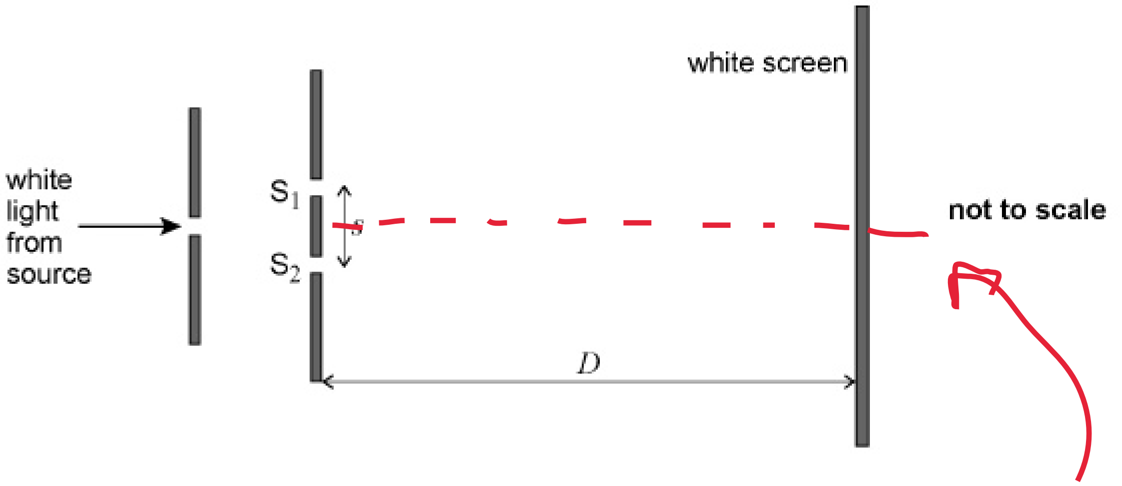
1 The figure below shows a diagram of apparatus used to demonstrate the formation of interference fringes using a white light source in a darkened room. Light from the source passes through a single slit and then through two narrow slits S_1 and S_2.



(a) Describe the interference pattern that is seen on the white screen.

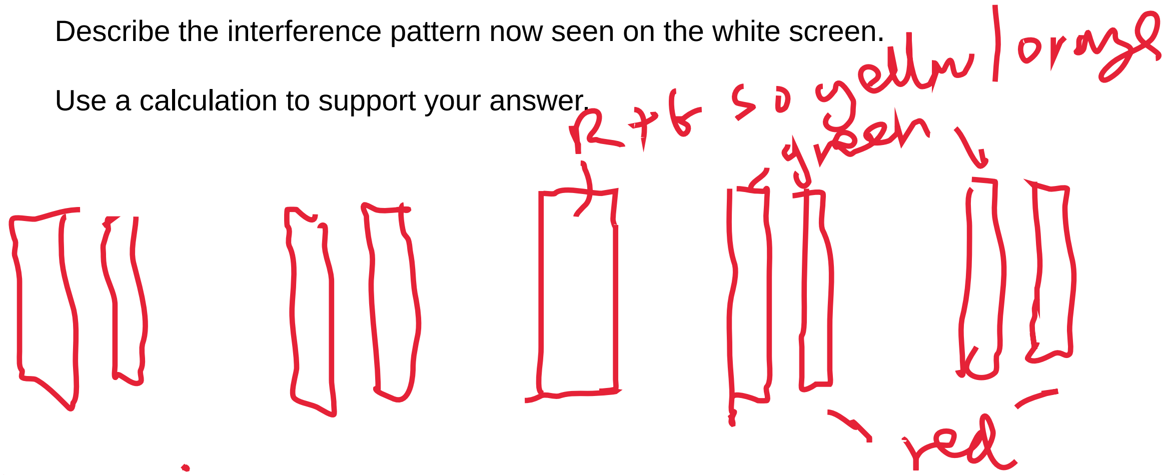
- symettrical around mid point
- bright white central max
- then "rainbow" fringes or spectra with blue nearest to central line.
- equally spaced dark bands

(2)

(b) A filter transmits only green light of wavelength λ and red light of wavelength 1.2λ
This filter is placed between the light source and the single slit.

Describe the interference pattern now seen on the white screen.

Use a calculation to support your answer.



fringe spacing → $W = \frac{\lambda D}{S}$

$\lambda_{red} = 1.2\lambda_{green}$

∴ red is 1.2 further from central band than its green partner in same set of fringes

(4)

(c) A student decides to use the apparatus shown in the figure to determine the wavelength of red light using a filter that transmits only red light.

$w = \frac{\lambda D}{s} \Rightarrow$

The student suggests the following changes:

- decrease slit separation s
- decrease D, the distance between the slits and the screen.

$\lambda = \frac{ws}{D}$

The student decides to make each change independently.

Discuss the effects each independent change has on the interference pattern, and whether this change is likely to reduce uncertainty in the determination of the wavelength.

Decrease s: spreads out fringes more. So the % uncertainty on W goes down. However S is smaller so the % on this goes up. Given that the % error is likely to be bigger ont he S than W then likely the % will go up overall as % errors add.

Decrease D. This will move the fringes closer together which will increase the % error on D and W. Again the % uncertainties will add

(6)

(Total 12 marks)

2 The table shows results of an experiment to investigate how the de Broglie wavelength λ of an electron varies with its velocity v.

v / 10^{7} m s^{-1}	λ / 10^{-11} m	λv
1.5	4.9	7.35×10^{-4}
2.5	2.9	7.25×10^{-4}
3.5	2.1	7.35×10^{-4}

(a) Show that the data in the table are consistent with the relationship $\lambda \propto \frac{1}{v}$

$\lambda v =$ constant see table

it is more or less constant

____

(2)

(b) Calculate a value for the Planck constant suggested by the data in the table.

$\lambda = \frac{h}{mv} \Rightarrow h = \lambda m v$

line 1 $h = 4.9 \times 10^{-11} \times 9.11 \times 10^{-31} \times 1.5 \times 10^{7}$

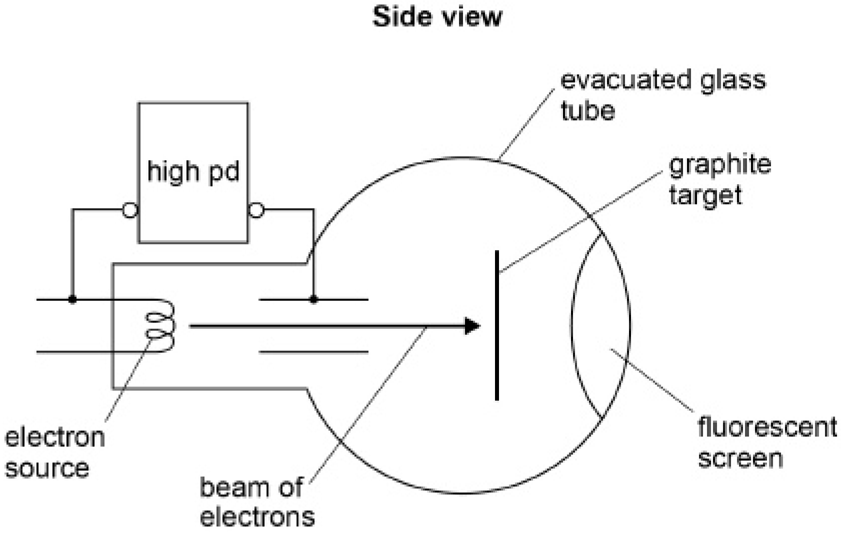
$= 6.7 \times 10^{-34}$ (2sf)

Planck constant = ____________________ J s

(2)

(c) **Figure 1** shows the side view of an electron diffraction tube used to demonstrate the wave properties of an electron.

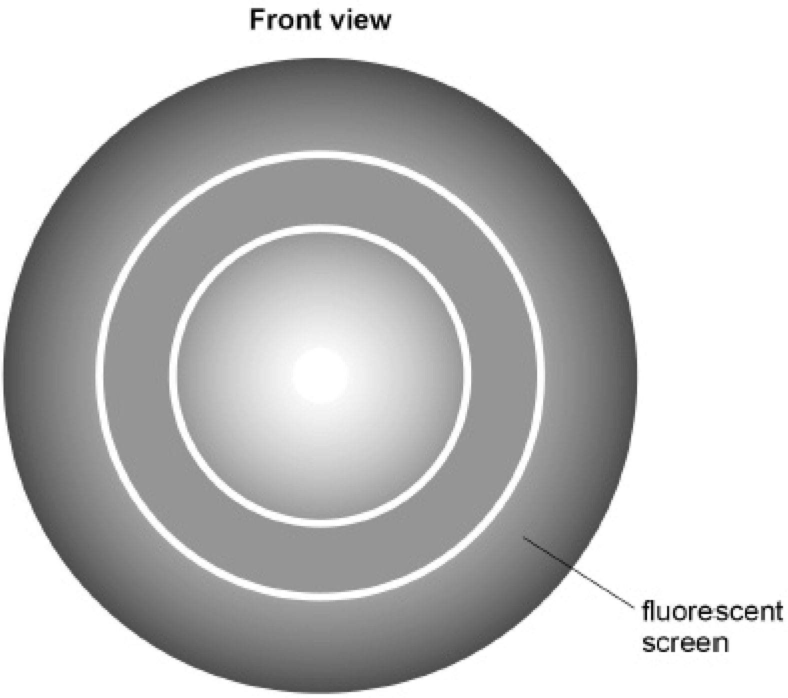
Figure 1



An electron beam is incident on a thin graphite target that behaves like the slits in a diffraction grating experiment. After passing through the graphite target the electrons strike a fluorescent screen.

Figure 2 shows the appearance of the fluorescent screen when the electrons are incident on it.

Figure 2



Explain how the pattern produced on the screen supports the idea that the electron beam is behaving as a wave rather than as a stream of particles.

It is a diffraction pattern which is uniquely a wave property. e^- diffracts around graphite molecules. The e interfere both constructively & destructively to produce the light/dark bands just like wave would.

(3)

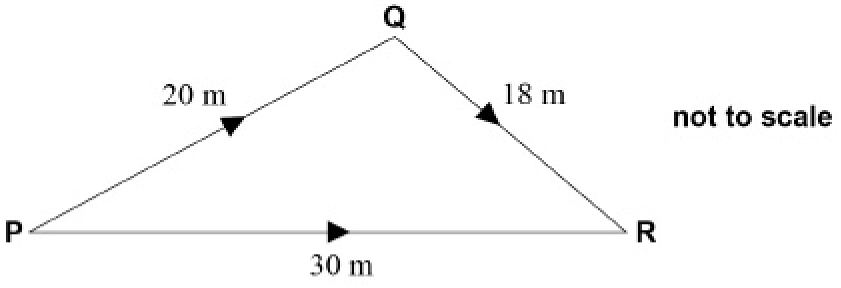
(d) Explain how the emission of light from the fluorescent screen shows that the electrons incident on it are behaving as particles.

e^- must carry discrete "bundles" of energy. There's no "gradual build up of energy" as you'd get with a wave. The e^- as "particles" provide enough to excite e^- in flourescent screen which then de-excite giving off a photon.

(3)

(Total 10 marks)

3 In the diagram, **P** is the source of a wave of frequency 50 Hz



The wave travels to **R** by two routes, **P** → **Q** → **R** and **P** → **R**. The speed of the wave is 30 m s−1

What is the path difference between the two waves at **R** in terms of the wavelength λ of the waves?

$c = f\lambda \Rightarrow \lambda = \frac{c}{f} = 0.6\,m$

$p.d. = 8m =$

$= \frac{8m}{0.6}\lambda = 13.3$

A 4.8λ ○

B 8.0λ ○

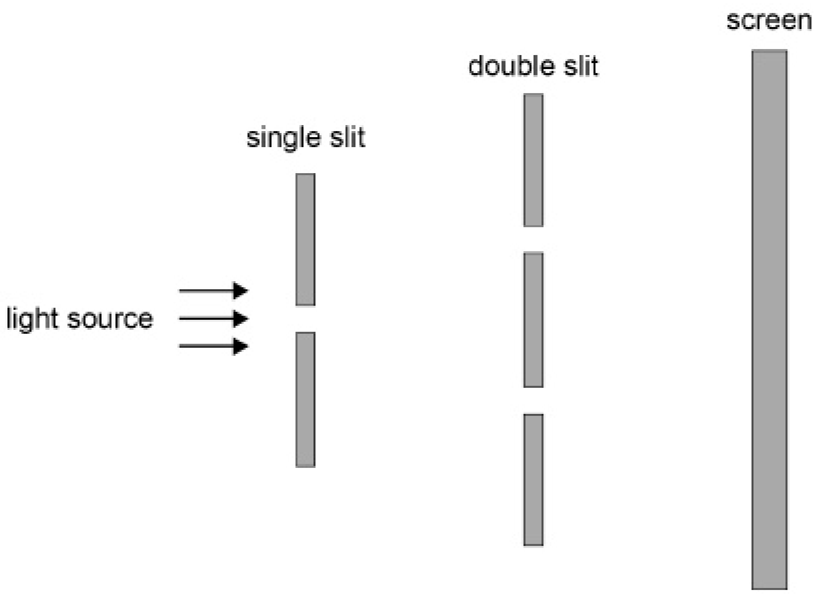
[✓ **C**] 13.3λ ○

D 20.0λ ○

(Total 1 mark)

4 Light from a point source passes through a single slit and is then incident on a double-slit arrangement. An interference pattern is observed on the screen.

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



What will increase the fringe spacing?

✗ **A** increasing the separation of the single slit and the double slit ○

✗ **B** increasing the width of the single slit ○

✗ **C** decreasing the distance between the double slits and the screen ○

✓ **D** decreasing the separation of the double slits [✓ ○]

(Total 1 mark)

Mark schemes

1 (a) TWO FROM:

central white fringe ✓

(fringes either side) showing range of colours/spectrum ✓

with red furthest and blue/violet closest to centre ✓

Allow rainbow for spectrum

Reject different colour fringes

If colours mentioned for last mark must be in right order i.e. red last

1
1
(MAX 2)

(b) FOUR FROM:

central fringe is a mixture of red and green light/two wavelengths ✓

EITHER (1 marks)

(separate) red and green fringes are seen (on either side) ✓

OR (for 2 marks)

spacing of green fringes is less than spacing of red fringe / green fringes closer to middle than red ✓ ✓

OR (for 3 marks)

spacing of red fringes is 20% (or 1.2 times)greater than green fringes ✓ ✓ ✓

6th green fringe overlaps with 5th red fringe ✓

Allow orange/yellow for central fringe

If w used must be identified as fringe spacing for third alternative

1
1
1
1
(MAX 4)

(c) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.**

Mark	**Criteria**	**QoWC**
6	Explains how (%) uncertainties combine to determine uncertainty in wavelength OR identify % uncertainty *s* as being the largest	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
5	Explain how wavelength is determined using $\lambda=\frac{ws}{D}$	
4	Explains how second change affects fringe spacing AND Comments on how change in fringe spacing affects (%)uncertainty / change in *s* OR *D* affects (%)uncertainty	The student presents relevant information and in a way which assists communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
3	Explains how second change affects fringe spacing OR Comments on how change in fringe spacing affects (%)uncertainty / change in *s* OR *D* affects (%)uncertainty	
2	States how one of the changes affects fringe separation (decrease *s* increases fringe separation / decrease *D* decrease fringe separation	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
1	States that one of the changes alters fringe separation	
0	No correct change identified	The student's presentation, spelling and grammar seriously obstruct understanding.

The following statements may be present for decreasing slit separation s:

Fringe separation increases
Uncertainty in measuring fringe separation will
decrease
and as this is needed to measure wavelength,
uncertainty in wavelength
measurement will decrease

The following statements may be present for smaller D:

Uncertainty in measuring D would increase
Fringe separation would also decrease
so uncertainty in measuring fringe separation would increase
Both are required to find wavelength so uncertainty in finding wavelength would increase

FOR Middle Band ***one*** *of these considered:*

Decrease s
Larger fringe separation so smaller (%) uncertainty (in w)
Smaller s so higher (%) uncertainty in s
Decrease D
Smaller fringe separation so larger (%) uncertainty (in w)
Smaller D so higher (%) uncertainty in D

If explain reverse change correctly (s increase D increase) no penalty

6

[12]

2 (a) Clear indication of correct process

two correct values for λv from working plus conclusion

(7.35; 7.25; 7.35) ✓

three correct values plus conclusion ✓

Condone no or misuse of powers of 10

Allow use of value of h as the constant to show that v values in table are consistent with the λ values

1

....

ratio approach $v_1/v_2 = \lambda_2/\lambda_1$ shown for 2 sets of data ✓

shown for two other sets of data + conclusion ✓

May predict one of the values assuming inverse proportionality and compare with table value

(once for 1 mark; twice for 2 marks)

1

(b) $h = \lambda mv$ or substitution of correct data in any form ✓

May determine average value using mean constant from 2.1 or average 3 calculations in this part

1

$6.7(0) \times 10^{-34}$ from first and third data set; $6.6(0) \times 10^{-34}$ from second ✓

1

(c) Particle behaviour would only produce a patch/circle of light /small spot of light or Particles would scatter randomly ✓

Wave property shown by diffraction/ interference ✓

Graphite causes (electron)waves/beam to spread out /electrons to travel in particular directions ✓

Bright rings/maximum intensity occurs where waves

interfere constructively/ are in phase ✓

for a diffraction grating maxima when sinθ = $n\lambda/d$ ✓

Marks are essentially for

1. Explaining appearance of screen if particle

2. Identifying explicitly a wave property

3. Explaining what happens when diffraction occurs

4. Explaining cause of bright rings

5. Similar to diffraction grating formula (although not same)

NB Not expected: For graphite target maxima occur when sinθ =$\lambda/2d$ (d =spacing of atomic layers in crystal)

1
1
1

(d) Electrons must provide enough (kinetic) energy

'instantly' to cause the excitation

OR

the atom or energy transfer in 1 to 1 interaction

OR

electron can provide the energy in discrete amounts

OR

energy cannot be provided over time as it would be in a wave

Description of Photoelectric effect = 0

Not allowed: any idea that wave cannot pass on energy, e.g. waves pass through the screen

1

Any 2 from

Idea of light emission due to excitation and de-excitation of electrons/atoms ✓

Idea of collisions by incident electrons moving electrons in atoms between energy levels/shells/orbits ✓

Light/photon emitted when atoms de-excite or electrons move to lower energy levels ✓

1
1

[10]

3 **C**

[1]

4 **D**

[1]