(3 marks)

8 (a) A laboratory ultrasound transmitter emits ultrasonic waves of wavelength 0.7 cm through two slits. A receiver, moving along line AB, parallel to the line of the slits, detects regular rises and falls in the strength of the signal.

A student measures a distance of 0.39 m between the first and the fourth maxima in the signal when the receiver is 1.5 m from the slits.

Figure 1



The ultrasound transmitter is a coherent source.

Explain what is meant by the term coherent source.

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(2 marks)

(b) Explain why the receiver detects regular rises and falls in the strength of the signals as it moves along the line AB.

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(4 marks)

(c) Calculate the distance between the two slits.

(3 marks)

(d) One of the slits is now covered. No other changes are made to the experiment.

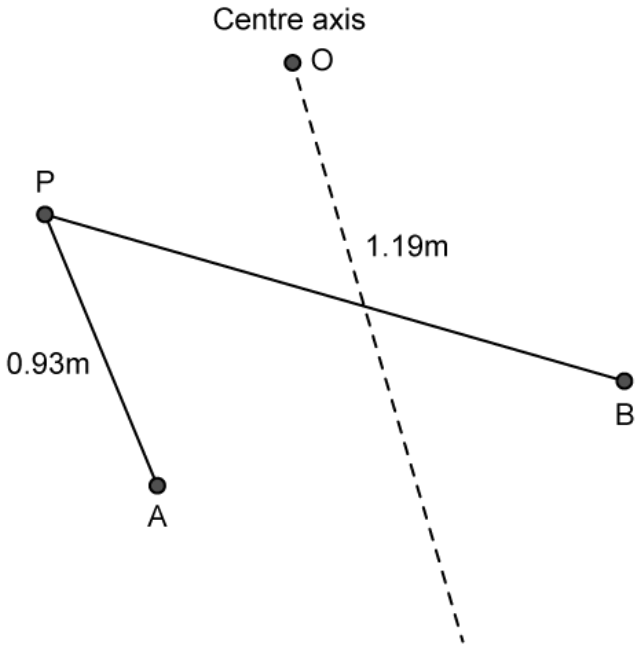
State and explain the difference between the observations made as the receiver is moved along AB before and after one of the slits is covered.

(3 marks)

Hard Questions

1 (a) Two coherent sources, A and B, which are in phase with each other, emit microwaves of wavelength 40.0 mm. The amplitude of waves from source B is twice that of source A.

A detector is placed at the point P where it is 0.93 m from A and 1.19 m from B. The centre axis is normal and a bisector to the straight line joining A and B.



With reference to the phase of the microwaves, deduce the magnitude of the detected signal at P and explain your reasoning.

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(3 marks)

(b) Discuss, with suitable calculations, what happens to the detected signal as the detector is moved from P to O.

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(5 marks)

(c) The source B is altered such that it emits waves that are 180° out of phase with source A.

Deduce the type of interference that now occurs at point P and explain your reasoning.

(2 marks)

2 Transverse, sinusoidal progressive waves of wavelength λ have points P and Q which are $\frac{5\lambda}{4}$ apart. The waves travel from P to Q.

With an appropriate sketch, discuss the motion of Q at the instant when P is displaced upwards but is moving downwards.

(3 marks)

3 (a) A student designs an experiment to replicate Young's double slit demonstration. The student uses a candle as a light source, with a piece of coloured filter paper to produce monochromatic light. They then consider additional apparatus required in order to observe an interference pattern.

Sketch a diagram, labelling all apparatus, as well as any important quantities, to show the setup the student should use to produce and observe an interference pattern.

(3 marks)

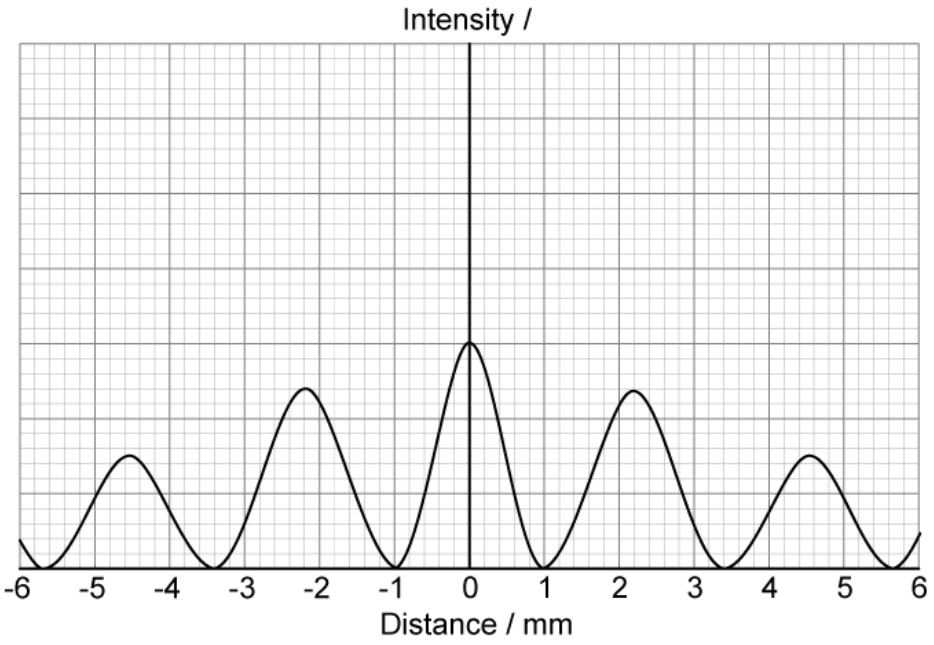
(b) The student labels the two slits on the double-slit grating slit X and slit Y. The student then paints over slit X, such that the intensity of light emerging from it is 50% of that emerging from slit Y.

Discuss the effects this change will have on the student's observations.

(4 marks)

(c) The student finishes setting up their apparatus and makes a quick note of two separate measurements, 0.75 mm and 2.0 m.

They then plot a graph of the intensity of light against the distance from the centre of the screen, represented by the origin.



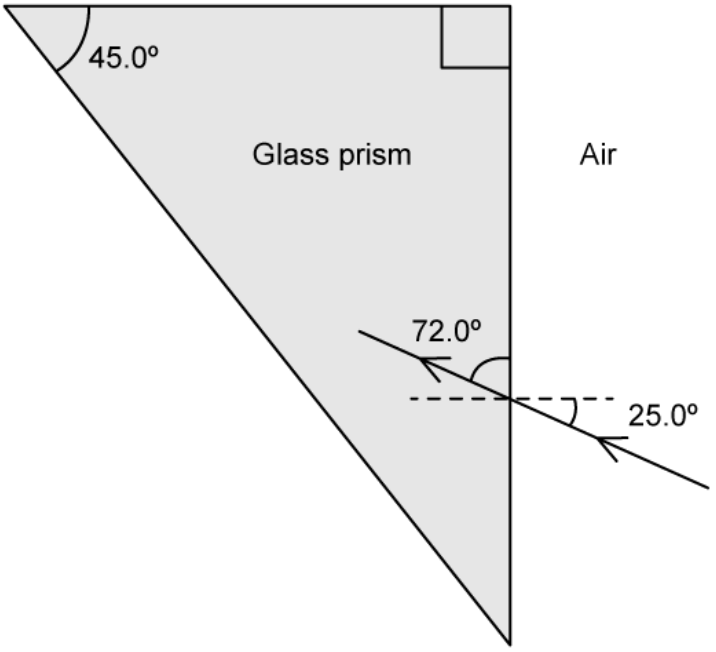
Determine which colour of filter paper the student most likely chose for this experiment.

(4 marks)

(d) Determine the phase angle between the waves meeting at the point that is 2.8 mm from the centre of the screen.

(2 marks)

4 (a) A ray of light passes from air into a glass prism.



As the light ray passes through the prism, it emerges back into the air.

Calculate the critical angle from the glass to the air.

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(2 marks)

(b) On the diagram from part (a), draw the continuation of the path of the ray of light until it emerges back into the air, labelling the values of the angles between the ray and any normals.

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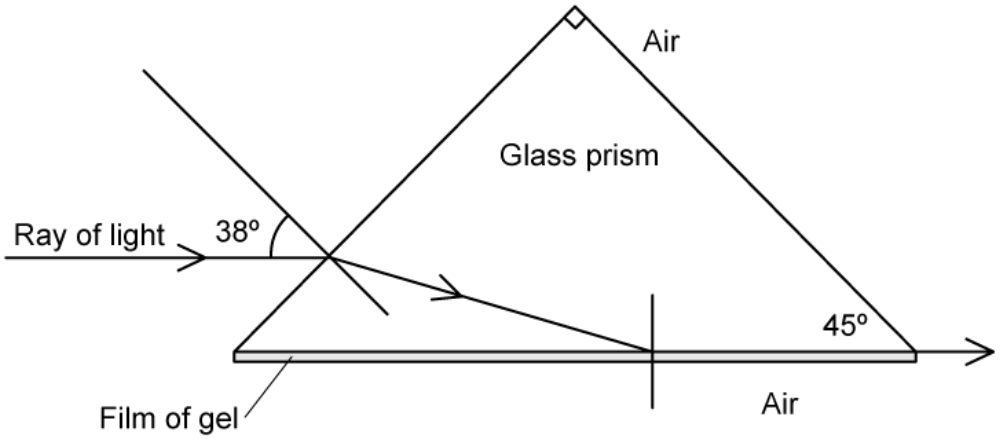
(2 marks)

(c) The prism is rotated and one side is coated with a film of transparent gel. A ray of light strikes the prism, at an angle of incidence of 38°, and continues through the glass to

strike the glass–gel boundary at the critical angle.



Calculate the refractive index of the gel.

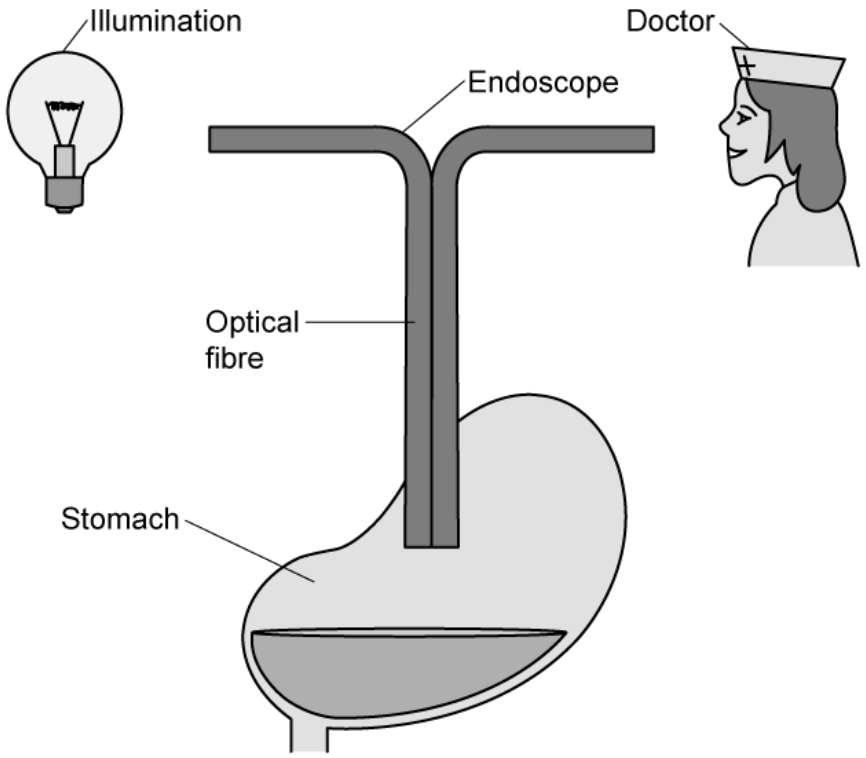
(3 marks)

(d) A ray of light now strikes the prism at an angle of incidence which means that it now refracts straight through the gel at the glass–gel boundary.

Without calculation, explain how the critical angle for the glass–gel boundary differs from the critical angle for the gel–air boundary.

(2 marks)

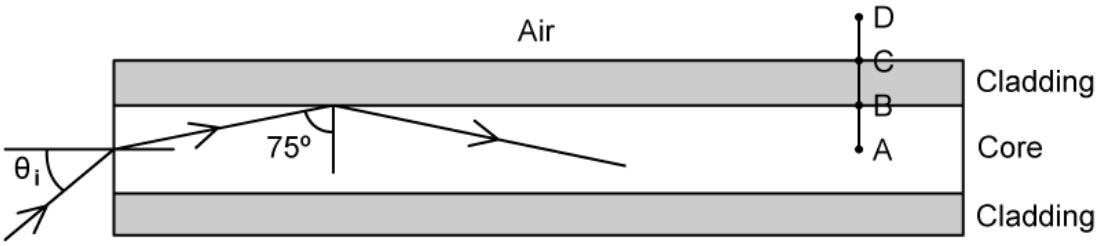
5 (a) The tube of an endoscope behaves like an optical fibre to examine the interior of the body for medical diagnosis. One end of the fibre is illuminated and an image of the inside of the stomach is viewed by the doctor.



Draw on the picture the complete path of the light from the illumination to the doctor.

(2 marks)

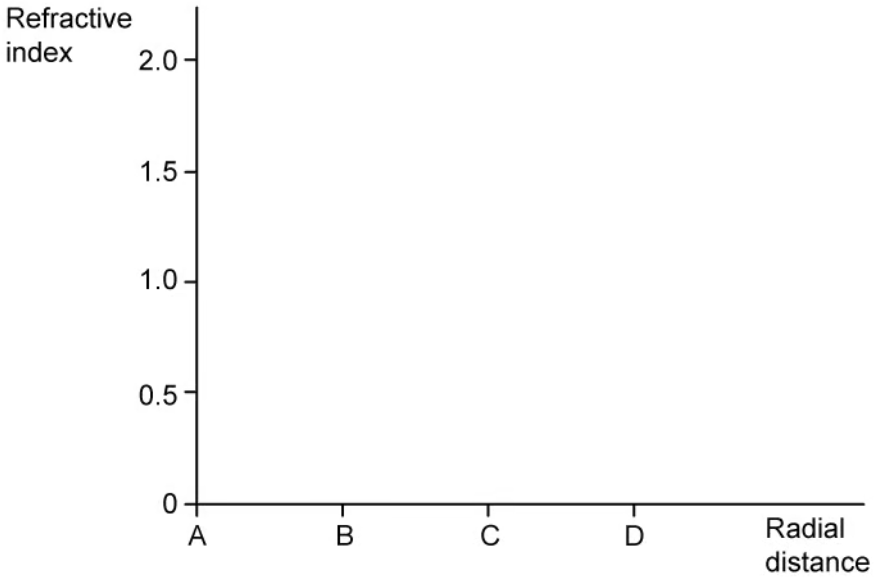
(b) The diagram shows a cross–section through an optical fibre used in an endoscope. The critical angle is 7% lower than the 75° angle to the normal at the core–cladding boundary. The refractive index of the cladding is 1.4.



Calculate the angle of incidence θ_i at the air–core boundary.

(4 marks)

(c) Complete the graph to show how the refractive index changes with radial distance along the line ABCD in Figure 2.



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(3 marks)