

22.1 Energy and momentum of a photon

Name: _____ Class: _____ Date: _____

Total: 12 marks

Objective

Build the skills to answer exam questions on the **photon** —its energy and momentum.

You must be able to:

- use $E = hf = \frac{hc}{\lambda}$ and the **electronvolt**
- use $p = E/c$ for the photon momentum

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

■ Photons

A **photon** is a **quantum** (packet) of electromagnetic energy:



$$E = hf = \frac{hc}{\lambda}, \quad p = \frac{E}{c}$$

$$E = hf = \frac{hc}{\lambda}, \quad p = \frac{E}{c},$$

with $h = 6.63 \times 10^{-34}$ J s. The **electronvolt**: $1 \text{ eV} = 1.6 \times 10^{-19}$ J.

Worked example. $\lambda = 500 \text{ nm}$: $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^8)}{500 \times 10^{-9}} = 4.0 \times 10^{-19} \text{ J}.$

2 Practice

Now apply the methods above.

2.1 Write the formula for the **energy** of a photon. [1]

2.2 State the value of the **Planck constant**. [1]

2.3 Find the energy of a photon of frequency 5.0×10^{14} Hz. [2]

2.4 Convert your answer to **electronvolts**. [1]

3 Exam-style questions

3.1 The momentum of a photon of energy E is: [1]

- **A** hf
- **B** E/c
- **C** mc
- **D** h/c

3.2 Calculate the energy of a photon of wavelength 500 nm. [3]

3.3 Calculate the **momentum** of this photon. [2]

3.4 State what a **photon** is.

[1]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **22.1 Energy and momentum of a photon** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/41 N25 —Q8 (photon energy and momentum)
- 9702/41 J25 —Q8 ($E = hf$, structured)
- 9702/43 J25 —Q8 (photon energy)
- 9702/42 M25 —Q8 (photon momentum)

Solutions

2.1 $E = hf$ (or $E = hc/\lambda$).

2.2 $h = 6.63 \times 10^{-34} \text{ J s}$.

2.3 $E = hf = (6.63 \times 10^{-34})(5.0 \times 10^{14}) = 3.3 \times 10^{-19} \text{ J}$.

2.4 $E = (3.3 \times 10^{-19})/(1.6 \times 10^{-19}) = 2.1 \text{ eV}$.

3.1 $B = E/c$.

3.2 $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^8)}{500 \times 10^{-9}} = 4.0 \times 10^{-19} \text{ J}$.

3.3 $p = E/c = (4.0 \times 10^{-19})/(3.0 \times 10^8) = 1.3 \times 10^{-27} \text{ kg m s}^{-1}$.

3.4 A quantum (packet) of electromagnetic energy.