



ANSWER BOOK

Wave-particle duality

Quantum phenomena · Year 12

AQA 3.2.2.4 · CIE 22.3 · OCR A 4.5.3

10 questions · 30 marks

NAVY EDITION

SECTION A · Warm-up

- A1** Electron diffraction shows that electrons (particles) behave as waves; the photoelectric effect shows that light (a wave) behaves as particles (photons).
- A2** $\lambda = h/p = (6.63 \times 10^{-34}) / (2.0 \times 10^{-24}) = 3.32 \times 10^{-10} \text{ m}$. [2]
- A3** $\lambda = h/mv (= h/p)$, where λ is the de Broglie wavelength, h the Planck constant, m the mass, v the speed and p the momentum. [2]

SECTION B · Standard

- B1** $\lambda = h/mv = (6.63 \times 10^{-34}) / (9.11 \times 10^{-31} \times 1.0 \times 10^6) = 7.28 \times 10^{-10} \text{ m}$. [3]
- B2** $E_k = eV = 1.60 \times 10^{-17} \text{ J}$. (a) $v = \sqrt{(2E_k/m)} = 5.93 \times 10^6 \text{ m s}^{-1}$. (b) $\lambda = h/mv = 1.23 \times 10^{-10} \text{ m}$. [4]
- B3** Electron: $\lambda = h/mv = 7.28 \times 10^{-9} \text{ m}$. Proton: $\lambda = 3.97 \times 10^{-12} \text{ m}$. The electron's wavelength is larger, because it has the smaller mass.
- B4** Diffraction is a wave property, produced when a wave passes through gaps comparable to its wavelength (here the atomic spacing). Electrons producing a diffraction pattern therefore behave as waves, evidence for wave-particle duality. [3]

SECTION C · Stretch

- C1** $\lambda = h/mv = (6.63 \times 10^{-34}) / (0.16 \times 30) = 1.38 \times 10^{-34} \text{ m}$. This is far smaller than any gap the ball could pass through (and than the ball itself), so the spreading is utterly negligible and no diffraction is seen.
- C2** $p = h/\lambda = (6.63 \times 10^{-34}) / (1.0 \times 10^{-10}) = 6.63 \times 10^{-24} \text{ kg m s}^{-1}$. $E_k = p^2/2m = 2.41 \times 10^{-17} \text{ J}$. $V = E_k/e = 151 \text{ V}$. [4]
- C3** A higher speed means greater momentum, so from $\lambda = h/mv$ the de Broglie wavelength is shorter. With a shorter wavelength the electrons diffract less, so the rings of the pattern move closer together (the pattern shrinks). [3]