Diffraction and Interference *[36 marks]*

1. For fringes to be observed in a double-slit interference experiment, the slits must emit waves that are coherent. *[1 mark]*

What conditions are required for the frequency of the waves and for the phase difference between the waves so that the waves are coherent?

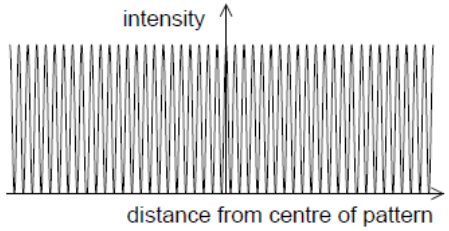
	Frequency of waves	Phase difference between waves
A.	same	variable
B.	same	constant
C.	constant difference	variable
D.	constant difference	constant

Markscheme

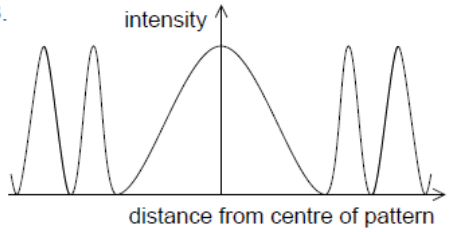
B

2. Monochromatic light is incident on a double slit. Both slits have a finite width. The light then forms an interference pattern on a screen some distance away. Which graph shows the variation of intensity with distance from the centre of the pattern? *[1 mark]*

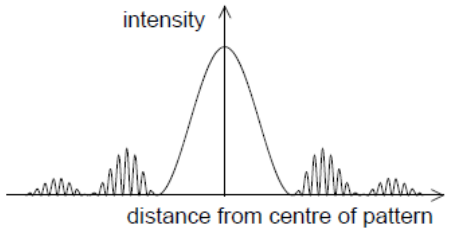
A.



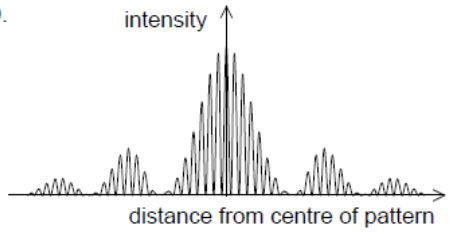
B.



C.



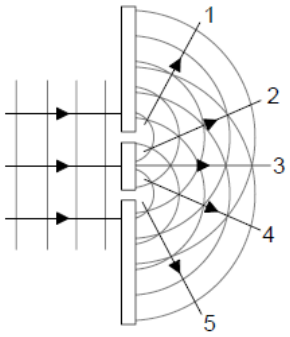
D.



Markscheme

D

3. Blue light is incident on two narrow slits. Constructive interference takes place along the lines labelled 1 to 5. *[1 mark]*



The blue light is now replaced by red light. What additional change is needed so that the lines of constructive interference remain in the same angular positions?

A. Make the slits wider

B. Make the slits narrower

C. Move the slits closer together

D. Move the slits further apart

Markscheme

D

4. Radiation is incident on a single rectangular slit. The diffracted beam that emerges from the slit is incident on a screen. The slit width is then doubled and the wavelength of the radiation is also doubled. The intensity of the radiation remains the same. *[1 mark]*

Which of the following correctly describes the angular width of the central maximum of the diffracted beam and the total number of photons incident every second on the screen?

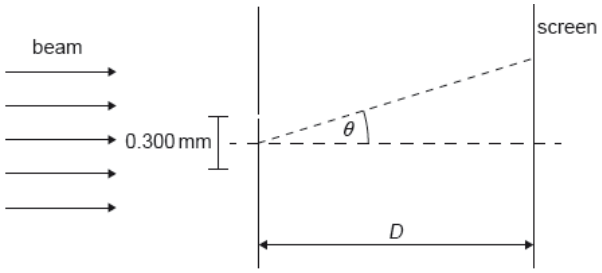
	Angular width of the central maximum	Number of photons incident every second on the screen
A.	unchanged	unchanged
B.	changed	unchanged
C.	unchanged	changed
D.	changed	changed

Markscheme

C

A beam of coherent monochromatic light from a distant galaxy is used in an optics experiment on Earth.

The beam is incident normally on a double slit. The distance between the slits is 0.300 mm. A screen is at a distance D from the slits. The diffraction angle θ is labelled.



5a. A series of dark and bright fringes appears on the screen. Explain how a dark fringe is formed. *[3 marks]*

Markscheme

superposition of light from each slit / interference of light from both slits

with path/phase difference of any half-odd multiple of wavelength/any odd multiple of π (in words or symbols)

producing destructive interference

Ignore any reference to crests and troughs.

[3 marks]

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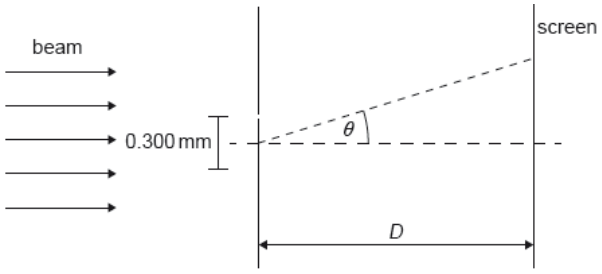


5b. Outline why the beam has to be coherent in order for the fringes to be visible. *[1 mark]*

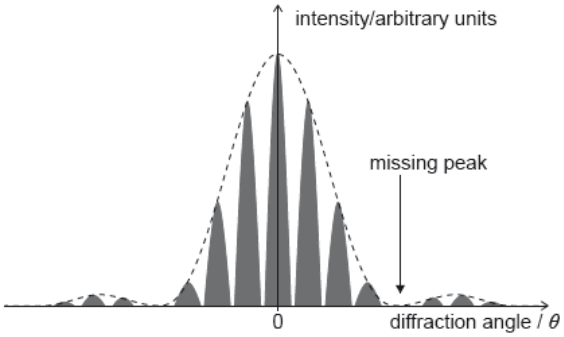
Markscheme

light waves (from slits) must have constant phase difference / no phase difference / be in phase

OWTTE

[1 mark]

The graph of variation of intensity with diffraction angle for this experiment is shown.



5c. Calculate the angular separation between the central peak and the missing peak in the double-slit interference intensity pattern. State your answer to an appropriate number of significant figures. *[3 marks]*

Markscheme

$\sin\theta = \frac{4\times 633.0\times 10^{-9}}{0.300\times 10^{-3}}$

$\sin\theta = 0.0084401\ldots$

final answer to three sig figs (*eg* 0.00844 or 8.44×10^{-3})

Allow ECF from (a)(iii).

*Award **[1]** for 0.121 rad (can award MP3 in addition for proper sig fig)*

Accept calculation in degrees leading to 0.481 degrees.

Award MP3 for any answer expressed to 3sf.

[3 marks]

5d. Deduce, in mm, the width of one slit. *[2 marks]*

Markscheme

use of diffraction formula «$b = \frac{\lambda}{\theta}$»

OR

$\frac{633.0\times 10^{-9}}{0.00844}$

«=» $7.5\text{«00»} \times 10^{-2}$ «mm»

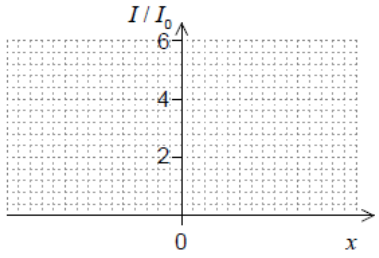
Allow ECF from (b)(i).

[2 marks]

6a. Monochromatic light from two identical lamps arrives on a screen. *[1 mark]*

The intensity of light on the screen from each lamp separately is I_0.

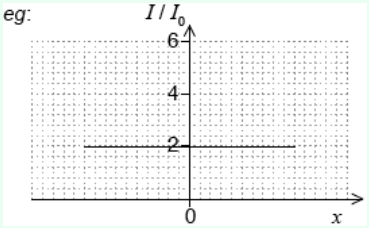
On the axes, sketch a graph to show the variation with distance x on the screen of the intensity I of light on the screen.



Markscheme

horizontal straight line through $I = 2$

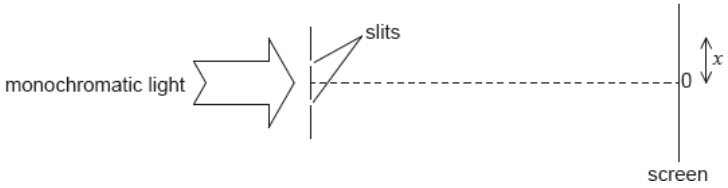
eg:



Accept a curve that falls from I = 2 as distance increases from centre but not if it falls to zero.

[1 mark]

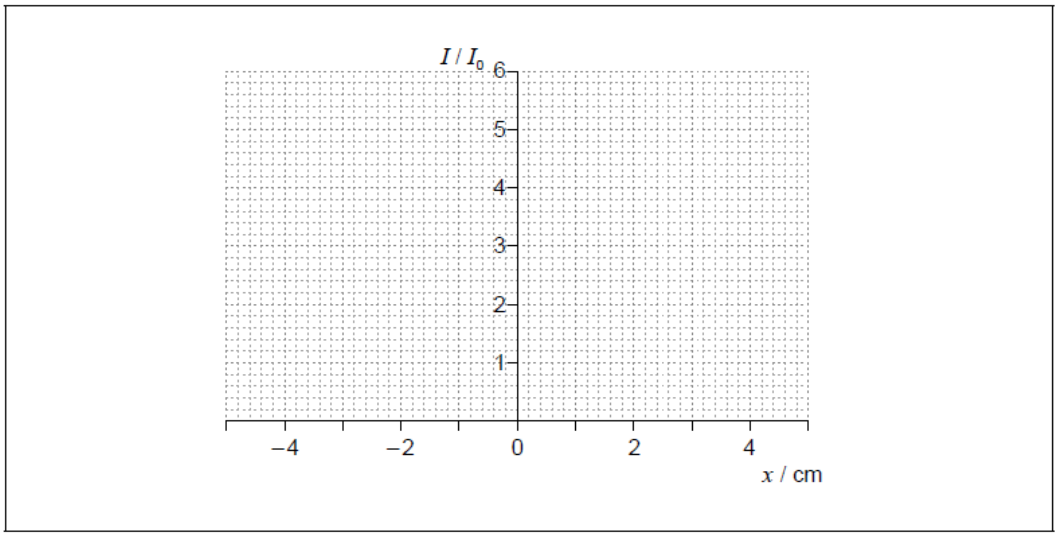
6b. Monochromatic light from a single source is incident on two thin, parallel slits. *[3 marks]*



The following data are available.

Slit separation	$= 0.12$ mm
Wavelength	$= 680$ nm
Distance to screen	$= 3.5$ m

The intensity I of light at the screen from each slit separately is I_0. Sketch, on the axes, a graph to show the variation with distance x on the screen of the intensity of light on the screen for this arrangement.



Markscheme

«standard two slit pattern»

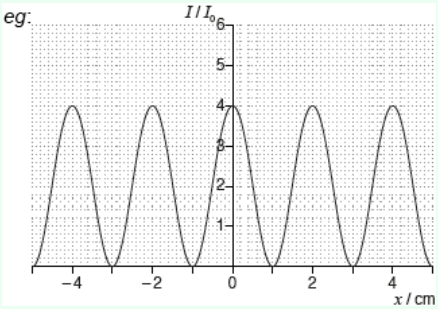
general shape with a maximum at $x = 0$

maxima at $4I_0$

maxima separated by «
$\frac{D\lambda}{s}$ =» 2.0 cm

Accept single slit modulated pattern provided central maximum is at 4. ie height of peaks decrease as they go away from central maximum. Peaks must be of the same width

eg:



[3 marks]

6c. The slit separation is increased. Outline **one** change observed on the screen. *[1 mark]*

Markscheme

fringe width/separation decreases

OR

more maxima seen

[1 mark]

7. Monochromatic light is incident on 4 rectangular, parallel slits. The first principal maximum is observed at an angle θ to the direction of the incident light. The number of slits is increased to 8 each having the same width and spacing as the first 4. *[1 mark]*

Three statements about the first principal maximum with 8 slits are

I. the angle at which it is observed is greater than θ

II. its intensity increases

III. its width decreases.

Which statements are correct?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

C

8. Monochromatic light is incident on two identical slits to produce an interference pattern on a screen. One slit is then covered so that no light emerges from it. What is the change to the pattern observed on the screen? *[1 mark]*

A. Fewer maxima will be observed.

B. The intensity of the central maximum will increase.

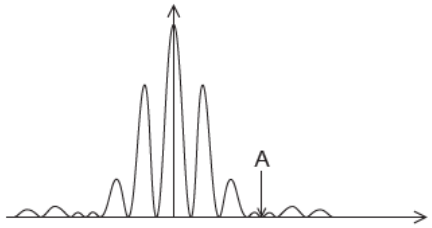
C. The outer maxima will become narrower.

D. The width of the central maximum will decrease.

Markscheme

A

Yellow light from a sodium lamp of wavelength 590 nm is incident at normal incidence on a double slit. The resulting interference pattern is observed on a screen. The intensity of the pattern on the screen is shown.



9a. Explain why zero intensity is observed at position A. *[2 marks]*

Markscheme

the diagram shows the combined effect of «single slit» diffraction and «double slit» interference

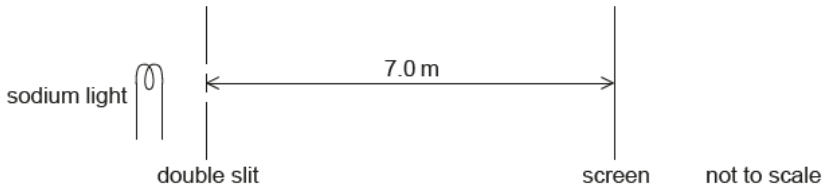
recognition that there is a minimum of the single slit pattern

OR

a missing maximum of the double slit pattern at A

waves «from the single slit» are in antiphase/cancel/have a path difference of $(n + \frac{1}{2})\lambda$/destructive interference at A

9b. The distance from the centre of the pattern to A is 4.1 x 10^{-2} m. The distance from the screen to the slits is 7.0 m. *[2 marks]*



Calculate the width of each slit.

Markscheme

$\theta = \frac{4.1 \times 10^{-2}}{7.0}$ ***OR*** $b = \frac{\lambda}{\theta}$ «= $\frac{7.0 \times 5.9 \times 10^{-7}}{4.1 \times 10^{-2}}$»

1.0 × 10^{-4} «m»

*Award **[0]** for use of double slit formula (which gives the correct answer so do not award BCA)*

Allow use of sin or tan for small angles

9c. Calculate the separation of the two slits. *[2 marks]*

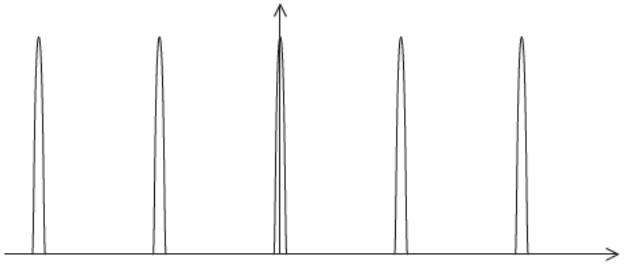
Markscheme

use of $s = \frac{\lambda D}{d}$ with 3 fringes «$\frac{590 \times 10^{-9} \times 7.0}{4.1 \times 10^{-2}}$»

3.0 x 10^{-4} «m»

Allow ECF.

The double slit is replaced by a diffraction grating that has 600 lines per millimetre. The resulting pattern on the screen is shown.



9d. State and explain the differences between the pattern on the screen due to the grating and the pattern due to the double slit. *[3 marks]*

Markscheme

fringes are further apart because the separation of slits is «much» less

intensity does not change «significantly» across the pattern ***or*** diffraction envelope is broader because slits are «much» narrower

the fringes are narrower/sharper because the region/area of constructive interference is smaller/there are more slits

intensity of peaks has increased because more light can pass through

*Award **[1 max]** for stating one or more differences with no explanation*

*Award **[2 max]** for stating one difference with its explanation*

*Award **[MP3]** for a second difference with its explanation*

Allow "peaks" for "fringes"

This question is about interference.

Light from a laser is incident on two identical parallel slits. The light from the two slits produces a fringe pattern on a screen.

A central bright fringe is produced at C. The next bright fringe is produced at A. There is a dark fringe at B.

The light from the laser is coherent and monochromatic.

10a. Outline what is meant by the term *[2 marks]*

(i) coherent.

(ii) monochromatic.

Markscheme

(i) constant/zero phase difference (between the light waves);

(ii) single/same wavelength/frequency; *(allow "narrow band" OWTTE)*

Do not allow "single colour".

10b. State the phase difference between the light waves from the two slits that meet at B. *[1 mark]*

Markscheme

$180^\circ/\pi\text{rad}$;

Do not accept $\frac{\lambda}{2}$.

The distance from the two slits to the screen is 1.5 m. The distance BC is 1.8 mm and the distance between the slits is 0.30 mm.

10c. (i) Show that the laser produces light of wavelength equal to 720 nm. *[4 marks]*

(ii) State the path difference, in metres, between the waves that meet at B.

Markscheme

(i) use of $\lambda = \frac{sd}{D}$;

$s = \frac{2}{} \times 1.8\,(\text{mm})$; *(award this mark for any evidence for the factor of 2)*

$\lambda = \frac{2 \times 1.8 \times 10^{-3} \times 0.30 \times 10^{-3}}{1.5}$ / *OWTTE*;

$(= 7.2 \times 10^{-7}\,\text{m})$

Exact answer is given, award marks for correct working.

(ii) $3.6 \times 10^{-7}\,\text{m}$ ***or*** 360 nm;

Allow ECF from (c)(i).