IB · DP · Physics

2 hours 13 questions

Structured Questions

9.3 Interference

9.3.1 Young's Double-Slit Experiment / 9.3.2 Two-Slit Interference Patterns / 9.3.3 Diffraction Grating Patterns / 9.3.4 The Diffraction Grating Equation / 9.3.5 Thin Film Interference

Easy (5 questions)	/49
Medium (5 questions)	/57
Hard (3 questions)	/42
Total Marks	**/148**

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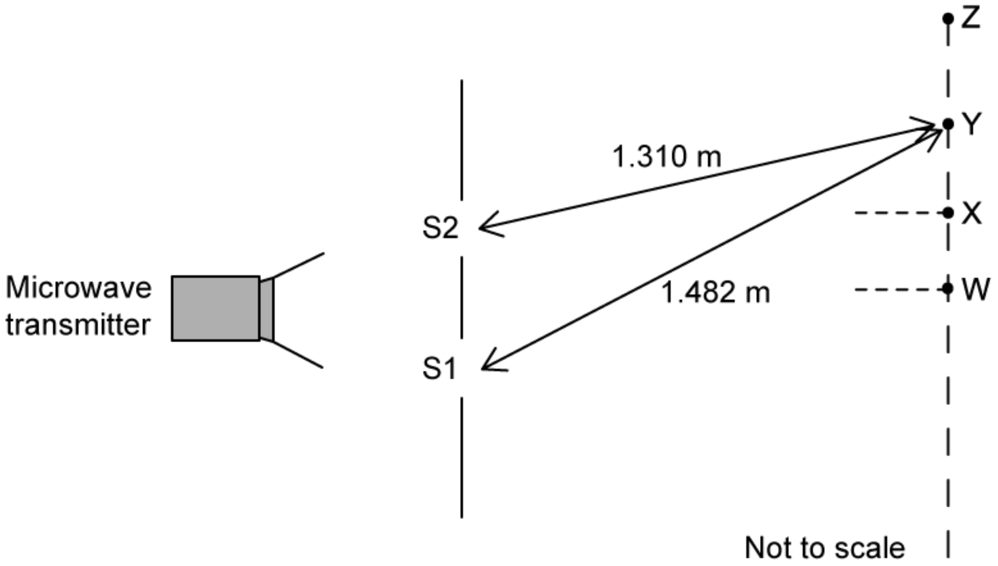
Easy Questions

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



1 (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.

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(1 mark)

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

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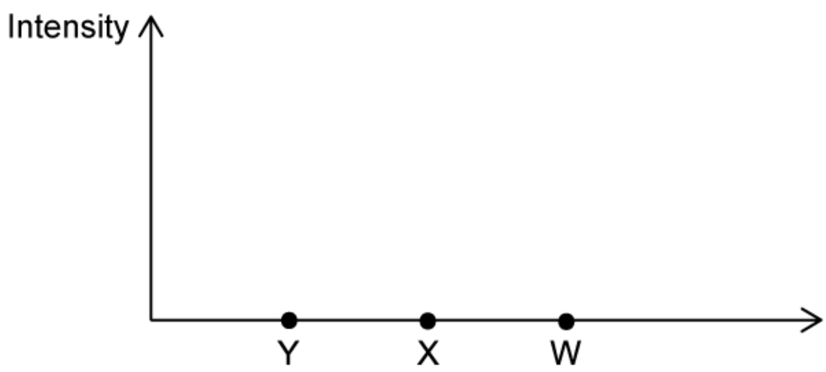
(2 marks)

(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.

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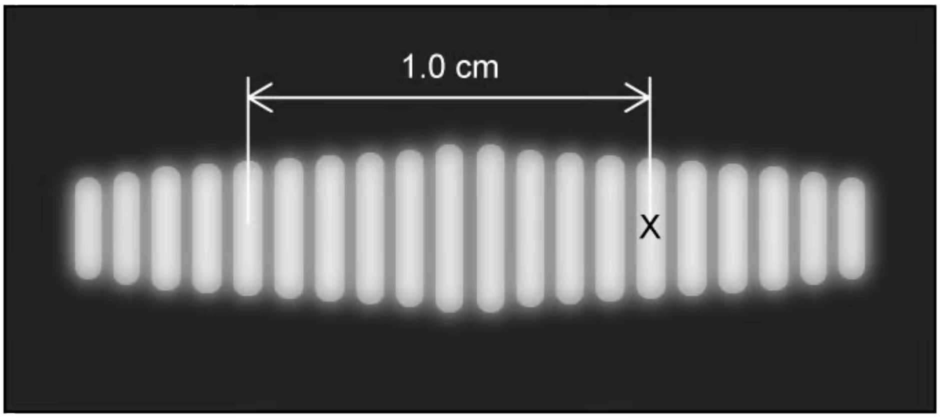
(3 marks)

2 (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.

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(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

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(4 marks)

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

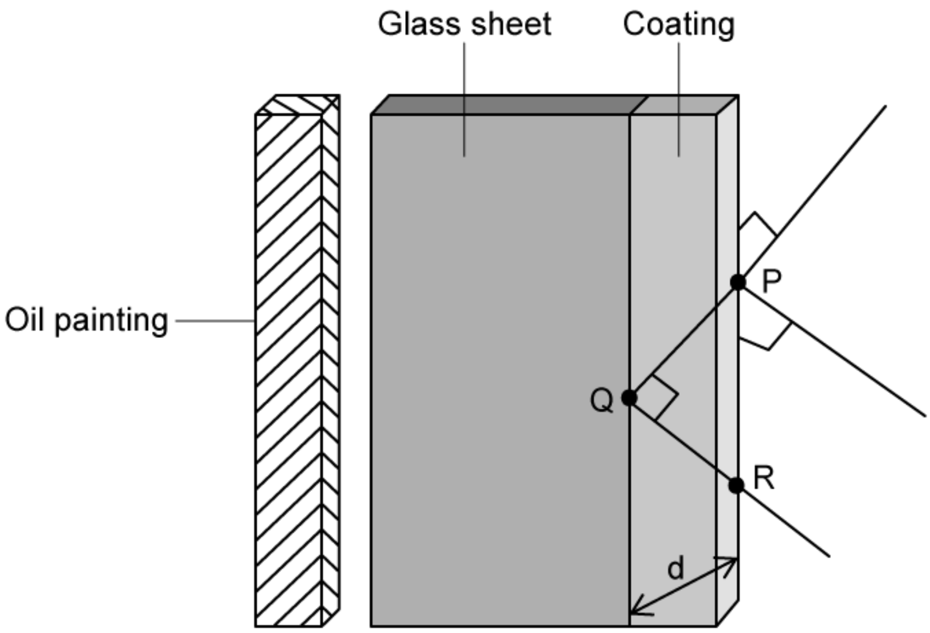
(5 marks)

(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)

3 (a) An oil painting is protected behind a sheet of thin transparent glass with a refractive index n_{glass}. A coating of thickness d is added to the glass sheet to reduce reflection. The refractive index of the coating is such that $n_{glass} > n_{coating} > 1$.

The diagram illustrates rays normally incident on the coating. The incident angles on the diagram are drawn away from the normal for clarity.



State the phase change of the ray reflected at Q.

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(1 mark)

(b) Destructive interference occurs between the waves reflected from P and Q.

State the visual effect this creates and a reason for why this is created.

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(2 marks)

(c) Place a tick (✔) in the correct box to identify which of the following statements are true and which are false.

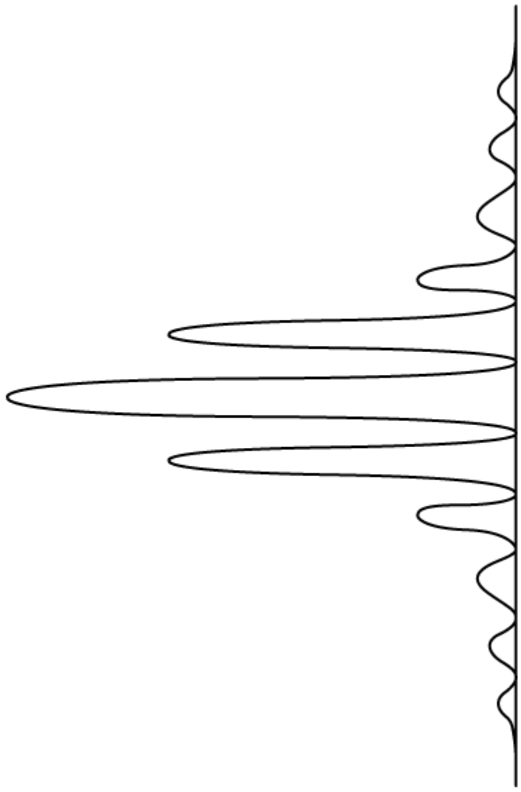
Statement	True	False
Light travelling from a less dense to a more dense medium will travel at a slower speed		
Light travelling from a less dense to a more dense medium will have a longer wavelength		
Light is reflected and transmitted at a boundary from a less dense to a more dense material		
Constructive interference occurs for a whole number multiple of wavelengths		

(4 marks)

(d) State the relationships between the thickness of the coating, *d* and the wavelength of the light λ for both constructive and destructive interference.

(2 marks)

4 (a) Blue light from a laser is incident at a normal incidence on a diffraction grating. The following pattern is observed on the screen.



State whether this shows the interference pattern or the diffraction pattern produced by the diffraction grating.

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(1 mark)

(b) Identify the number of slits on the diffraction grating and give a reason for your answer.

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(2 marks)

(c) Identify, by placing a tick (✔) in the correct box, the statements about double slit interference patterns that are true.

Statement	Place a tick (✔) in this box if the statement is true
For two source interference fringes to be observed the sources of the waves must be coherent	
When two waves interfere the resultant wave depends on the path difference	
When two waves interfere the path difference is proportional to the intensity	
Two source interference fringes are observed when light is monochromatic	

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(3 marks)

(d) State the most important piece of equipment that is needed to be added to the experiment in order to recreate Young's Double slit experiment and give a reason for your choice.

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(2 marks)

5 (a) A diffraction grating has 8000 lines and is 4 cm wide.

Calculate the number of lines per meter.

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(2 marks)

(b) Hence, use your answer from part (a), to calculate the slit spacing on the diffraction grating and state the units.

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(3 marks)

(c) In an experiment, red light of wavelength 650 nm is incident upon this diffraction grating.

Calculate the angle of diffraction at the second order maximum.

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(4 marks)

(d) Determine the equation for the maximum number of fully formed bright fringes that are visible on the screen.

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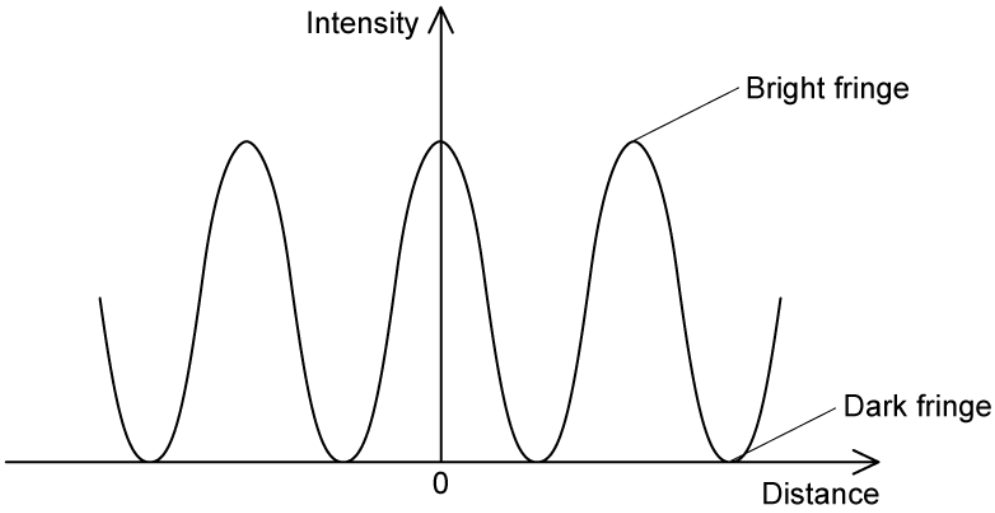
(2 marks)

Medium Questions

1 (a) Several students are conducting investigations with Young's Double Slit Experiment.

In the first investigation, monochromatic light passes through a double-slit arrangement. The intensity of the fringes varies with distance from the central fringe. This is observed on a screen, as shown in the diagram below.



The intensity of the monochromatic light passing through one of the slits is reduced.

Explain the effect of this change on the appearance of the dark and bright fringes.

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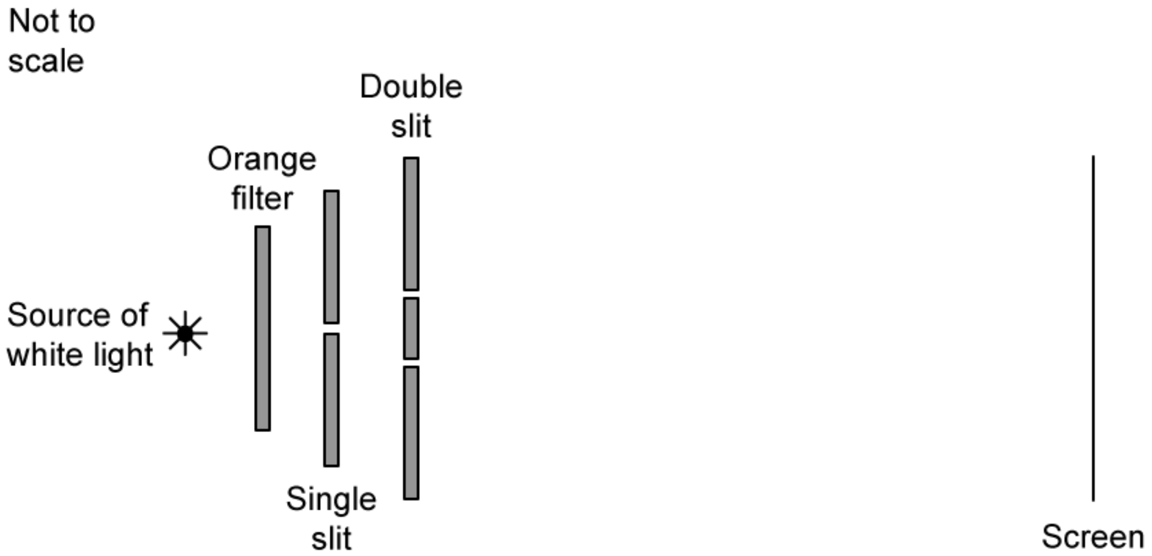
(2 marks)

In investigation, two white light is incident on an orange filter, a single slit, and then a double-slit. An interference pattern of light and dark fringes is observed on the screen.

(b)



(i) The orange filter is now replaced by a green filter. State and explain the change in appearance, other than the change in colour, of the fringes on the screen.

[1]

(ii) The green filter is now removed. State and explain the change in appearance of the central maximum fringe, as well as the fringes away from this central position.

[3]

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(4 marks)

(c) In a third experiment, the white light is replaced by orange light of wavelength 600 nm. The double-slit has a separation of 0.350 mm and the screen is 6.35 m away.

Calculate the distance between the central and first maximum as seen on the screen.

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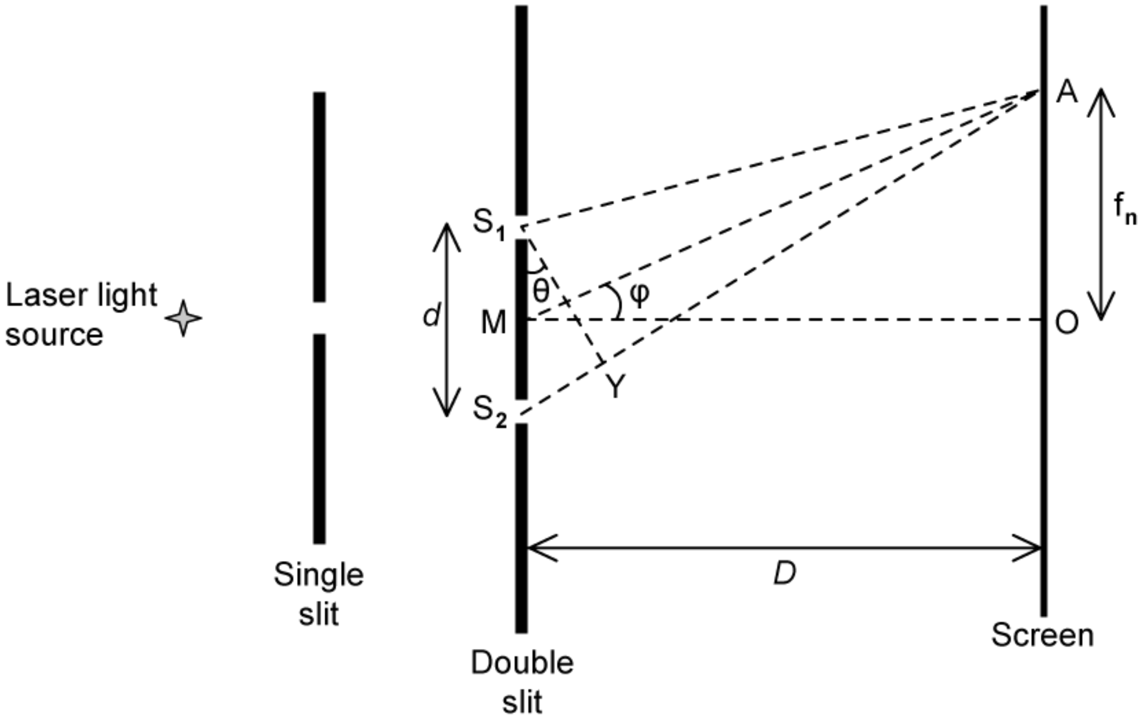
(2 marks)

(d) The light source is now changed to a blue LED of wavelength 450 nm.

Explain the features of the interference pattern that will now be observed on the screen.

(3 marks)

2 (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.

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(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)

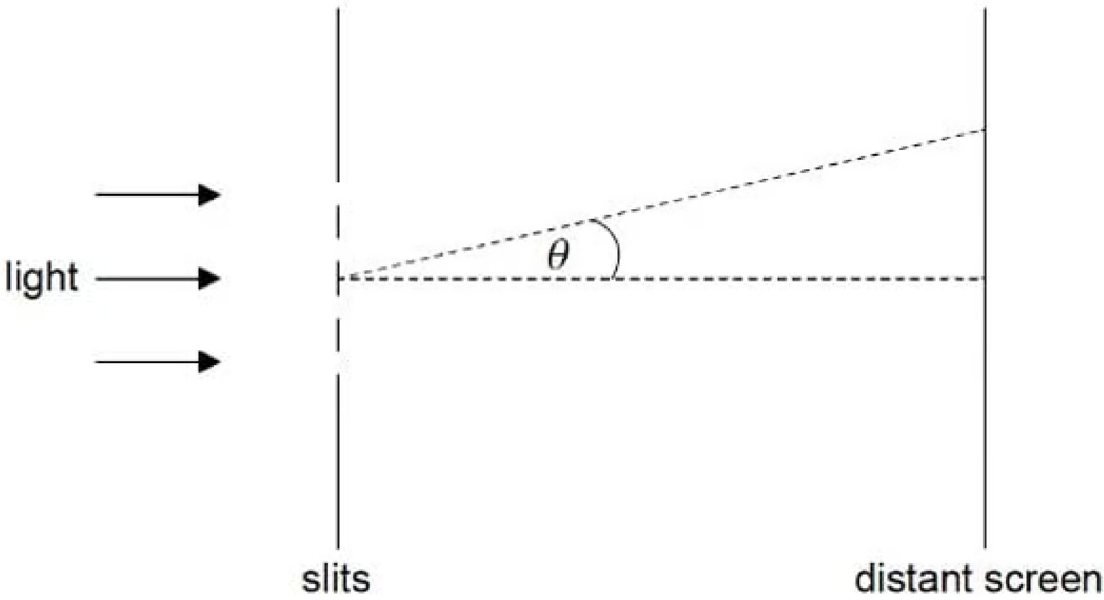
(d) The separation of the slits S_1 and S_2 is 1.30 mm. The distance MO is 1.40 m. The distance f_n is the distance of the ninth bright fringe from O and the angle θ is 3.70×10^{-3} radians.

Calculate the wavelength of the laser light.

(2 marks)

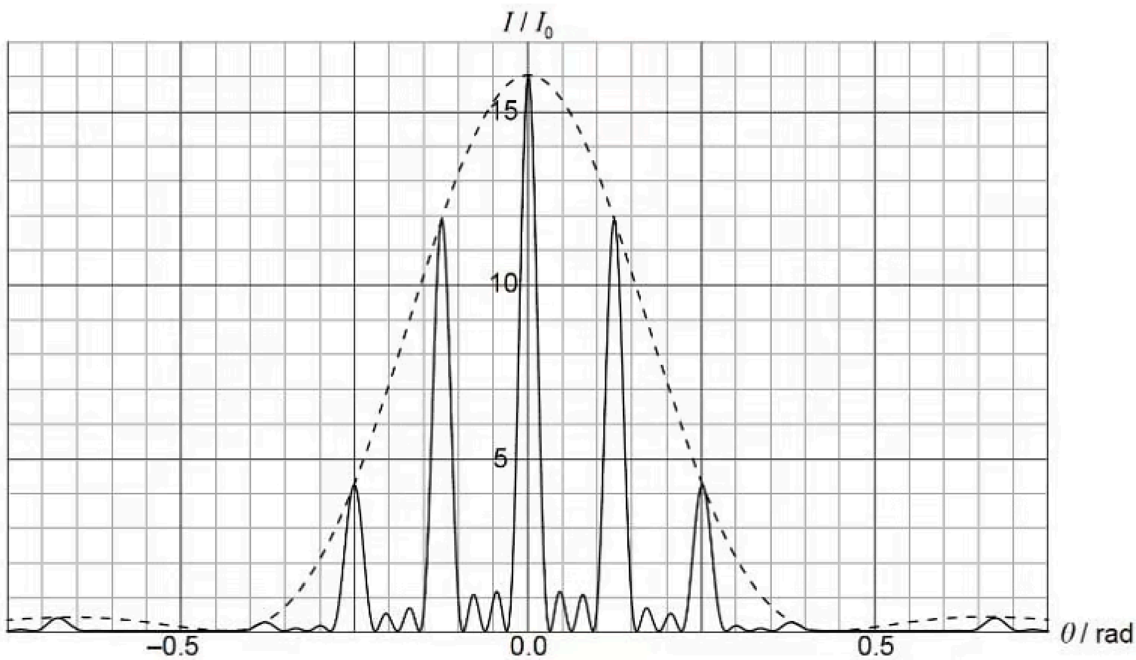
3 (a) Monochromatic light is incident normally on four, thin, parallel, rectangular slits.

IMAGE



The graph shows the variation with diffraction angle θ of the intensity of light I on a distant screen.

IMAGE



I_0 is the intensity of the light at the middle of the screen from one slit.

State the value of the light intensity in terms of I_0 when $\theta = 0$ and explain where this value comes from.

(4 marks)

(b) The width of each slit is 2.0 μm.

Use the graph to estimate the wavelength of the light.

(2 marks)

(c) Use the graph to calculate the number of lines per meter on the diffraction grating.

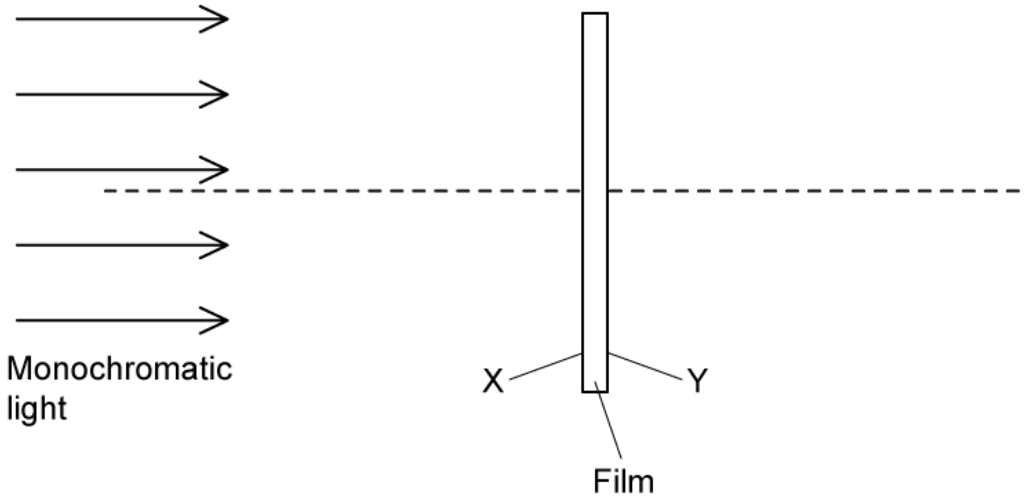
(3 marks)

The four slits are now changed for a grating where the number of slits becomes very large. The separation of the slits and their width stays the same.

(d) State two changes to the graph that will appear as a result of this modification.

(2 marks)

4 (a) Monochromatic light is incident on a thin film of transparent plastic as shown below.



The plastic film is in the air.

Light is partially reflected at both surfaces X and Y on the film.

State and explain the reasons for the phase change that occurs when light is reflected from:

(i) Surface X

[2]

(ii) Surface Y

[2]

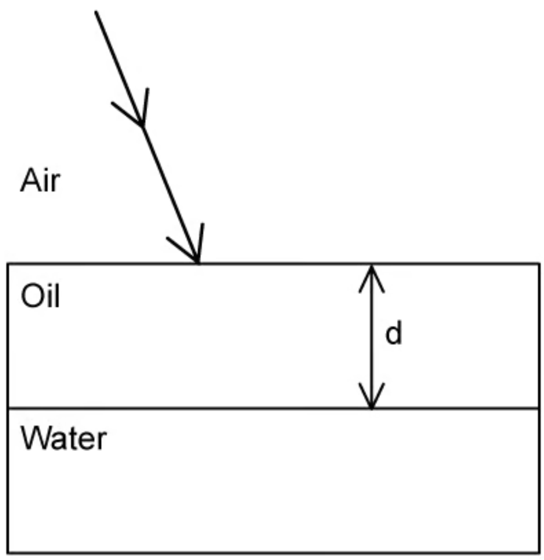
(4 marks)

(b) The red light incident on the transparent plastic has a wavelength of 630 nm. The refractive index of the plastic is 1.50.

Calculate the minimum thickness of the plastic for the light reflected from surface X and surface Y to undergo constructive interference.

(2 marks)

(c) In the second investigation, a thin film of colourless oil floats on water as shown in the diagram below. The refractive index of the oil is 1.47 and the water is 1.52. The same red light is now incident on the oil.



Complete the diagram to show the two light rays reflected from the two surfaces of the oil and label them P and Q.

(3 marks)

(d) The observer notices that the red light reflected from the oil is now darker than that reflected from the transparent plastic.

Calculate how many times thicker the thinnest film of oil is compared to the thinnest film of transparent plastic.

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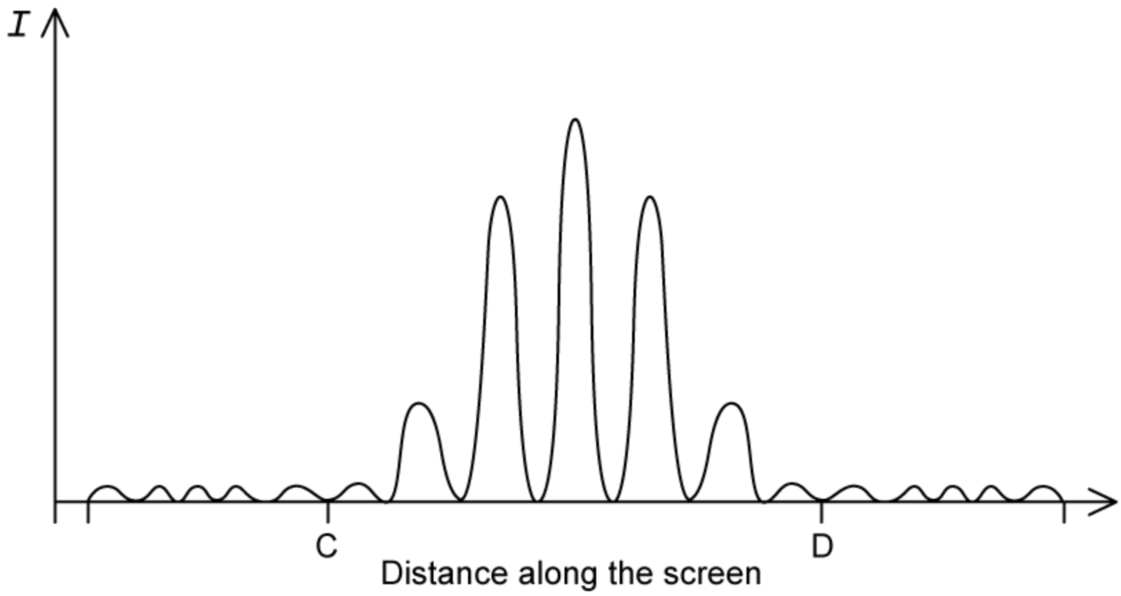
(4 marks)

5 (a) Monochromatic light is incident on a double-slit diffraction grating. After passing through the slits the light is brought to a focus on a screen. The intensity distribution of the light on the screen is shown in the diagram below.



The double-slit diffraction grating is now changed to a grating with many narrower slits, the same widths as the slits above.

Sketch the new intensity pattern for the light between points C and D on the screen.

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(3 marks)

(b) The wavelength of the monochromatic light incident on the diffraction grating is 550 nm. The slit spacing of the diffraction grating is 1.34×10^{-6} m.

Calculate the angle between the two second-order maxima.

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(2 marks)

(c) Calculate the total number of orders of diffracted light that can be observed on the screen.

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(2 marks)

(d) Two sources of light now replace the light incident on the diffraction grating. One is the same as the wavelength of the previous source and the other has a slightly longer wavelength.

Compare and contrast the new intensity pattern with the original. Comment on the intensity of the central maxima and the width of all maxima.

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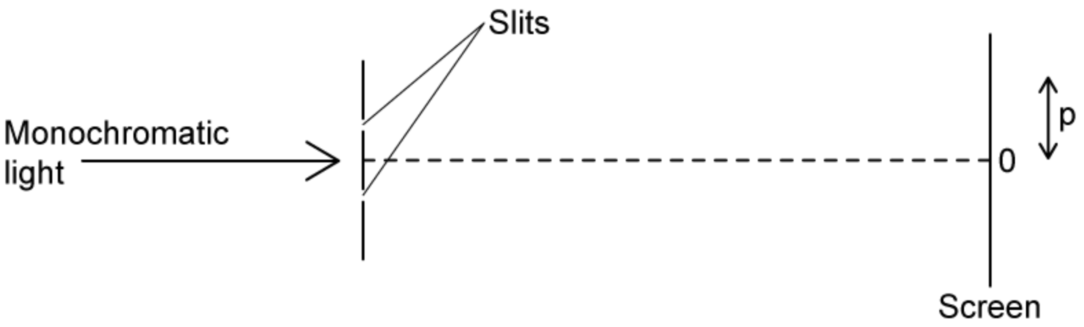
(3 marks)

Hard Questions

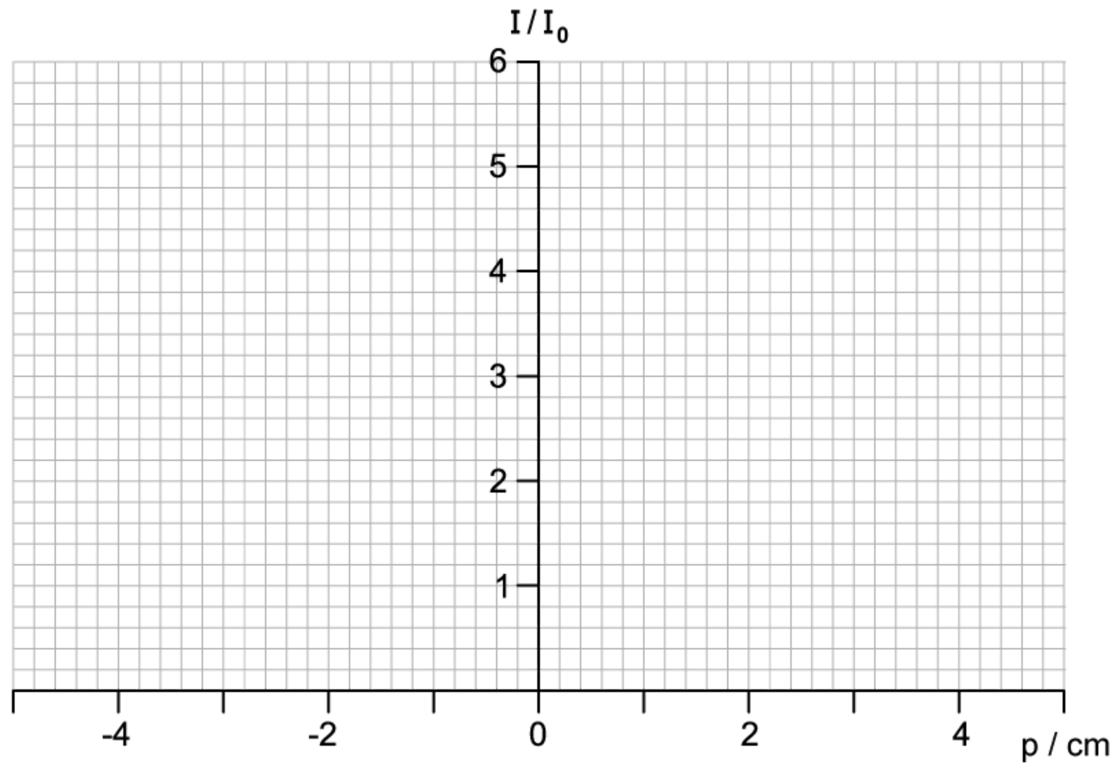
1 (a) Monochromatic light from a single source is incident on two thin parallel slits.



The following data are available:

- Distance from slits to screen = 4.5 m
- Wavelength = 690 nm
- Slit separation = 0.14 mm

The intensity, *I* of the light on the screen from each slit separately is I_0.



Sketch, on the axis, a graph to show variation with distance *p* on the screen against the intensity of light detected on the screen for this arrangement.

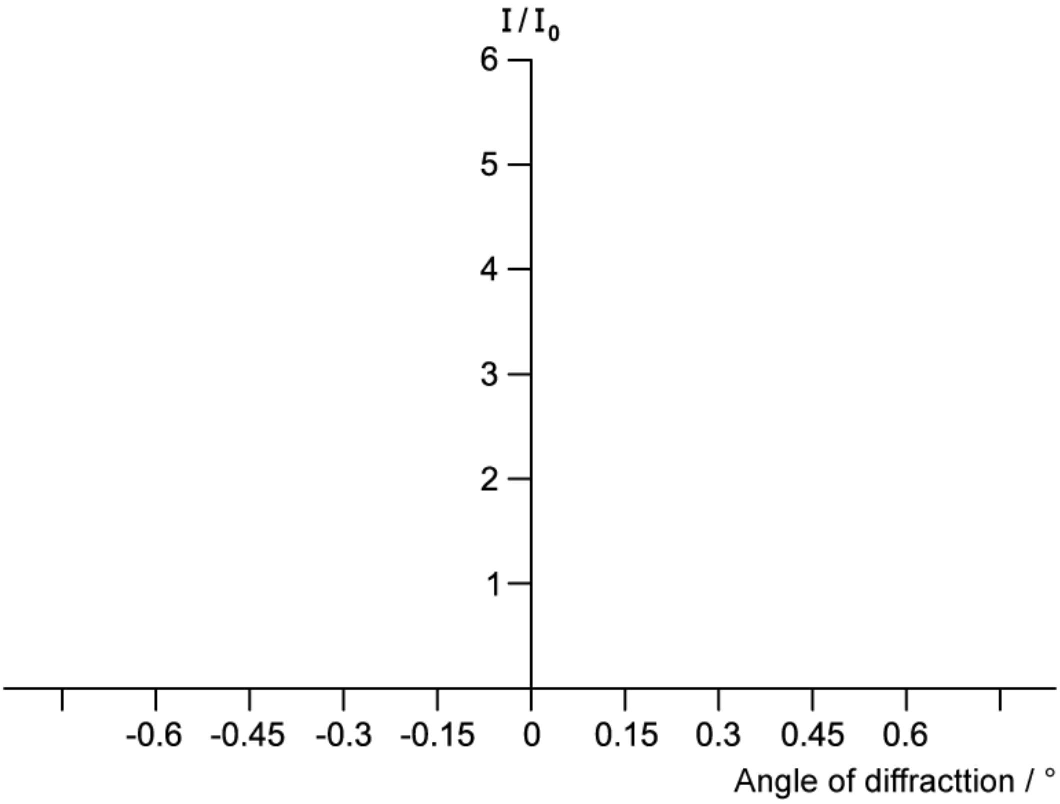
(3 marks)

(b) Calculate the angle of diffraction of the central and subsequent two bright fringes that would appear on the screen.

Give your answer in degrees to one significant figure.

(3 marks)

(c) The relative intensity I_1 for the first bright fringe is $0.75I_0$ and for the second bright fringe I_2 is $0.25I_0$.



Plot, on the axis, a graph to show this diffraction pattern.

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(4 marks)

(d) State and explain the changes that will occur to the diffraction pattern when the number of slits is increased from two to three.

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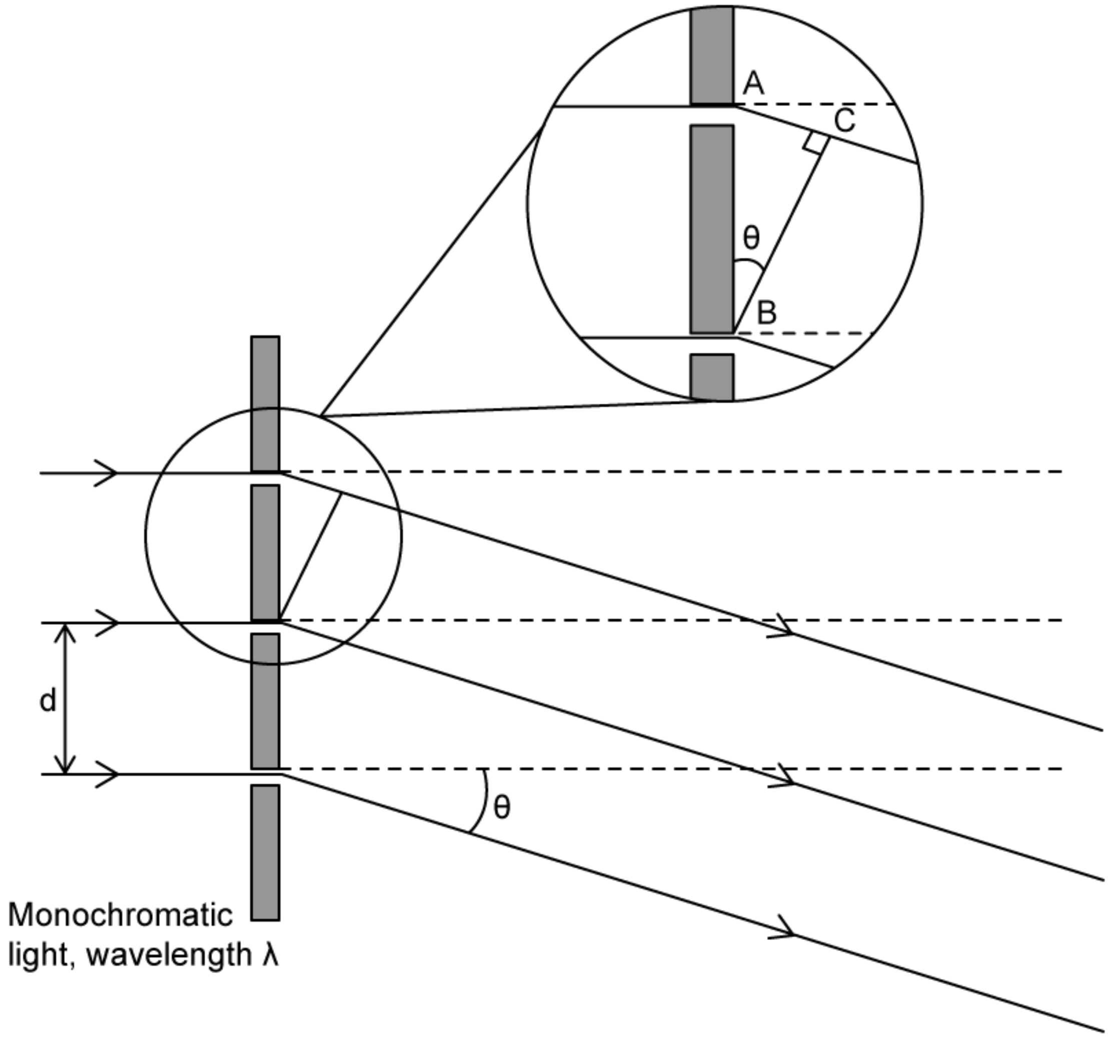
(4 marks)

2 (a) Students in a laboratory have created the following set-up. Parallel rays of monochromatic light from two adjacent slits A and B of wavelength λ are incident normally on a diffraction grating with a slit separation *d*.



Use the diagram to derive the equation $n\lambda = d\sin\theta$ where θ is the angle of diffraction of a maxima order *n* visible on a screen.

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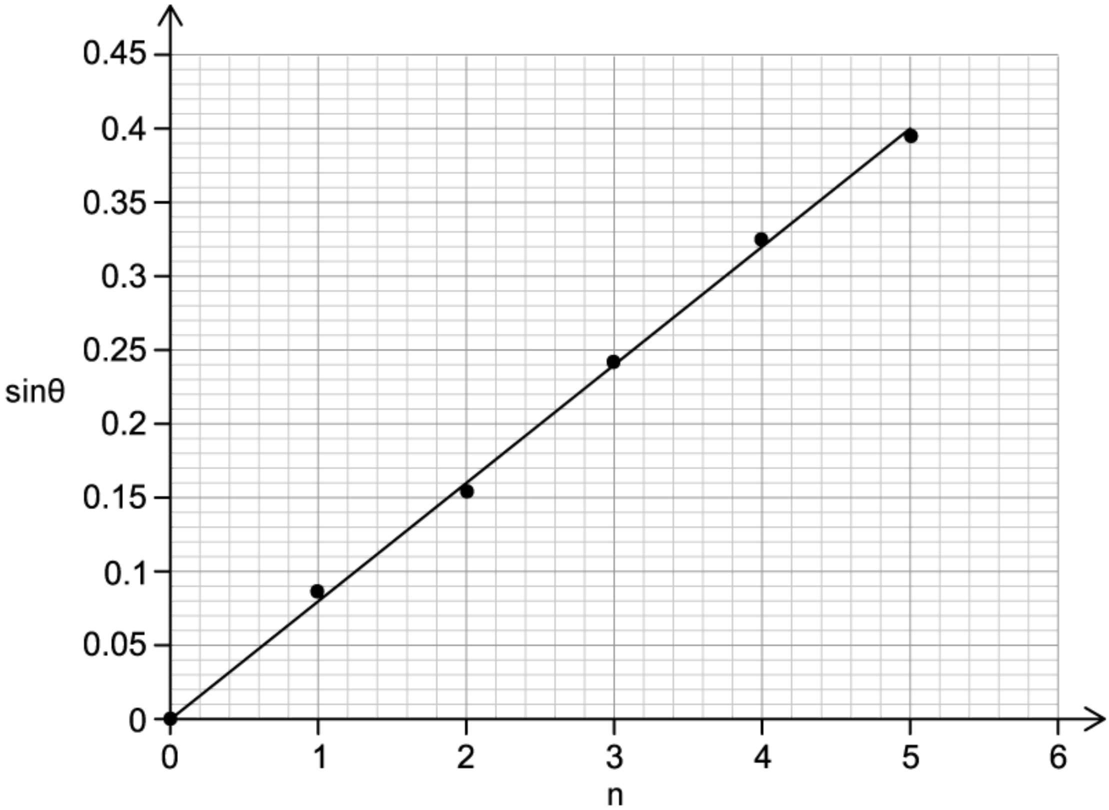
(6 marks)

(b) The monochromatic light in the set-up in part (a) has a wavelength of 545 nm. The graph shows the variation of sinθ with the order n of the maximum. The central order corresponds to n = 0.



Determine a mean value for the number of slits per mm of the grating.

(5 marks)

(c) The grating is 40 mm wide.

Determine the number of slits required to obtain a maximum of six bright fringes on the screen.

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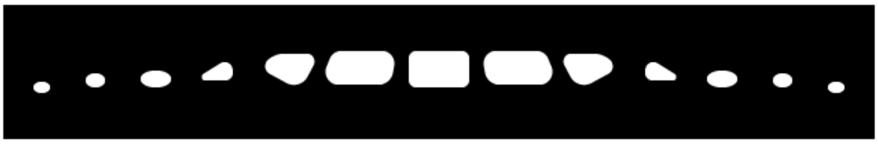
(3 marks)

(d) The students claim that they observed the following diffraction pattern on the screen for the grating from part (c).



State two reasons why the interference pattern obtained cannot be correct.

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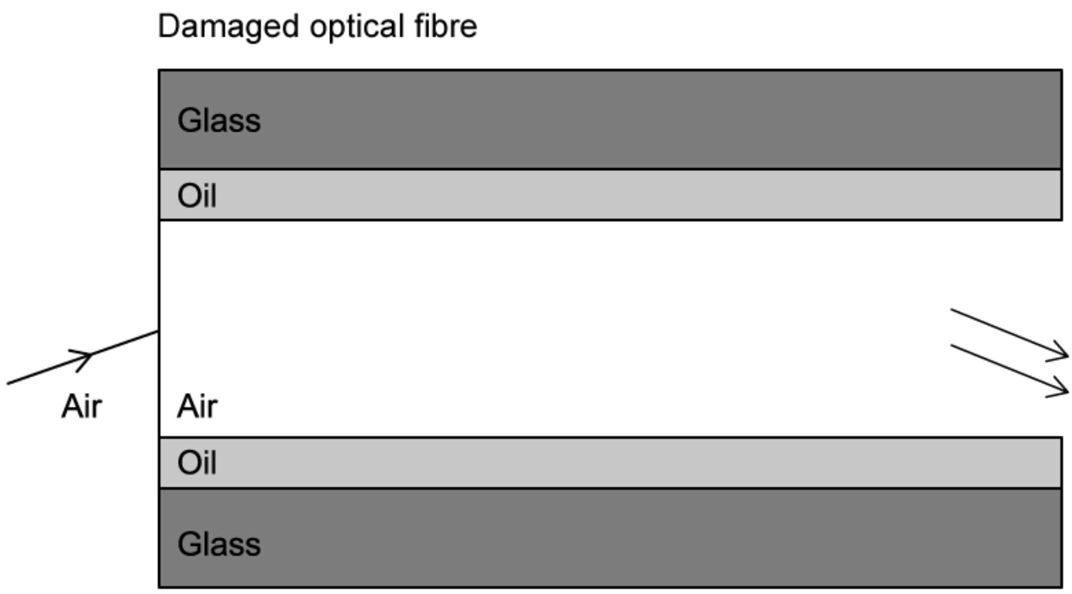
(2 marks)

3 (a) An internet company is looking to improve the amount of light transmitted through its optical fibres. The fibres are made of glass and have a refractive index n_g.

The proposed solution has been to spread a thin film of oil on the inside surface with a refractive index n_o. The air inside the fibre has a refractive index n_a and the air outside has a refractive index n.

$$n < n_a < n_o < n_g$$



Complete the ray diagram to show the path of the incident light ray along the optical fibre.

You do not need to indicate any angles of refraction.

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(3 marks)

(b) Outline the conditions for constructive interference to occur as two light rays travel down in an optical fibre with oil on the inside.

You may include a diagram in your answer.

(3 marks)

(c) The oil has a thickness of 100 nm and a refractive index of 1.4.

Determine the longest possible wavelength of light that can be incident on the oil to obtain constructive interference.

(2 marks)

(d) Analyse whether the oil improves the amount of light transmitted through the optical fibres.

(i) Describe the path of the ray with the presence of oil.

[1]

(ii) Describe the path of the ray without the presence of oil.

[1]

(iii) State and explain whether the oil improves the amount of light transmitted through the optical fibres.

[2]

(4 marks)