9.2 Single-Slit Diffraction

Question Paper

Course	DP IB Physics
Section	9. Wave Phenomena (HL only)
Topic	9.2 Single-Slit Diffraction
Difficulty	Hard

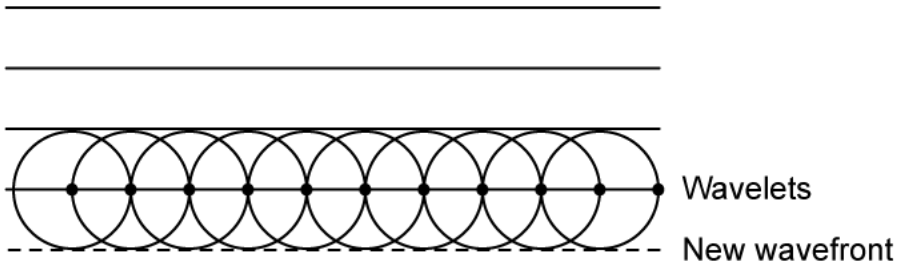
Time allowed: 50

Score: /41

Percentage: /100

Question 1a

Huygen's principle states that all points on a wavefront may be regarded as new sources of wavelets that expand in every direction.



(a)

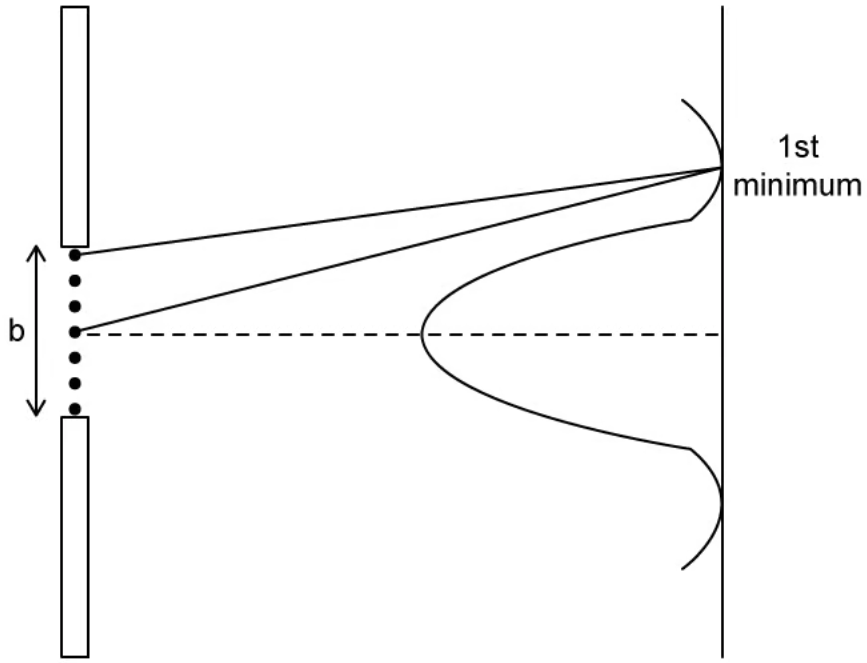
Use Huygen's principle to explain single slit diffraction. You may include diagrams in your explanation.

[4]

[4 marks]

Question 1b

Huygen's principle explains how destructive interference occurs at the minima of the interference pattern.



The angle of diffraction, θ, is related to the wavelength, λ, of the incident light, and the slit width, b, by the following relationship:

$$\theta = \frac{\lambda}{b}$$

(b)
Demonstrate, using geometry, that the minima can be calculated using this equation. You should include a diagram in your answer.

[6]

[6 marks]

Question 1c

(c)
Use the information from parts (a) and (b) to prove that, for single-slit diffraction, destructive interference occurs at both odd and even integer multiples of wavelengths, $n\lambda$.

[5]

[5 marks]

Question 2a

Some students in a lab are performing a single-slit diffraction investigation. They have a green laser but they do not know the exact wavelength of the light.

(a)
Describe which measurements the students can take and how they can use them to calculate the wavelength.

[5]

[5 marks]

Question 2b

The students recorded the following information:

Green laser	Repeat 1	Repeat 2	Repeat 3	Repeat 4	Repeat 5
Distance from slit to screen, D / m	3.11	3.12	3.11	3.11	3.12
Slit width, b / mm	0.14	0.10	0.71	0.11	0.13
Width of central maximum, w / cm	2.8	2.7	2.9	2.9	2.6

(b)
Calculate the wavelength of the laser and give its fractional uncertainty.

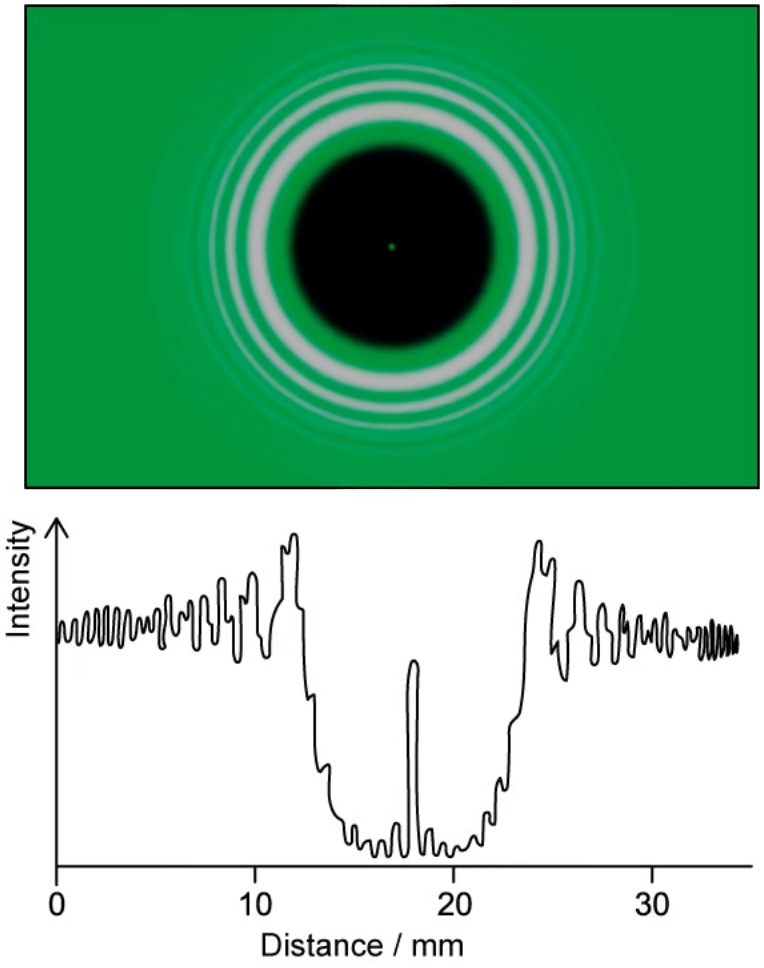
[5]

[5 marks]

Question 3a

Single-slit diffraction patterns provide evidence for light as a wave.

The images below show the diffraction of light around a small circular object.



(a)
Suggest how the images provide evidence for light as a wave.

[2]

[2 marks]

Question 3b

The image shows a diffraction pattern from a single rectangular slit.

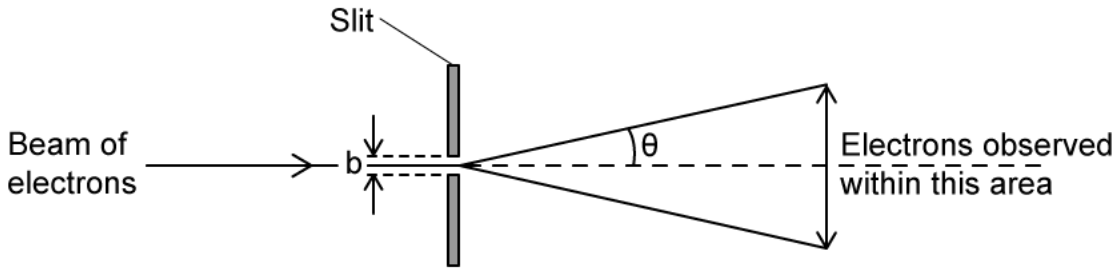
(b)
Sketch the diffraction pattern if the slit width was 20% smaller.

[4]

[4 marks]

Question 4a

A beam of electrons is incident normally to the plane of a narrow slit of width *b*. The beam of electrons can be observed to diffract over an angular area of 2θ.



The uncertainty in the position, Δx, and momentum, Δp, of an electron in the beam can be described by Heisenburg's uncertainty principle

$$\Delta x \Delta p \geqslant \frac{h}{4\pi}$$

This expression can be derived by considering the possible paths an electron might take as it passes through the slit.

(a)

(i)
Write an expression for Δx in terms of slit width *b*.

[1]

(ii)
Write an expression for Δp in terms of diffraction angle θ.

[1]

(iii)
Hence, show that

$$\Delta x \Delta p \approx \frac{p\lambda}{2}$$

[2]

[4 marks]

Question 4b

(b)
Outline the effects on the range of diffraction angles and the uncertainties of position and momentum expected when

(i)
The width of the slit is increased.

[3]

(ii)
The width of the slit is reduced.

[3]

[6 marks]