

22.1 Energy and momentum of a photon

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS photon 光子 • momentum 动量 • electronvolt 电子伏特 • wavelength 波长
• electron 电子

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 $5.0 \times 10^{14} \text{ Hz}$. [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 | B |
| C | D |
- 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]

3.5 A nucleus of uranium-238 decays by emitting an α -particle and a single gamma photon. Take $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$, $c = 3.00 \times 10^8 \text{ m s}^{-1}$, $h = 6.63 \times 10^{-34} \text{ J s}$ and $1 \text{ MeV} = 1.60 \times 10^{-13} \text{ J}$.

(a) **State** what is meant by a **photon**. [2]

(b) The gamma photon carries an energy of 0.050 MeV. **Determine** its wavelength. [3]

(c) **Determine** the momentum of that photon. [2]

(d) The photon is emitted by a nucleus that was at rest. **Explain** why the nucleus recoils, and **determine** its recoil speed, given that its mass is 234 u. [3]

(e) Gamma radiation from a sample of this nuclide has a **single** wavelength. **Suggest** what this tells you about the energy levels of the nucleus. [2]