5 **(a)** In 1965, Richard Feynman hypothesised that electrons could be used in the double slit experiment to demonstrate wave particle duality. This experiment has since been conducted and verified by physicists.

A simplified set-up of the experiment is shown in Fig. 5.1.

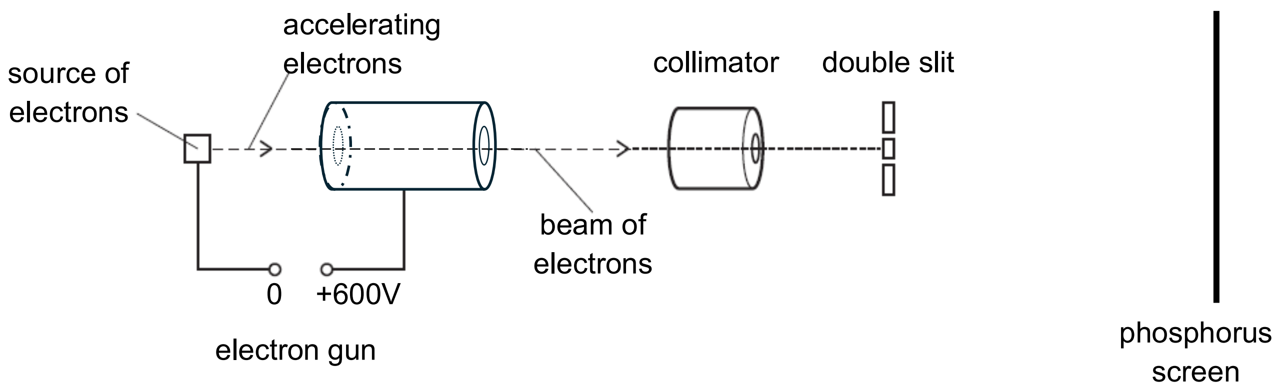

Fig. 5.1

An electron gun accelerates electrons in vacuum through a potential difference of 600 V. The collimator narrows the beam of electrons which then passes through the double slit.

The double slit only allows electrons to pass through one at a time, with each electron detected as a single bright spot on the phosphorus screen. The bright spots cumulate with time, showing a pattern formed on the screen as shown in Fig. 5.2.

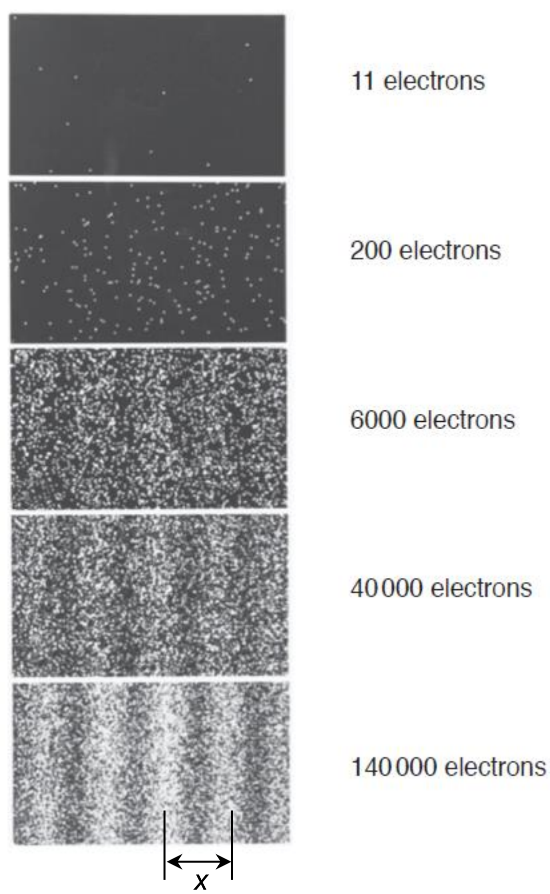

Fig. 5.2 (not to scale)

(i) Explain how the images in Fig. 5.2 show that electrons exhibit both particle-like and wave-like properties.

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................[2]

(ii) Calculate the de Broglie wavelength of the electrons reaching the double slit.

wavelength = ... m [3]

(iii) The double slit consists of two 50 nm wide slits with a separation of 280 nm. The distance from the double slit to the screen is 1.2 m.

Calculate the expected value of the centre-to-centre distance x shown in the last image of Fig. 5.2.

x = ... m [2]

(iv) In order for clear patterns to be formed, suggest why it is important for the electrons reaching the double slit to have velocities very close to a single value.

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................[1]

(b) In 1927, Werner Heisenberg proposed that we can only be clear about what is meant by the position of an object if we can specify experiments by which its position can be measured.

Heisenberg realised that a microscope using visible light would be useless for making a precise measurement of the position of something as small as an electron. He thought of using a 'gamma ray microscope', where gamma rays bounce off the electron and into a measuring device which can be used to determine the location of the electron.

(i) Explain why scattering light or gamma rays bouncing off an electron causes the electron to change its momentum.

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................[2]

(ii) By reference to how the momentum change of an electron depends on the wavelength of the electromagnetic radiation used to observe it, explain why using gamma rays could allow a more precise measurement of position to be made.

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................[2]

[Total: 12]