

Questions

Q1.

Answer the question with a cross in the box you think is correct ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.

A moving electron has a de Broglie wavelength of 656 nm.

Which of the following could be used to determine the speed of the electron?

- ☐ A $\frac{6.63 \times 10^{-34}}{(656 \times 10^{-9})(9.11 \times 10^{-31})}$
- ☐ B $\frac{(656 \times 10^{-9})(9.11 \times 10^{-31})}{6.63 \times 10^{-34}}$
- ☐ C $\frac{(656 \times 10^{-9})(6.63 \times 10^{-34})}{9.11 \times 10^{-31}}$
- ☐ D $\frac{9.11 \times 10^{-31}}{(656 \times 10^{-9})(6.63 \times 10^{-34})}$

(Total for question = 1 mark)

Q2.

Electromagnetic radiation can be described in terms of a photon model.

Which of the following demonstrates the photon model of light?

- ☐ A diffraction patterns
- ☐ B Huygens' construction
- ☐ C photoelectric effect
- ☐ D plane polarisation

(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

An electron has a velocity of $2 \times 10^7 \text{ m s}^{-1}$.

Which of the following expressions gives the de Broglie wavelength of the electron in metres?

☐ **A** $\frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 2 \times 10^7}$

☐ **B** $\frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 2 \times 10^7}$

☐ **C** $\frac{9.11 \times 10^{-31} \times 2 \times 10^7}{6.63 \times 10^{-34}}$

☐ **D** $\frac{1.67 \times 10^{-27} \times 2 \times 10^7}{6.63 \times 10^{-34}}$

(Total for question = 1 mark)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of the following has the largest de Broglie wavelength?

☐ **A** an electron travelling at $3.0 \times 10^5 \text{ m s}^{-1}$

☐ **B** an electron travelling at $4.0 \times 10^5 \text{ m s}^{-1}$

☐ **C** a neutron travelling at $3.0 \times 10^5 \text{ m s}^{-1}$

☐ **D** a neutron travelling at $4.0 \times 10^5 \text{ m s}^{-1}$

(Total for question = 1 mark)

Q5.

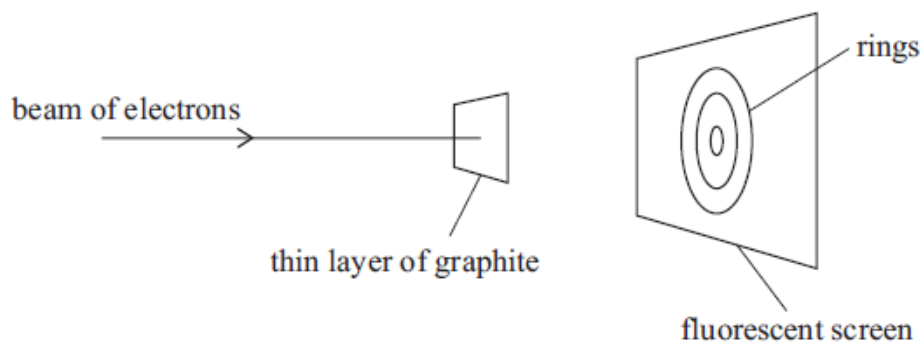
The evidence for the wave nature of electrons came from experiments involving

- ☐ **A** diffraction.
- ☐ **B** polarisation.
- ☐ **C** reflection.
- ☐ **D** refraction.

(Total for question = 1 mark)

Q6.

A beam of electrons passes through a thin layer of graphite. The electrons are then incident on a fluorescent screen, causing a series of rings to form, as shown.



Explain what the rings show about the nature of electrons.

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(Total for question = 2 marks)

Q7.

An electron is moving with velocity $3.6 \times 10^7 \text{ m s}^{-1}$.

Calculate the de Broglie wavelength of this electron.

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de Broglie wavelength =

(Total for question = 3 marks)

Q8.

A particle travelling at a speed of $9.89 \times 10^5 \text{ m s}^{-1}$ has a de Broglie wavelength of $7.37 \times 10^{-10} \text{ m}$.

Deduce whether this particle has a mass equal to the electron mass.

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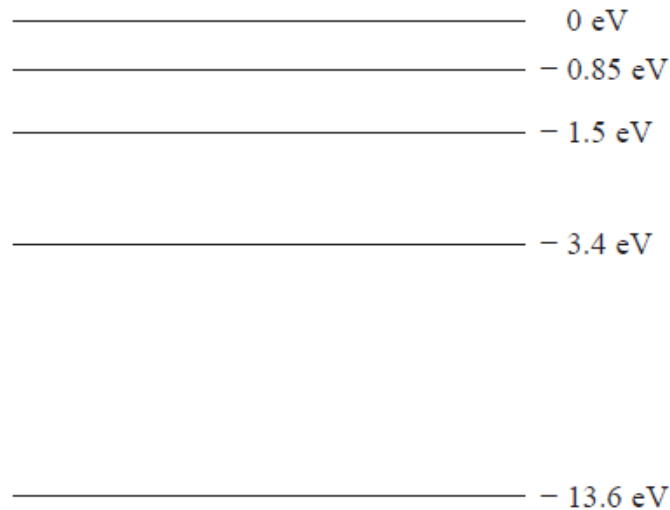
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(Total for question = 3 marks)

Q9.

The diagram shows some of the energy levels for an atom of hydrogen.



When an electron with a kinetic energy of 12.3 eV interacts with this atom, an electron in the atom moves from the -13.6 eV level to the -1.5 eV level.

When a photon with a photon energy of 12.3 eV is incident on this atom, the electron in the atom at the -13.6 eV level remains at the 13.6 eV level.

Explain these observations.

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(Total for question = 4 marks)

Q10.

An electron is accelerated from rest through a potential difference of 4.8 kV in a cathode ray tube.

(a) Show that the kinetic energy gained by the electron is about 7.7×10^{-16} J.

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(b) Calculate the de Broglie wavelength of the electron.

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de Broglie wavelength =

(Total for question = 5 marks)

Q11.

A fishing boat uses a pulse-echo technique to determine the depth of fish under the water surface.

The boat has a transducer which emits pulses of sound into the water and detects returning

pulses of sound.

(a) The transducer emits a pulse of sound and detects an echo from a fish after a time of 37 ms.

speed of sound in water = 1500 ms^{-1}

Calculate the distance between the transducer and the fish.

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Distance =

(b) After each pulse is emitted by the transducer, there is a fixed time T before the next pulse is emitted.

Explain how T affects the maximum distance at which a fish can be detected.

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(c) The transducer can emit pulses of sound waves of different frequency.

Explain how the frequency should be adjusted to improve the accuracy when detecting the location of a fish.

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(Total for question = 7 marks)

Q12.

Niels Bohr developed an early model of the atom where electrons could only exist in fixed orbits around a nucleus.

When an atom is ionised, an electron moves from its orbit around the nucleus to be free of the atom. Bohr derived an expression for the ionisation energy E , in joules, for a hydrogen atom:

$$\left(\frac{e^2}{kh}\right)^2 \times \frac{m}{8}$$

where

m = mass of electron

e = charge of electron

$k = 8.85 \times 10^{-12} \text{ C V}^{-1} \text{ m}^{-1}$

h = Planck constant

(a) Calculate E for a hydrogen atom, in eV.

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$E = \dots\dots\dots \text{ eV}$

(b) The Bohr model can also be used to predict an approximate radius for an atom. The equation for the radius r of the hydrogen atom is:

$$r = \frac{h^2 k}{\pi m e^2}$$

where

m = mass of electron

A student suggests that, for a speed of $1.4 \times 10^7 \text{ m s}^{-1}$, neutrons would have a wavelength similar to the radius of a hydrogen atom.

Determine whether the student is correct.

mass of neutron = $1.67 \times 10^{-27} \text{ kg}$

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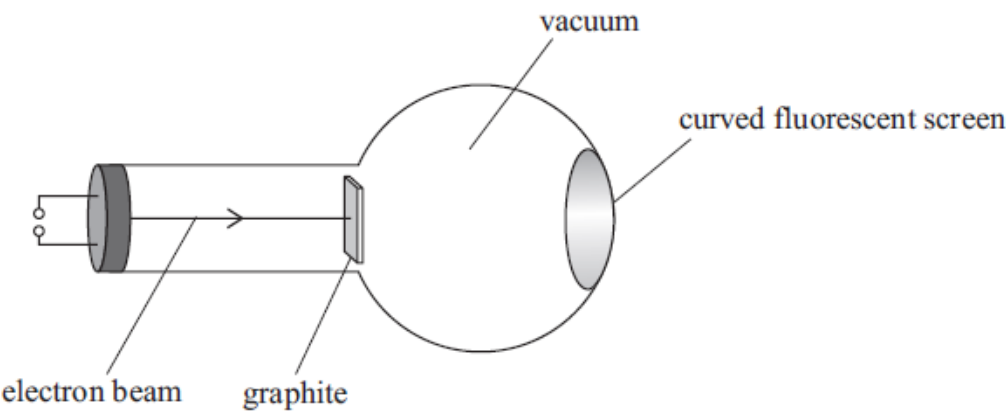
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(Total for question = 8 marks)

Q13.

The diagram shows apparatus used to demonstrate the diffraction of an electron beam in a school laboratory.



A beam of electrons is accelerated by a high potential difference towards a piece of graphite. The graphite diffracts the electron beam, producing a diffraction pattern on the fluorescent screen.

(a) State what is meant by diffraction.

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(b) An electron is accelerated through a potential difference of 4.9 kV.

(i) Show that the de Broglie wavelength for the electron is about 1.8×10^{-11} m.

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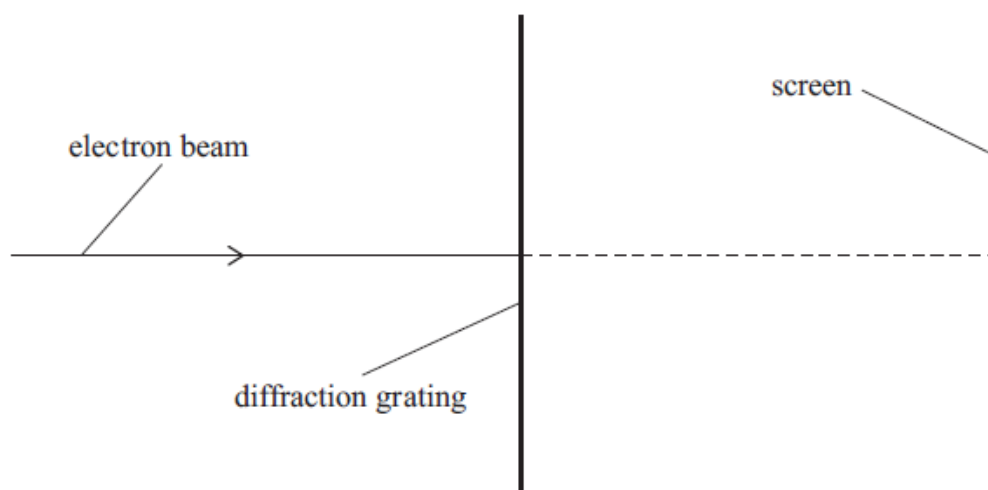
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(ii) A student suggests that the beam of electrons would produce a diffraction pattern if a diffraction grating with 5000 lines per cm was used.



Deduce whether a second order maximum would be clearly visible on a screen. The screen is placed about a metre away from the grating.

$$\lambda = 1.8 \times 10^{-11} \text{ m}$$

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(Total for question = 9 marks)

Q14.

A 'smart meter' collects information about the use of electricity in the home. This information is transmitted to the electricity company using radio waves.

- (a) A typical smart meter emits radio waves with a power output of 1.00 W.
An intensity of radiation greater than 4.5 W m^{-2} is dangerous to people.

A person stands 25 cm from a smart meter.

Deduce whether the radiation emitted by this smart meter would be dangerous to the person at this distance.

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- (b) It is suggested that the energy per photon could be important in determining if the radiation emitted by the smart meter is dangerous.

The smart meter transmits radio waves of frequency 902 MHz.

Calculate the energy per photon, in eV, of the photons emitted by the smart meter.

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Energy per photon = eV

(c) The display of the smart meter in one household is shown. This shows the total electrical energy used in one day.



1 kW h is a unit of energy equivalent to 1 kW of power used for 1 hour.

The kettle in this house has a power of 1200 W. The kettle takes 125 seconds to heat the water to boiling. The kettle then switches off.

A student suggests that boiling the kettle once uses less than 1% of the total energy shown on the smart meter display.

Assess the student's suggestion.

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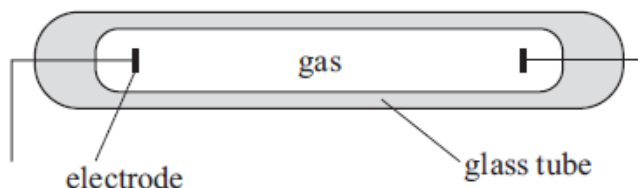
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(Total for question = 9 marks)

Q15.

In the second half of the 19th century, scientists began to investigate interactions between photons and electrons.

(a) A discharge tube is a glass tube containing gas, as shown.



When the discharge tube is connected into an electrical circuit, the gas atoms emit photons. The photons have specific frequencies.

(i) One of the emitted photons has an energy of $3.44 \times 10^{-19} \text{ J}$.

Calculate the frequency of this photon.

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Frequency of photon =

*(ii) The electrical circuit applies a large potential difference (p.d.) across the discharge tube.

Explain how the p.d. across the discharge tube causes photons to be emitted by the gas atoms.

(6)

This image shows a full page of white paper with horizontal dashed lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

(b) Photons with energy 4.75 eV are incident on a metal surface. These photons cause electrons to be emitted from the metal surface.

(i) Show that the maximum speed of the emitted electrons is about $5.3 \times 10^5 \text{ ms}^{-1}$.

work function of metal = $6.30 \times 10^{-19} \text{ J}$

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(ii) Calculate the de Broglie wavelength of electrons moving at $5.3 \times 10^5 \text{ ms}^{-1}$.

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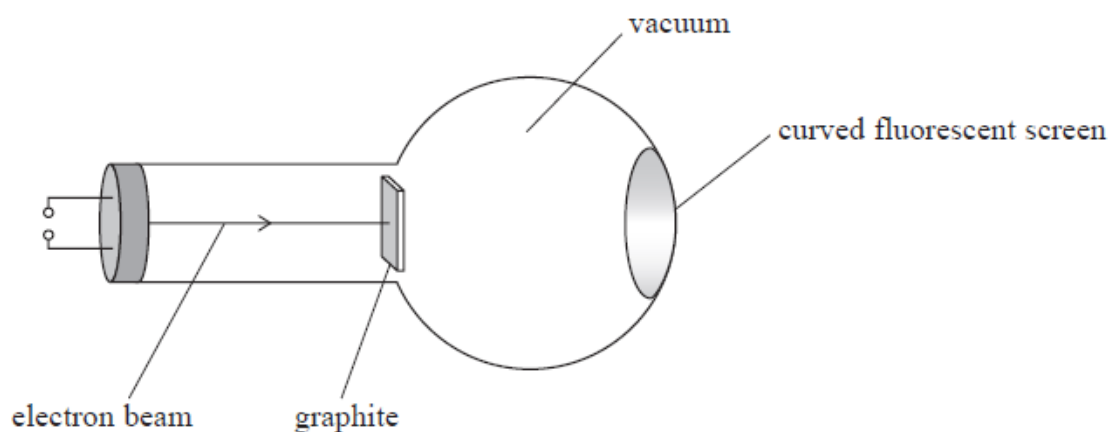
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de Broglie wavelength =

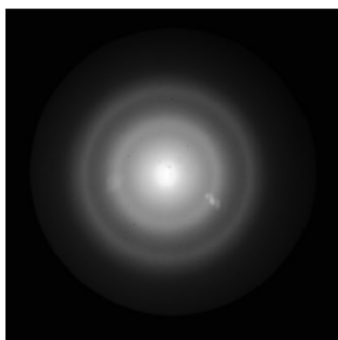
(Total for question = 13 marks)

Q16.

A teacher demonstrated the behaviour of electrons travelling through graphite. An electron beam was directed through a thin piece of graphite towards a fluorescent screen, as shown.



The electrons produced a pattern on the fluorescent screen as shown below.



(Source: © ANDREW LAMBERT PHOTOGRAPHY/SCIENCE PHOTO LIBRARY)

(a) This demonstration can be used to make conclusions about the behaviour of the electrons and the structure of the graphite.

State these conclusions.

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(b) The electrons were accelerated through a potential difference (p.d.) of 2400 V before interacting with the graphite.

(i) Show that the work done on each electron is about 4×10^{-16} J.

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(ii) Calculate the maximum velocity of the electrons.

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Maximum velocity =

(iii) The accelerating p.d. was then increased.

Explain how the pattern on the screen would change.

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(Total for question = 11 marks)

Q17.

Some types of glue can be hardened by exposure to ultraviolet (UV) light.

(a) One type of UV lamp contains mercury atoms in an evacuated glass tube. When a large potential difference is applied between two electrodes in the tube, electrons move between the two electrodes. These electrons collide with the mercury atoms in the tube.

These mercury atoms then emit photons.

Explain why the mercury atoms emit photons.

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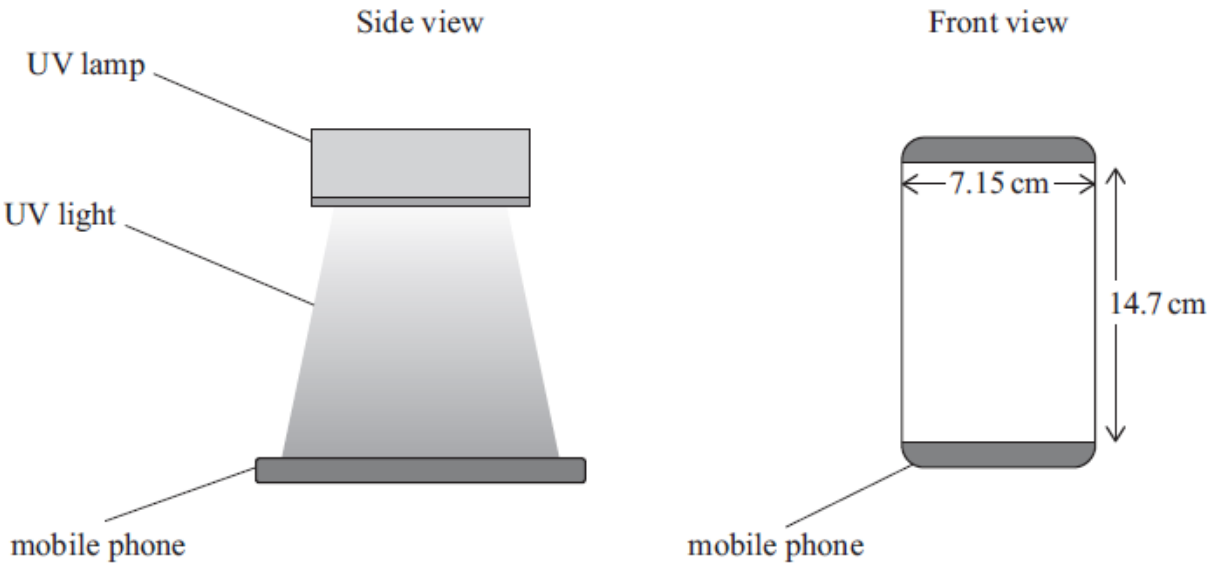
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(b) A technician is replacing the screen on a mobile phone. He spreads a layer of glue over the phone surface and attaches the glass screen. The glue is then hardened when exposed to UV light.

The equipment used and screen dimensions are as shown in the following diagram.



The intensity of the UV light received on the screen is 50 mW cm^{-2} .

The glue takes 25 s to harden.

(i) Show that the total energy incident on the glass screen during this time is about 130 J.

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(ii) Determine the number of photons incident on the glass screen in this time.

wavelength of UV light = 395 nm

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Number of photons =

(c) The potential difference applied between the electrodes in the UV lamp is increased.

Explain the effect this would have on the frequency of the UV light produced by the lamp.

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(d) Suggest why the hardening time of the glue is reduced if the UV lamp is moved closer to the mobile phone screen.

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(Total for question = 14 marks)

