Access Tuition

A-Level Physics

Wave Particle Duality

Question Paper

Time available: 44 minutes
Marks available: 36 marks

1. (a) State de Broglie's hypothesis.

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(2)

(b) Neutrons in a narrow beam can be diffracted by crystals thereby exhibiting wave behaviour. Calculate the de Broglie wavelength of a neutron of kinetic energy 0.021 eV. Give your answer to an appropriate number of significant figures.

de Broglie wavelength ____________________ m

(4)

(c) Explain why an electron of the same de Broglie wavelength as the neutron in part (b) has much more kinetic energy than 0.021 eV. Assume relativistic effects are negligible.

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(2)

(Total 8 marks)

2. (a) Light has a dual wave-particle nature. State and outline a piece of evidence for the wave nature of light and a piece of evidence for its particle nature. For each piece of evidence, outline a characteristic feature that has been observed or measured and give a short explanation of its relevance to your answer. Details of experiments are not required.

The quality of your written communication will be assessed in your answer.

(6)

(b) An electron is travelling at a speed of 0.890 c where c is the speed of light in free space.

(i) Show that the electron has a de Broglie wavelength of 1.24×10^{-12} m.

(2)

(ii) Calculate the energy of a photon of wavelength 1.24×10^{-12} m.

answer = ____________________ J

(1)

(iii) Calculate the kinetic energy of an electron with a de Broglie wavelength of 1.24×10^{-12} m.
Give your answer to an appropriate number of significant figures.

answer = ____________________ J

(2)

(Total 11 marks)

3. (a) Describe **one** piece of evidence that shows that matter has

(i) a wave-like nature,

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(ii) a particle-like nature.

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(3)

(b) For a proton of kinetic energy 5.0 MeV,

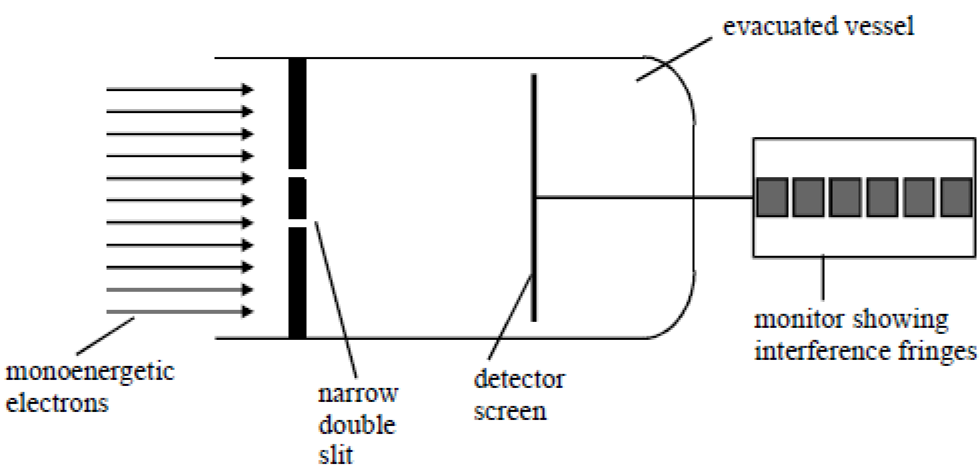
(i) show that its speed is 3.1×10^7 m s^{-1},

(ii) calculate its de Broglie wavelength.

(4)

(Total 7 marks)

4. A beam of electrons travelling at 1.2×10^3 m s^{-1} inside an evacuated container is directed normally onto a double slit arrangement, as shown in the diagram. An array of detectors forms a screen which collects the electrons that pass through the slits for a selected period of time. The number of electrons collected by the detectors is displayed as a fringe pattern on a monitor.



(a) (i) Show that the de Broglie wavelength of the incident electrons is 6.1×10^{-7} m. Ignore relativistic effects.

(ii) The monitor screen shows six bright fringes. Estimate the number of electrons that contribute to each bright fringe when the detector current is 4.8×10^{-13} A and the electrons are collected over a period of 1.0 m s.

(4)

(b) (i) The intensity of the incident electron beam is reduced to a level where only one electron is travelling through the slits at a time. The collection time is increased to allow the original number of electrons to be collected. Compare the pattern observed on the monitor screen with that originally observed.

(ii) The speed of the electrons in the beam is reduced to half by reducing the anode potential of the electron gun that produced the beam. Describe and explain how the pattern observed on the monitor screen would differ from that originally observed in part (a).

(4)

(c) The electrons are replaced with a source of monochromatic light and the detector screen is replaced with a light-sensitive detecting screen. Determine the frequency of light that would produce fringes with the same fringe spacing as those originally observed using electrons.

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(2)

(Total 10 marks)