Solutions

Each answer shows the steps, then the **result**.

2.1

- the **photoelectric effect**

2.2

- **interference** (e.g. double-slit) or **diffraction**

2.3

- $\lambda = h/p$

2.4

- that **particles** (electrons) have a **wave nature**

3.1 B

- de Broglie: $\lambda = h/p$

3.2

- $\lambda = h/p$

$$\lambda = \frac{6.63 \times 10^{-34}\ \text{J s}}{4.5 \times 10^{-23}\ \text{kg m s}^{-1}} = \mathbf{1.5 \times 10^{-11}}\ \text{m}$$

3.3

- electrons fired at a crystal produce a pattern of **rings/maxima** on a screen
- this is a **diffraction** pattern, and **only waves diffract**
- so the electrons must have a **wave nature** (matching $\lambda = h/p$)

3.4

- matter and radiation show **both** wave-like behaviour (interference/diffraction)
- **and** particle-like behaviour (photons/photoelectric effect)

3.5

- $p = mv$

$$p = (9.1 \times 10^{-31}\ \text{kg})(4.9 \times 10^{7}\ \text{m s}^{-1}) = 4.5 \times 10^{-23}\ \text{kg m s}^{-1}$$

- $\lambda = h/p$

$$\lambda = \frac{6.63 \times 10^{-34}\ \text{J s}}{4.5 \times 10^{-23}\ \text{kg m s}^{-1}} = \mathbf{1.5 \times 10^{-11}}\ \text{m}$$

3.6

(a) the wavelength associated with a **moving particle**

- $\lambda = h/p$, where p is its momentum

(b) the work done by the accelerating p.d. becomes kinetic energy: $eV = \frac{1}{2}mv^2$

$$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times (1.60 \times 10^{-19}\ \text{C})(4800\ \text{V})}{9.11 \times 10^{-31}\ \text{kg}}} = \mathbf{4.1 \times 10^{7}}\ \text{m s}^{\mathbf{-1}}$$

(c) $\lambda = h/(mv)$

$$\lambda = \frac{6.63 \times 10^{-34}\ \text{J s}}{(9.11 \times 10^{-31}\ \text{kg})(4.11 \times 10^{7}\ \text{m s}^{-1})} = \mathbf{1.8 \times 10^{-11}}\ \text{m}$$

(d) the spacing between the graphite atoms is of the same order as this wavelength

- so the electrons are **diffracted** by the atomic planes and the diffracted waves **interfere** to give rings
- diffraction and interference are wave behaviours, so this shows that particles have a **wave nature**

(e) a larger p.d. gives the electrons more momentum, so $\lambda = h/p$ is **smaller**

- less diffraction means the rings move **closer together**