Young's double slit experiment is set up by students in a laboratory as shown in Figure 2. Monochromatic light is shone onto the slits which are placed at a large distance from the screen. The intensity pattern produced on the screen is a pattern of light and dark bands.

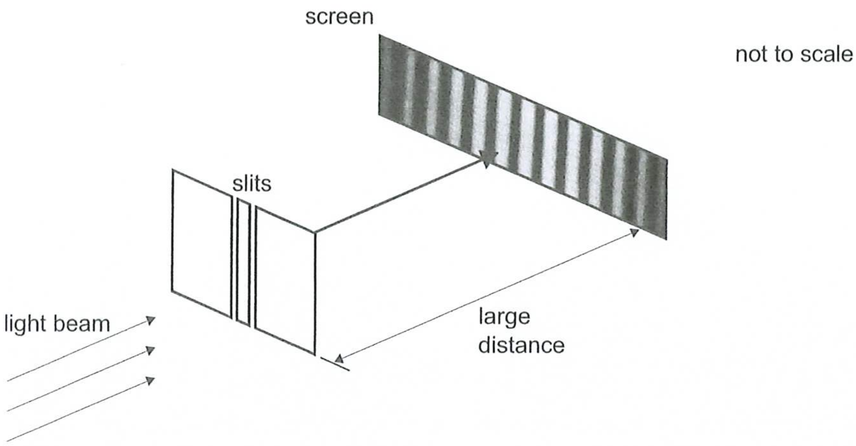


Figure 2

The students then wonder what will happen if the light used is white light rather than monochromatic light. All the students agree that there will be bands of colour on the screen, but have different opinions about the centre band. Pat expects a white band in the centre while Robyn believes a coloured band will be produced.

Question 5 9%

Select which of the students is correct and justify your answer in the space below.

Pat / Robyn

Pat correct - white band expected in the center
Light bands represent constructive interference
which position is determined by wavelength.
For central band path difference is zero
for all wavelengths, so all wavelengths will
have maximum at the center creating
white band.
Extention - all other bands will have colours separated
as $\Delta x \propto \lambda$ so maximum of violet light will
be closest to the center and red furthest away.

3 marks

9%

Question 11

In the space below describe how the wave-particle duality of electrons can be used to explain the quantised energy levels of the atom.

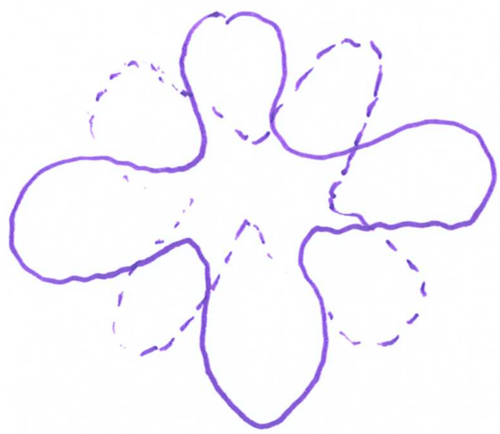
Electrons have a de Broglie wavelength. Electrons can exist only in states where standing wave can be formed around the nucleus. ~~Cir~~ For standing wave to form, circumference of

3 marks

Working space

13 %

the orbit must be equal to the whole number of wavelength. $2\pi r = n\lambda$
So only energies corresponding to those specific wavelength will exist.



Area of study 2 – Interactions of light and matter

Question 2

The table below contains some predictions for the behaviour of light incident on a shiny metal sheet. Complete the table by placing a 'Y' (Yes) or 'N' (No) in the appropriate boxes if the prediction is supported by the wave **and/or** particle model of light. Some answers have already been provided. It is possible for predictions to be supported by both models.

Prediction	Wave model	Particle model
The number of photoelectrons produced is proportional to the intensity of the incident beam.	Y	Y
Light of low intensity will give rise to the emission of photoelectrons later than light of high intensity.	Y	N
Light of high intensity will produce photoelectrons with a greater maximum kinetic energy than light of low intensity.	Y	N
Light of sufficient intensity of any frequency should produce the photoelectric effect.	Y	N

4 marks

24%

Figure 2 shows the energy levels of a sodium atom.

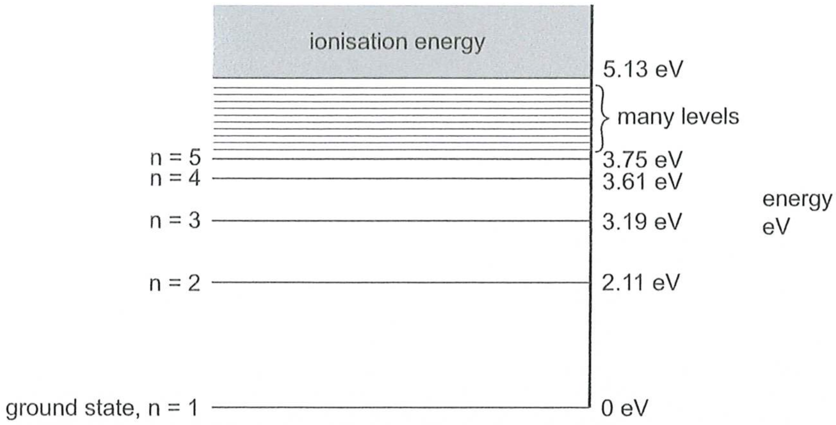


Figure 2

Figure 2 shows that electrons in a sodium atom can only occupy specific energy levels.

Question 6 Same as q. 11 2005

Describe how the wave nature of electrons can explain this.

2 marks

In an experiment, monochromatic laser light of wavelength 600 nm shines through a narrow slit, and the intensity of the transmitted light is recorded on the screen some distance away as shown in Figure 2a. The intensity pattern seen on the screen is shown in Figure 2b.

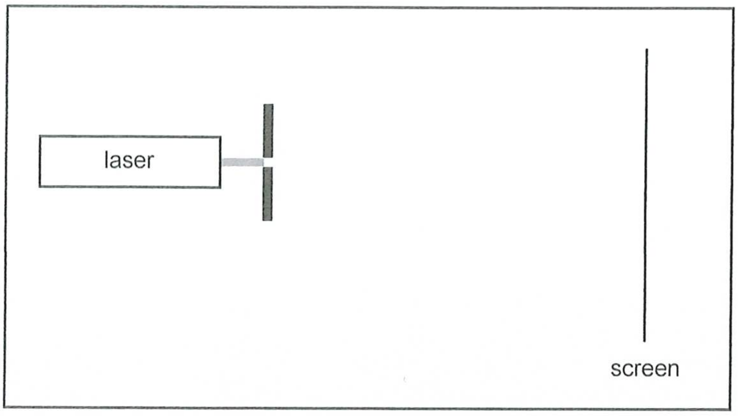


Figure 2a

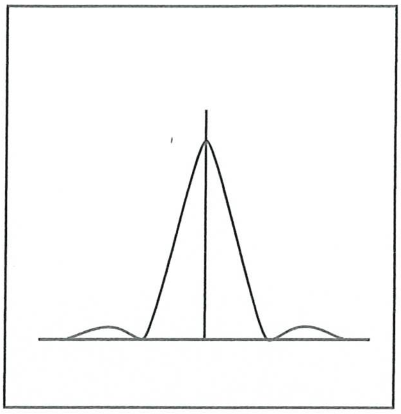
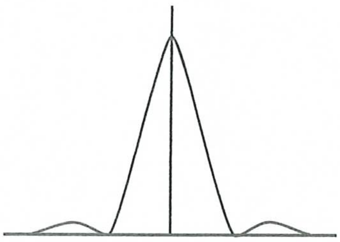


Figure 2b

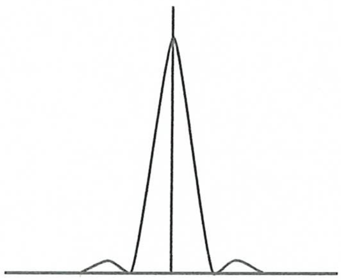
Question 6

Which one of the intensity patterns **(A–D)** below best indicates the pattern that would be seen if a wider slit was used?

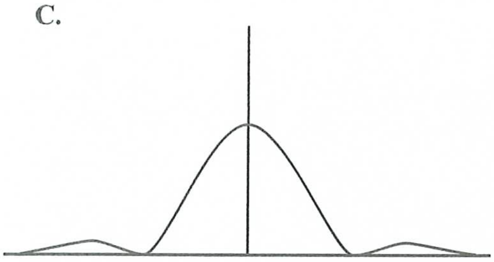
A.



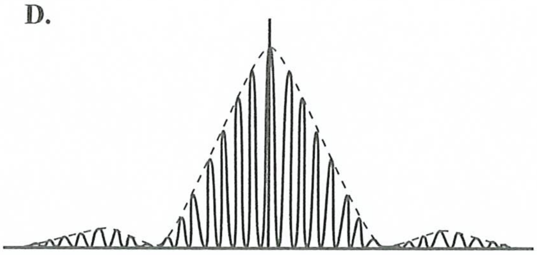
B.



C.



D.



B

Wider slit produce narrower pattern

47%

2 marks

Figure 5a shows part of the emission spectrum of hydrogen in more detail.

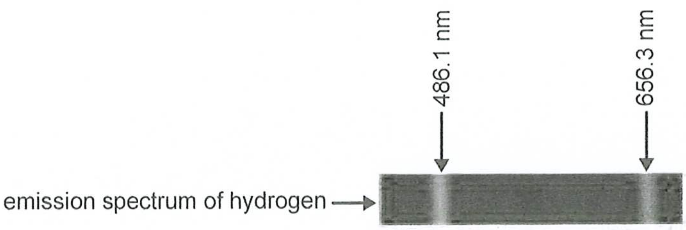


Figure 5a

With a spectroscope, Val examines the spectrum of light from the sun. The spectrum is continuous, with colours ranging from red to violet. However there were black lines in the spectrum, as shown in Figure 5b.

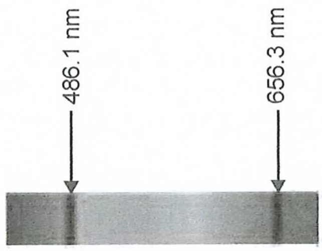


Figure 5b

Question 9

Explain why these dark lines are present in the spectrum from the sun.

The dark lines indicate presence of hydrogen. When continues spectrum of light passing through hydrogen gas photons with energies corresponding to the difference between energy levels of hydrogen are absorbed creating dark lines.

3 marks

14%

Use the following information to answer Questions 3–5.

A group of students is studying Young's double slit experiment using microwaves (λ = 3.0 cm) instead of light.

A microwave detector is moved along the line PQ, and the maxima and minima in microwave intensity are recorded.

The experimental apparatus is shown in Figure 1.

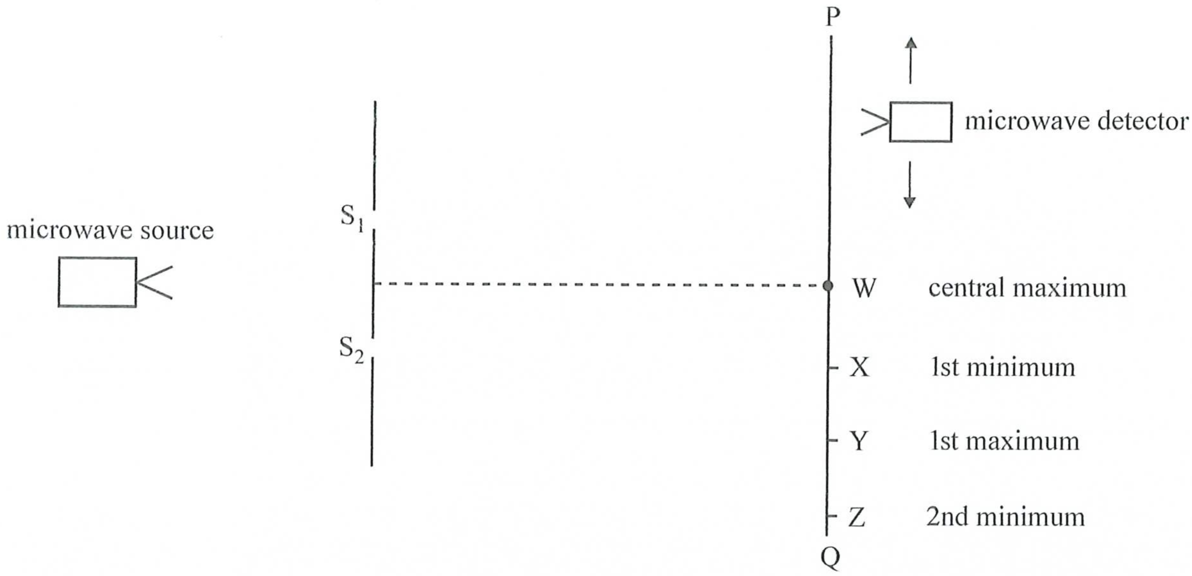


Figure 1

Question 4

Explain why there is a maximum in microwave intensity detected at point Y.

At Y path difference is 1 wavelength

so constructive interference take place

2 marks

20%

Area of study 2 – Interactions of light and matter

Question 1

At the time of Young's double-slit experiment there were two competing models of the nature of light.

Explain how Young's experiment supported one of these models compared with the other.

Bright and dark bands on the screen demonstrate constructive and destructive interference which are exclusive features of waves. Particle model can not explain the interference effect.
So Young's experiment support wave model.

3 marks

39%

Question 2

Einstein's explanation of the photoelectric effect reopened the question about the nature of light.

Explain briefly how the results of the photoelectric effect experiment supported a competing model to the one supported by Young's experiment.

The photoelectric effect supports the particle model of light as it shows threshold (minimum) frequency (energy) for electrons to be emitted, energy of the emitted electrons depends on frequency and independent from intencity of the incident light, the emission of electrons start immidiately (without time delay) or never. None of this can be explained by wave model and all are explained by particle model

3 marks

38%

The following information relates to Questions 3 and 4.

Louise and Thelma set up the apparatus shown in Figure 1. It consists of a laser providing light of a single wavelength, which passes through two narrow slits and produces a pattern of bright and dark bands on a screen some distance away.

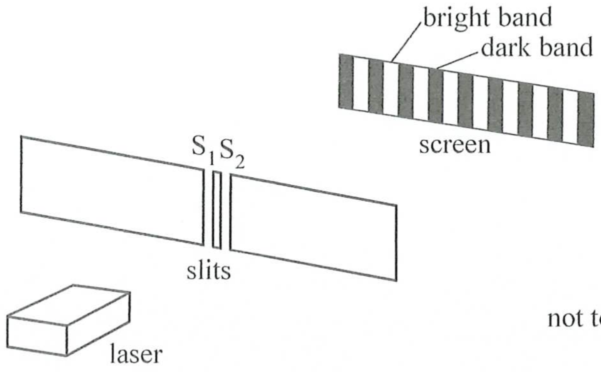


Figure 1

Question 3

Before doing the experiment, Louise believes that the central band (the one exactly opposite the centre point between the two slits) is a dark band. Thelma believes that this is a bright band.

Who is correct? Outline your reasoning clearly.

Thelma is correct. As the path difference to the centre point equal to zero there will be constructive interference producing bright band.

3 marks

40 %

The following information relates to Questions 5–7.

The photoelectric effect occurs when photons falling on a metal surface cause the emission of electrons. Einstein's equation for the photoelectric effect can be written as follows.

$$E_{K\,max} = hf - W$$

Kristy and Adrian have set up an experiment to study the energy of photoelectrons emitted from a potassium plate. Their apparatus consists of

- a light source
- a set of filters, each of which allows through only one wavelength
- an evacuated tube containing a potassium plate onto which the light falls, and a collector electrode.

A variable DC source allows a voltage (stopping voltage) to be applied between the potassium plate and the collector electrode. A voltmeter (V_s) measures this voltage, and a microammeter (A) reads the current.

Their apparatus is shown in Figure 3.

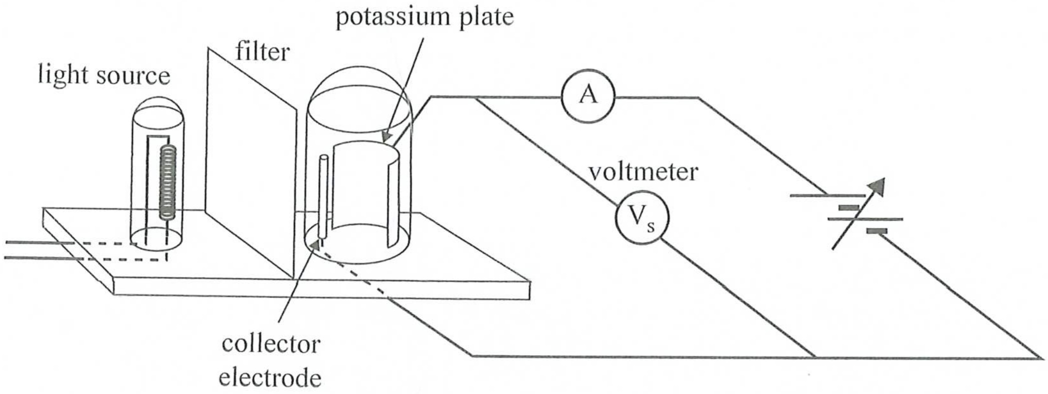


Figure 3

Question 5

Explain **in words** the physical meaning of the terms $E_{K\,max}$, f, and W in the equation above. Your explanation must show how each term relates to the experiment in Figure 3.

$E_{K\,max}$

Maximum kinetic energy of emitted electrons

f

Frequency of the incident light after passing through the filter.

W

Work function – minimum energy required to emit electron

3 marks

21%

Area of study 2 – Interactions of light and matter

Question 1

Over the last few centuries, scientists have proposed two conflicting models to explain the nature of light.

- the wave model
- the particle model

Name a historical experiment that supports the wave model rather than the particle model. Explain how the experiment supports the wave model rather than the particle model.

young's double slit experiment.
It demonstrate interference pattern which is a wave fenomena. Particle model ~~wi~~ predicted 2 bright bands on the screen behind slits

3 marks

39%

The photoelectric effect experiment supports the particle model of light rather than the wave model of light.

The following are observed in a photoelectric effect experiment.

Observation 1: The number of emitted electrons (the photocurrent) depends on the intensity of the incident light.

Observation 2: The energy of emitted electrons depends only on the frequency of the incident light and is independent of the intensity.

Observation 3: The energy of the emitted electrons depends on the metal surface involved.

The particle model can account for all the above three observations.

The wave model can explain two of these observations but not a third.

Question 2

Select the observation that the wave model **cannot** explain.

Explain how the particle model satisfactorily explains this observation.

Observation number 2

Observation 2 cannot be explained by the wave model. According to the particle model energy of incident fotons depends on frequency. $E = hf$ Changing intensity of the light increases number of photons but not their energy. As one photon interacts with one electron, energy of the emitted electrons depends on frequency. The number of emitted electrons depends on intensity (number of photons).

3 marks

10%

The following information relates to Questions 5 and 6.

Students set up the following apparatus as shown in Figure 2 to study the photoelectric effect.

They have a number of photocells with different metal plates in them.

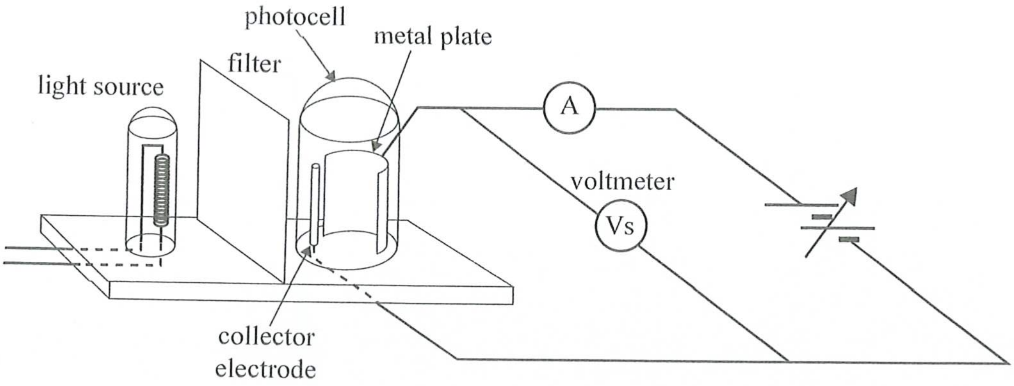


Figure 2

With a selenium plate in place, and using their data, the students draw the graph of maximum kinetic energy of photoelectrons versus frequency of light incident on the selenium plate. This is shown in Figure 3.

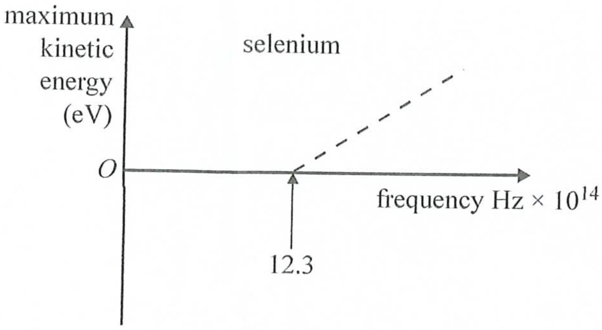


Figure 3

The students now use a photocell with a magnesium plate.

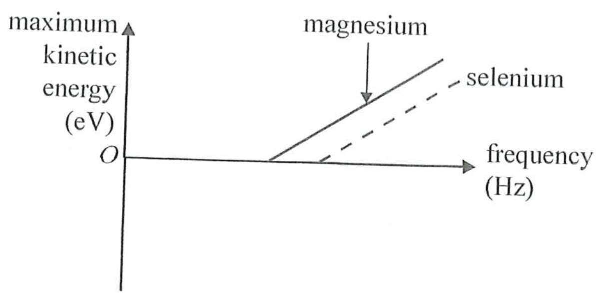
The work function of magnesium (3.7 eV) metal is less than that of selenium (5.1 eV).

The dotted line on each graph shows the original graph for selenium.

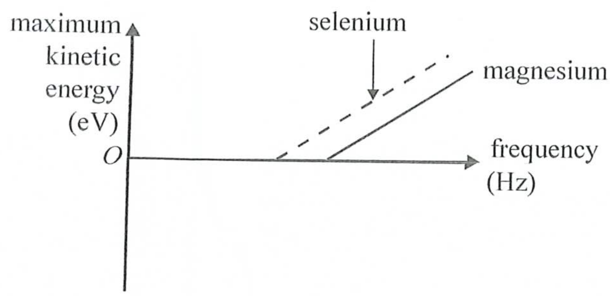
Question 6

Which one of the following graphs will now show their results? Explain your answer.

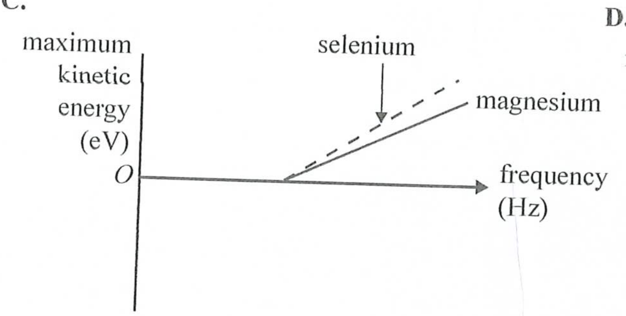
A.



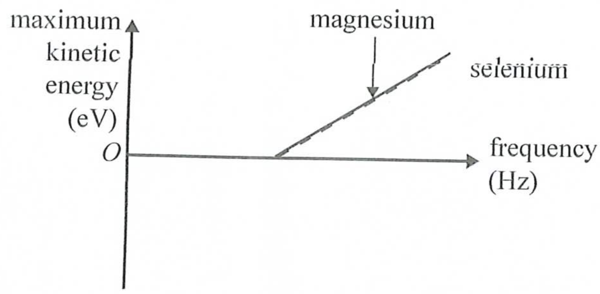
B.



C.



D.



A

Gradient has to be the same as it is equal to Plank's constant. As work function of magnesium is lover, the y-intercept will be higher or threshold frequency will be lower

3 marks

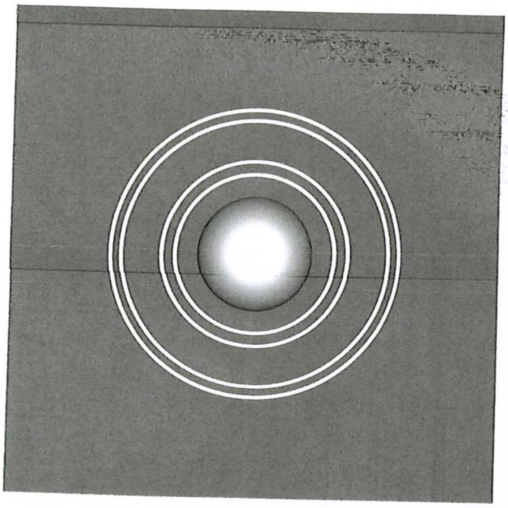
50%

Question 8

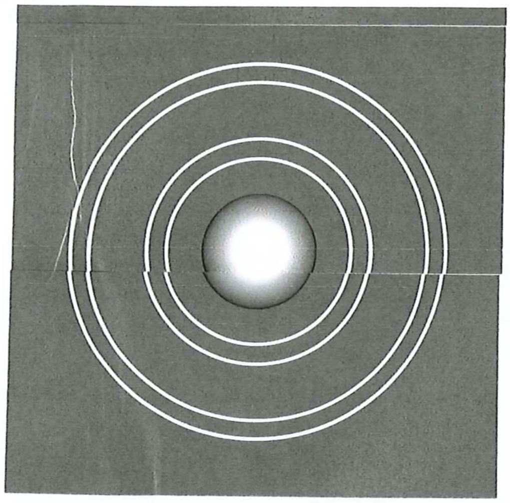
The students now increase the accelerating voltage and hence the speed of the electrons.

Which one of the options below now best shows the pattern they will observe on the screen?

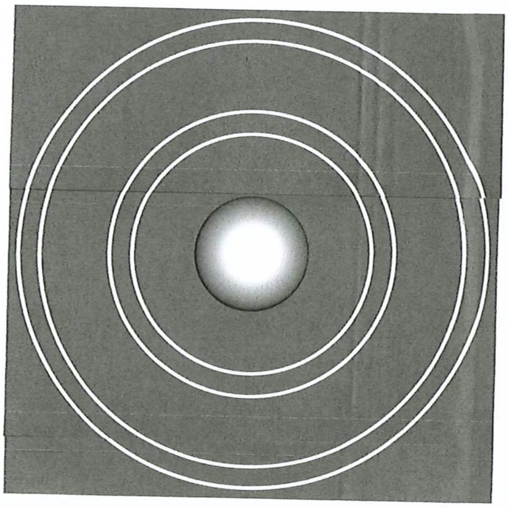
Explain your answer.



option A



option B (identical to original pattern)



option C

A

Higher speed results in higher momentum which decreases wavelength of electrons. $\lambda = \frac{h}{p}$ Smaller wavelength results in less diffraction.

36%

2 marks

Figure 5a shows the diffraction with electrons of 600 eV. The students now replace the electron gun with an X-ray source. Then they observe the pattern shown in Figure 5b below.

Figures 5a and 5b are drawn to the same scale.

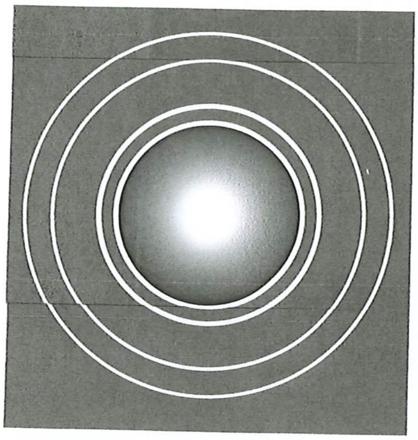


Figure 5a

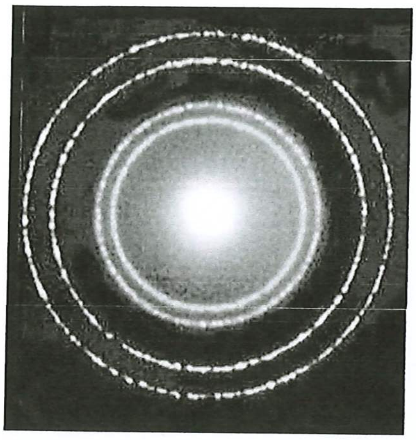


Figure 5b

Question 9

Explain why the electrons and the X-rays produce a very similar pattern.

Diffraction determined by wavelength. Same diffraction pattern means they have same wavelength and momentum.

2 marks

56%