Multiple choice questions

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.

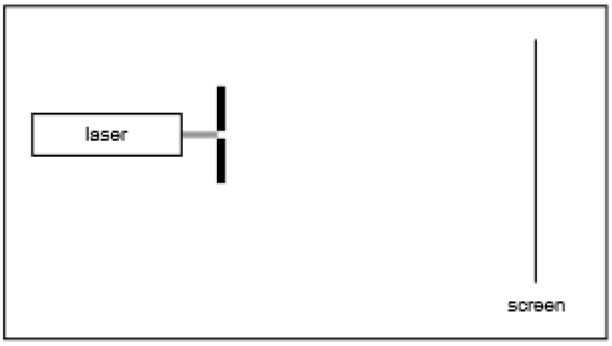


Figure 2a

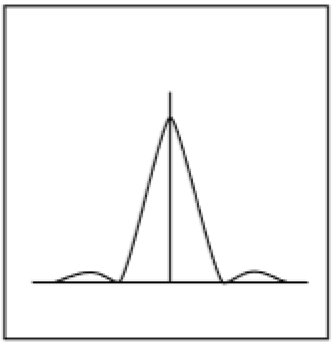
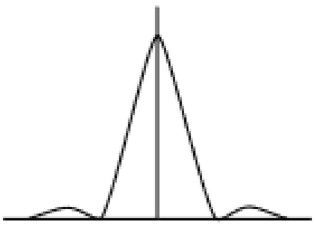


Figure 2b

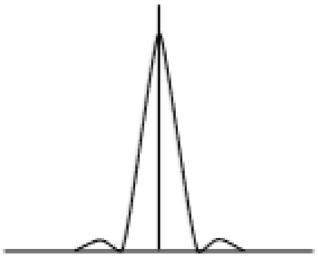
Example 1 2007 Question 6, 2 marks

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

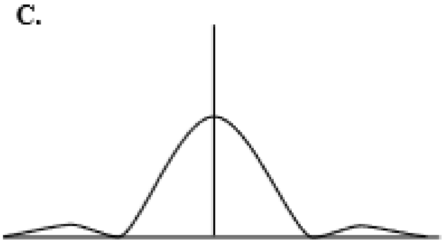
A.



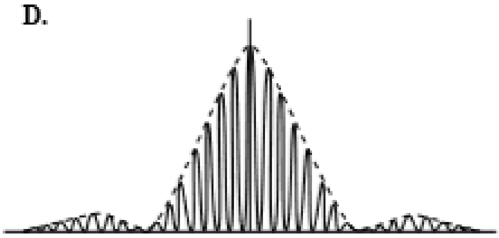
B.



C.



D.



Example 2 2005 Question 8, 2 marks

Light sometimes behaves as a particle and sometimes as a wave. Which **one or more** of the following properties does light sometimes show?

A. mass
B. momentum
C. charge
D. energy

Figure 3a is the image obtained by scattering electrons off a collection of many small crystals with random orientation. Figure 3b, reproduced to the same scale, is the diffraction image obtained with the scattering of X-rays rather than electrons. The X-rays have a wavelength of 35 pm.

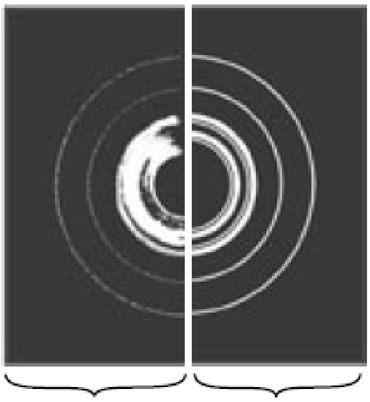
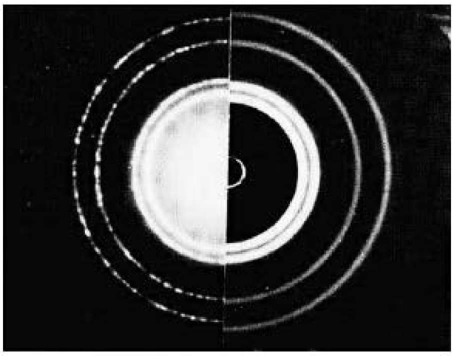


Figure 3a Figure 3b

Example 3 2004 Question 7, 2 marks

The scattering of electrons and X-rays produces similar diffraction patterns.
Which one of the following best explains why this occurs?

A. they have the same wavelength
B. they have the same frequency
C. they have the same speed
D. they have the same energy



electrons X-rays

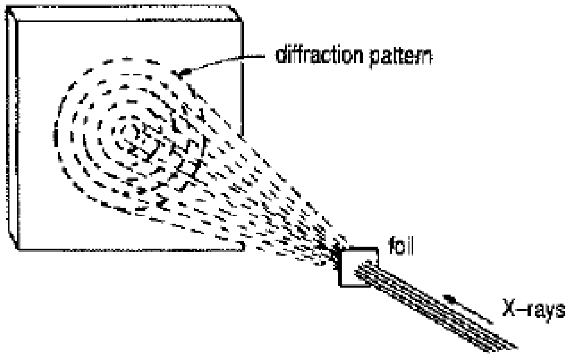
The figure above shows a picture of diffraction of X-rays and electrons through aluminium foil. The picture has been made by combining an X-ray diffraction pattern (on the right) with an electron diffraction pattern (on the left). The pictures are to the same scale and the X-rays have a photon energy of 70 keV.

Example 4 2002 Question 4, 2 marks

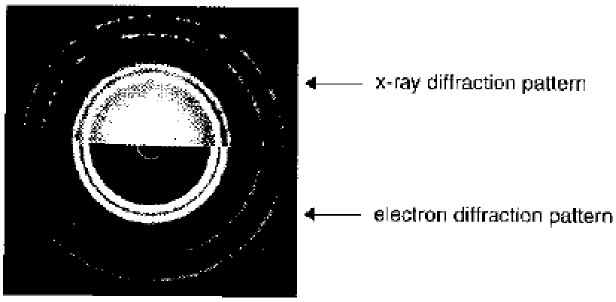
Which of the statements **(A – D)** best explains why it is possible to compare X-ray and electron diffraction patterns?

A. X-rays can exhibit particle-like properties.
B. Electrons can exhibit wave-like properties.
C. Electrons are a form of high energy X-rays.
D. Both electrons and X-rays ionise matter.

In early experiments the properties of X-rays were investigated by firing them at a thin aluminium foil. The foil consisted of many randomly arranged microscopic crystals of aluminium. X-rays passing through the foil were diffracted to form distinct rings centred on the X-ray axis. The experimental arrangement is illustrated below.



In 1928 George Thomson fired **electrons** at a similar aluminium foil, and obtained a similar diffraction pattern. The figure below shows both an X-ray diffraction pattern (the upper half of the figure), and a diffraction pattern obtained using electrons (the lower half of the figure). Both were obtained with an aluminium foil.



Example 5 1995 Question 6, 1 mark

Which one of the following statements best explains why electrons and X-rays can produce similar patterns when passed through aluminium foil?

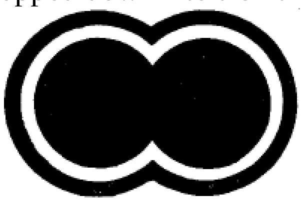
A. Both X-rays and electrons exhibit particle-like properties when they pass through the foil.

B. Both X-rays and electrons exhibit wave-like properties when they pass through the foil.

C. X-rays are very fast electrons.

D. The beams of X-rays and electrons both produce shadows of the structure of the foil.

Two point sources of white light, close together, are photographed with a camera " stopped down " to a small aperture. The diagram represents the film negative,



Example 6 1972 Question 60, 1 mark

Which one or more of the following modifications would increase the resolution of the images?

A. move the camera further away from the point sources

B. use a blue filter over the camera lens when taking the photograph

C. use a larger aperture in the camera lens

D. increase the brightness of the point sources

Short answer questions

Electrons of mass 9.1×10^{-31} kg emerge from an electron gun with a speed of 2.0×10^{7} m s^{-1}.

Example 7 2008 Question 9, 2 marks

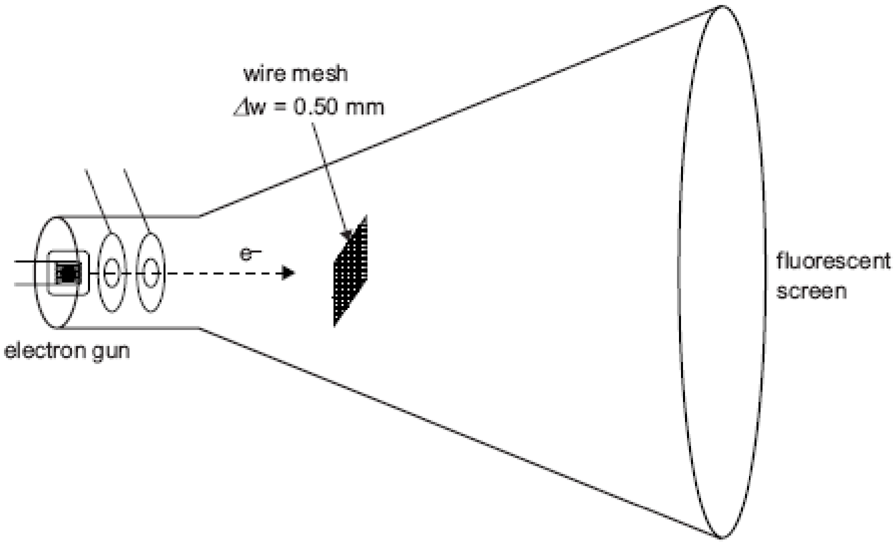
What is the de Broglie wavelength of the electrons in nm?
Show working.

Neutrons are subatomic particles and, like electrons, can exhibit both particle-like and wave-like behaviour. A nuclear reactor can be used to produce a beam of neutrons, which can then be used in experiments.
The neutron has a mass of 1.67×10^{-27} kg.
The neutrons have a de Broglie wavelength of 2.0×10^{-10} m.

Example 8 2007 Question 4, 2 marks

Calculate the speed of the neutrons.

A sketch of a cathode ray tube (CRT) is shown below.
In this device, electrons of mass 9.10×10^{-31} kg are accelerated to a velocity of 2.0×10^{7} m s^{-1}.
A fine wire mesh in which the gap between the wires is w = 0.50 mm has been placed in the path of the electrons, and the pattern produced is observed on the fluorescent screen.
Planck's constant: $h = 6.63 \times 10^{-34}$ J s



Example 9 2005 Question 6, 3 marks
Calculate the de Broglie wavelength of the electrons. You must show your working.

Example 10 2005 Question 7, 2 marks
Explain, with reasons, whether or not the students would observe an electron diffraction pattern on the fluorescent screen due to the presence of the mesh.

Figure 3a is the image obtained by scattering electrons off a collection of many small crystals with random orientation. Figure 3b, reproduced to the same scale, is the diffraction image obtained with the scattering of X-rays rather than electrons. The X-rays have a wavelength of 35 pm.

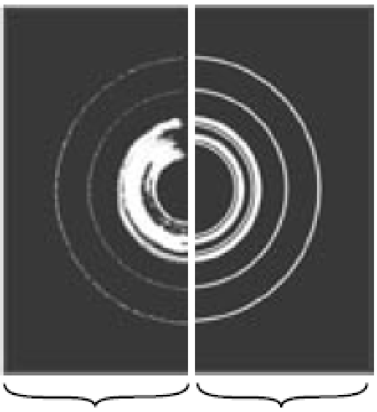
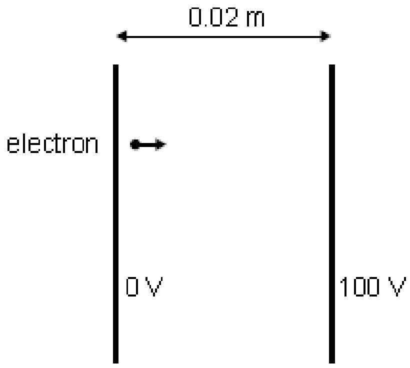


Figure 3a Figure 3b

Example 11 2004 Question 8, 3 marks

Calculate the momentum of the electrons above. Make sure you include units in your answer.

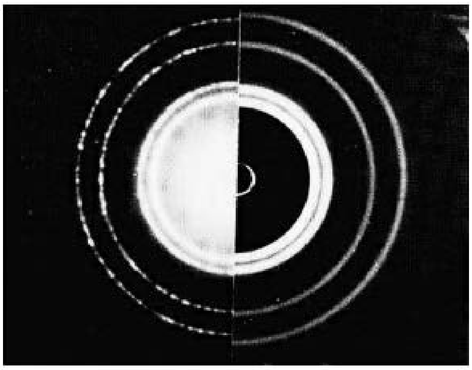
An electron is accelerated from rest between two parallel charged plates in a vacuum with a potential difference of 100 V as shown below. The plates are separated by a distance of 0.02 m.



Example 12 2004 Question 4, 2 marks
Calculate the electric field strength between the parallel plates, (in Vm^{-1}).

Example 13 2004 Question 5, 4 marks
Calculate the de Broglie wavelength of the electron just before it hits the positive plate.

Example 14 2003 Question 3, 4 marks
An electron gun accelerates electrons across a potential difference of 2500 V. The initial speed of the electrons can be considered to be almost zero.
Show that the final speed of the electrons is approximately 10% of the speed of light.



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Example 15 2002 Question 1, 2 marks

Calculate the wavelength of the 70 keV X-rays.

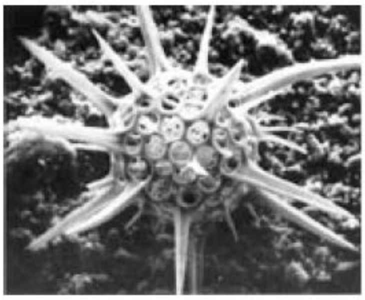
Example 16 2002 Question 2, 2 marks

What is the de Broglie wavelength of the electrons?

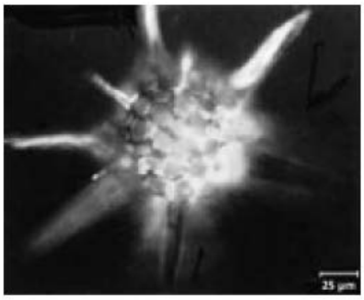
Example 17 2002 Question 3, 4 marks

Calculate the kinetic energy of the electrons in keV.

The two images below show a radiolarian, a unicellular organism, taken with an electron microscope and an optical microscope. The electron microscope gives a clearer image than the optical microscope.



radiolarian, electron microscope



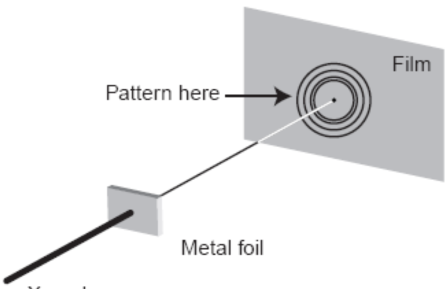
radiolarian, optical microscope

Example 18 2001 Question 3, 3 marks

Explain why the electron microscope gives a clearer image than the optical microscope.

Example 19 2000 Question 7, 2 marks

When a beam of X-rays of a single wavelength passes through a metal foil, a pattern of rings is detected by photographic film.



Explain how the X-rays produce this pattern of rings.

Example 20 1999 Question 5, 2 marks

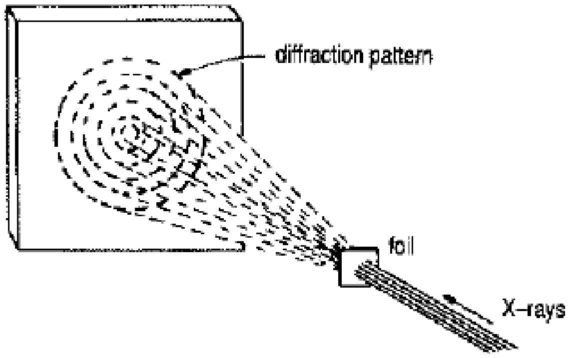
Electrons of kinetic energy 54 eV are used to investigate the spacing of atoms in a nickel crystal. These electrons have a de Broglie wavelength of 1.67×10^{-10} m and the atomic spacing in the nickel crystal is 2.15×10^{-10} m.

Calculate the momentum of a 54 eV electron. ($h = 6.63 \times 10^{-34}$ J s)

Example 21 1999 Question 6, 3 marks

Discuss why electrons of de Broglie wavelength of 1.67×10^{-10} m can be used for this experiment, rather than visible light of wavelength 400 nm (400×10^{-9} m).

In early experiments the properties of X-rays were investigated by firing them at a thin aluminium foil. The foil consisted of many randomly arranged microscopic crystals of aluminium. X-rays passing through the foil were diffracted to form distinct rings centred on the X-ray axis. The experimental arrangement is illustrated below.



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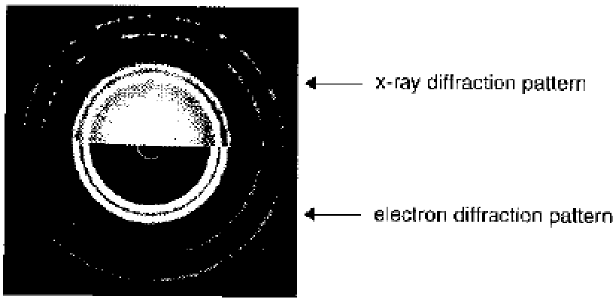


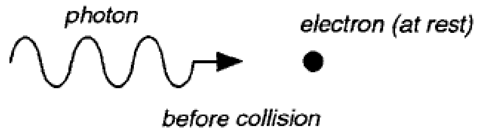
The X-ray photons had an energy of 2.38×10^{-16} J, and a momentum of 7.94×10^{-25} kg m s^{-1}.

Example 22 1995 Question 4, 1 mark

What was the wavelength of the X-rays used in this experiment?

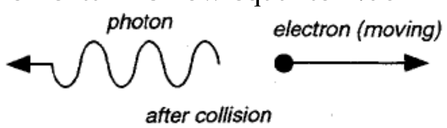
Example 23 1995 Question 5, 2 marks

The electron and X-ray diffraction patterns have the same spacing between rings. Did the electrons which produced the pattern have the same **energy** as the X-ray photons used, or the same **momentum** as the X-ray photons? Explain.



Example 24 1993 Question 4, 1 mark
Calculate the magnitude of the momentum of the photon before the collision.

After the collision, the photon returns along its original path, as shown. The electron momentum is now equal to 2.06 x 10^{-23} kg m s^{-1}.



Example 25 1993 Question 5, 1 mark
What is the de Broglie wavelength of the electron after the collision?

Example 26 1993 Question 6, 1 mark
Is the wavelength of the photon now greater or less than it was before the collision? Give reasons for your answer.

Example 27
You measure the speed of an electron to be 2.05×10^{6} m s^{-1}, which is known with a precision of 0.50%. What is the minimum uncertainty with which you can measure the position of the electron.

Example 28
Imagine playing baseball in a universe (not ours) where Planck's constant is 0.60 J s. What would be the uncertainty in the position of a 0.50 kg baseball that is moving at 20 m s^{-1} along an axis if the uncertainty of the speed is 1 m s^{1}.

Example 29
Repeat the previous example in our universe.