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]

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(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.

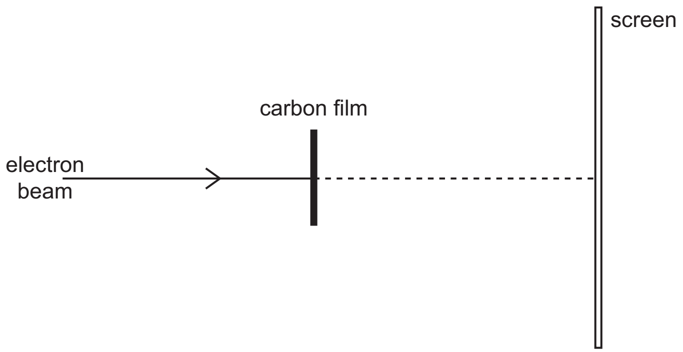

Fig. 9.1

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

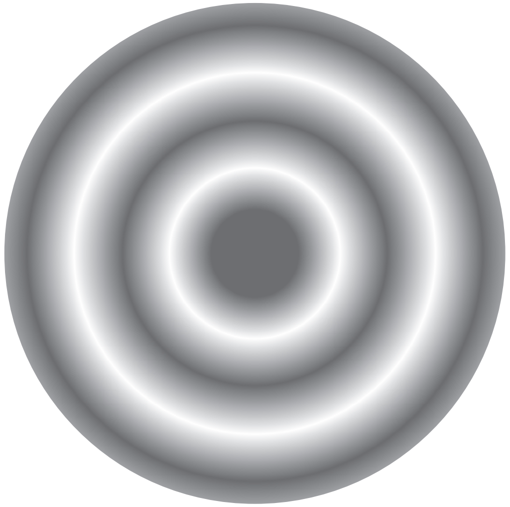

Fig. 9.2 (not to scale)

(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]