Exercise walk-through

Quantum Theory and Wave-Particle Duality ▪ 15.1

eXercise

You must be able to

- describe a **photon 光子** as a quantum of light with energy $E = hf$
- explain **wave-particle duality 波粒二象性**: light and matter show both behaviours
- relate a particle's momentum to its **de Broglie wavelength 德布罗意波长** $\lambda = h/p$

Method — The photon

Light is delivered in quanta called **photons**, each with energy $E = hf$, where $h = 6.63 \times 10^{-34}$ J s.

Method — Wave-particle duality

Light and matter each show **wave** behaviour (interference, diffraction) and **particle** behaviour (photons, collisions), depending on the experiment.

Method — De Broglie wavelength

Every particle has a wavelength $\lambda = \frac{h}{p}$.

Practice 2.1 ▪ 2 marks

Find the energy of a photon of frequency 6.0×10^{14} Hz ($h = 6.63 \times 10^{-34}$).

Solution 2.1

Method: The photon

Worked steps

$E = hf = (6.63 \times 10^{-34})(6.0 \times 10^{14}) = 4.0 \times 10^{-19}$ J M1 A1.

Practice 2.2 ▪ 1 mark

State the equation for the de Broglie wavelength.

Solution 2.2

Method: De Broglie wavelength

Worked steps

$\lambda = \dfrac{h}{p}$ B1.

Practice 2.3 ▪ 1 mark

State what “wave-particle duality” means.

Solution 2.3

Method: Wave-particle duality

Worked steps

that light and matter each behave both as waves and as particles B1.

Exam-style 3.1 ▪ 1 mark

The energy of a photon is

A hf

B h/f

C hp

D $\frac{1}{2}mv^2$

Solution 3.1

Method: The photon

A hf ✓

B h/f

C hp

D $\frac{1}{2}mv^2$

Worked steps

A.

Exam-style 3.2 ▪ 1 mark

The de Broglie wavelength of a particle is

A hp

B h/p

C p/h

D hf

Solution 3.2

Method: De Broglie wavelength

A hp

B h/p ✓

C p/h

D hf

Worked steps

B.

Exam-style 3.3 ▪ 2 marks

A photon has a wavelength of 500 nm ($c = 3.0 \times 10^{8}$, $h = 6.63 \times 10^{-34}$).
(a) Find its frequency.
(b) Find its energy.

Solution 3.3

Method: The photon

Worked steps

(a) $f = \dfrac{c}{\lambda} = \dfrac{3.0 \times 10^8}{500 \times 10^{-9}} = 6.0 \times 10^{14}$ Hz **M1** **A1**. (b) $E = hf = (6.63 \times 10^{-34})(6.0 \times 10^{14}) = 4.0 \times 10^{-19}$ J **M1** **A1**.