

Exercise walk-through

15.1

Quantum Theory and Wave-Particle Duality

AP Physics 2

Photons and wave-particle duality

Light comes in packets called **photons**, each carrying:

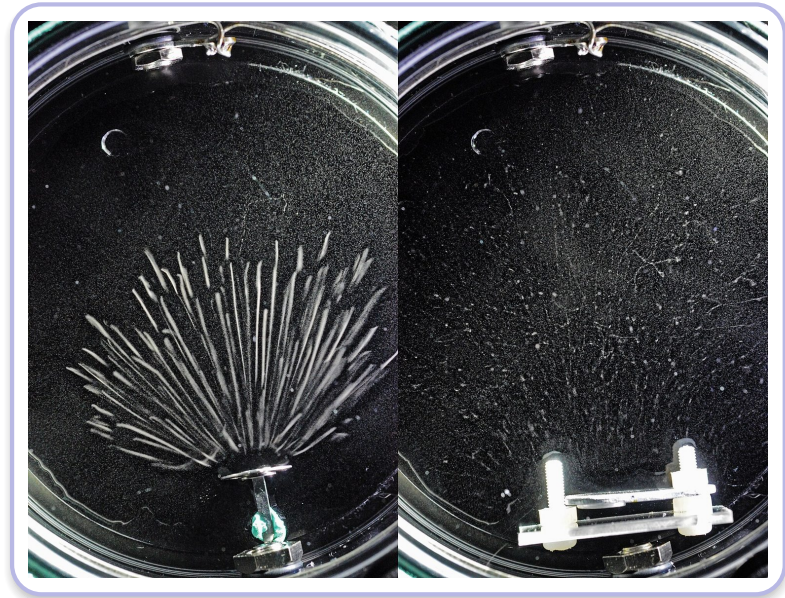
Photon energy

$$E = hf$$

Matter waves

$$\lambda = \frac{h}{p}$$

the **de Broglie wavelength**.



Particles leave tracks of ionisation

The evidence for duality

Double-slit experiment

The **double-slit experiment** gives interference fringes – and they build up one photon at a time, so each photon interferes with itself.

Photoelectric effect

Light behaving as particles: the electron's energy depends on the *frequency*, not the intensity.

Wave-particle duality

Wave-particle duality: which behaviour appears depends on what the apparatus asks. De Broglie extends it to matter, $\lambda = h/p$.

Absorption spectrum

An **absorption spectrum** is dark lines on a continuous background – the same energies the atom would emit, taken out on the way through.

Emission and absorption lines match exactly, which is what shows the energy levels are a property of the atom.

Exercises 2.1-2.3

2.1 Find the energy of a photon of frequency 6.0×10^{14} Hz ($h = 6.63 \times 10^{-34}$). [2]

2.2 State the equation for the de Broglie wavelength. [1]

2.3 State what “wave-particle duality” means. [1]

Exercises 2.1-2.3

2.1 Find the energy of a photon of frequency 6.0×10^{14} Hz ($h = 6.63 \times 10^{-34}$). [2]

2.1

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

2.2 State the equation for the de Broglie wavelength. [1]

2.2

- $\lambda = \frac{h}{p}$

2.3 State what “wave-particle duality” means. [1]

2.3

- that light and matter each behave both as waves and as particles

Exercises 3.1-3.2

3.1 The energy of a photon is

[1]

☐

A hf

B h/f

C hp

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

3.2 The de Broglie wavelength of a particle is

[1]

☐

A hp

B h/p

C p/h

D hf

Exercises 3.1-3.2

3.1 The energy of a photon is

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A hf

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

3.1 A

- hf .

3.2 The de Broglie wavelength of a particle is

[1]

☐

A hp

B h/p

C p/h

D hf

3.2 B

- h/p .

Exercise 3.3 (a)

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

(a) Find its frequency.

[2]

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

(a) Find its frequency.

[2]

(a)

- $$f = \frac{c}{\lambda} = \frac{3.0 \times 10^8}{500 \times 10^{-9}} = 6.0 \times 10^{14} \text{ Hz}$$

Exercise 3.3 (b)

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

(b) Find its energy.

[2]

Exercise 3.3 (b)

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

(b) Find its energy.

[2]

(b)

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