8 **(a)** State what is meant by the de Broglie wavelength.

....

.... [1]

(b) Calculate the de Broglie wavelength of an electron moving at a speed of $4.9 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

wavelength = ... m [2]

(c) State **one** similarity and **one** difference between an electron and a positron.

similarity: ....

....

difference: ....

....
[2]

(d) An electron moving at a speed of $4.9 \times 10^{7}\,\mathrm{m\,s^{-1}}$ collides with a positron that is travelling at the same speed in the opposite direction. As a result of the collision, two gamma-ray photons are produced.

(i) State the name of this type of reaction.

.... [1]

(ii) State what happens to the electron and to the positron.

....

....

.... [2]

(iii) Explain why two gamma-ray photons are produced, rather than just one.

....

.... [1]

(iv) Show that the kinetic energy of the electron before the collision is $1.1 \times 10^{-15}\,\mathrm{J}$.

[1]

(v) Use the information in **(d)(iv)** to determine, to three significant figures, the wavelength associated with the gamma radiation emitted in the collision.

wavelength = ... m [3]

[Total: 13]

9 **(a)** **(i)** Describe what is meant by wave–particle duality.

....

....

.... [2]

(ii) State the relationship between the de Broglie wavelength λ of a particle and its momentum p. State the meaning of any other symbols that you use.

....

.... [2]

(b) A narrow beam of electrons, all with the same speed, is incident normally on a carbon film. The electrons then move on to a fluorescent screen, as illustrated in Fig. 9.1.

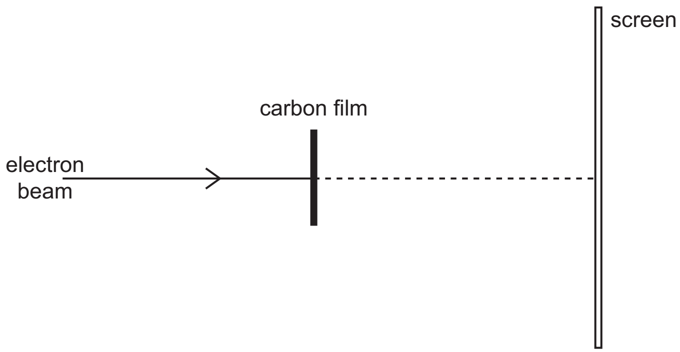

Fig. 9.1

The apparatus is in a vacuum.
The pattern produced on the screen is shown in Fig. 9.2.

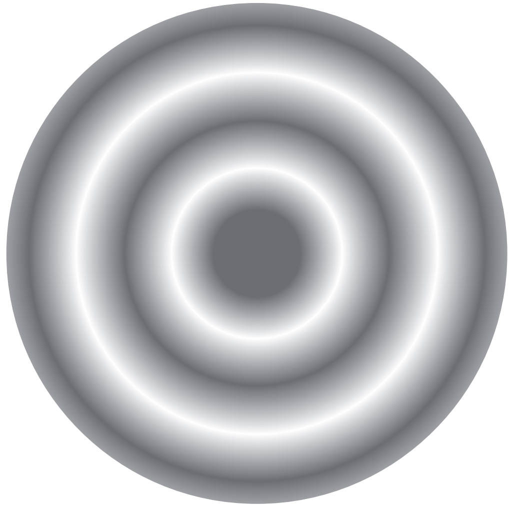

Fig. 9.2 (not to scale)

(i) Explain why the pattern in Fig. 9.2 provides experimental evidence to indicate a wave nature for the electrons.

....

....

.... [2]

(ii) The speed of the electrons is increased.

Suggest, with a reason, how this change affects the pattern observed on the screen.

....

....

.... [2]

[Total: 8]

9 Electrons in a vacuum are accelerated from rest through a potential difference (p.d.) V to form a beam. The electrons each have mass m and charge q.

The beam is incident on a graphite crystal that acts as a diffraction grating. After passing through the crystal, the beam reaches a fluorescent screen. An interference pattern is observed on this screen.

(a) Explain what this observation shows about the nature of electrons.

....

....

.... [1]

(b) Determine an expression, in terms of m, q and V, for the momentum p of an electron in the beam.

p = ... [3]

(c) The p.d. through which the electrons are accelerated is now increased to a greater value.

Describe and explain the effect of this change on the interference pattern observed.

....

....

.... [2]

(d) The electrons are now accelerated through different values of V, resulting in pairs of corresponding values for p and the de Broglie wavelength λ.

(i) On Fig. 9.1, sketch the variation of p with $\frac{1}{\lambda}$.

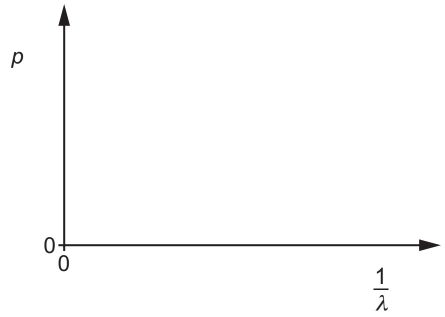

Fig. 9.1

[2]

(ii) State the name of the quantity represented by the gradient of the line in Fig. 9.1.

.... [1]

[Total: 9]