A-LEVEL PHYSICS • EXERCISE SHEET

22.2 Photoelectric effect

Name: _____ Class: _____ Date: _____ **Total: 29 marks**

KEY WORDS photoelectric effect 光电效应 • threshold frequency 极限频率 • work function 逸出功 • photoelectron 光电子 • frequency 频率

Objective

Build the skills to answer exam questions on the **photoelectric effect**.

You must be able to:

- use **threshold frequency** and **work function**
- use $hf = \Phi + \frac{1}{2}mv_{\max}^2$
- explain why max KE is independent of intensity but the current is not

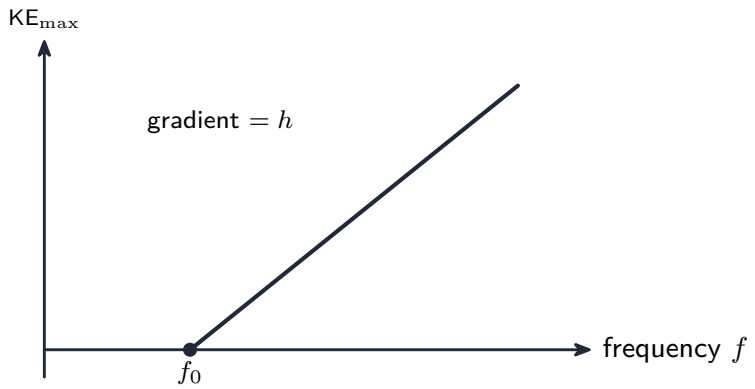
1 Worked examples

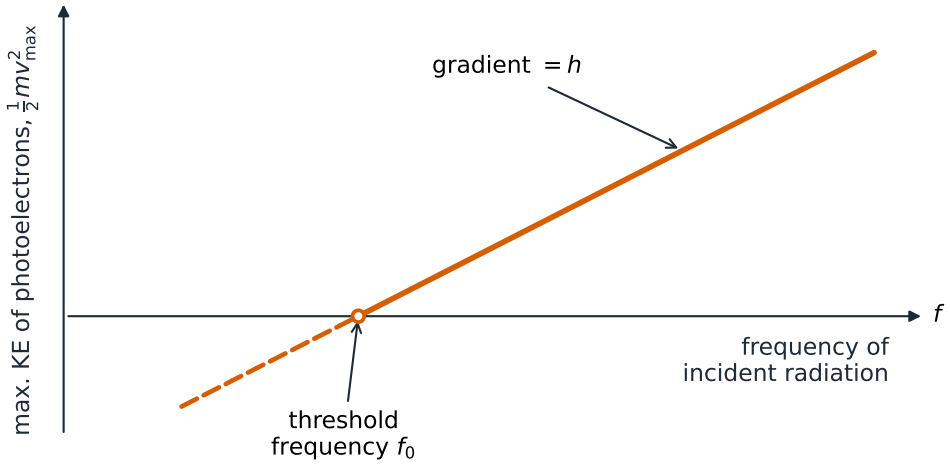
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Photoelectric effect

Light above a **threshold frequency** f_0 frees electrons from a metal. The **work function** $\Phi = hf_0$ is the least energy to free an electron:

$$hf = \Phi + \tfrac{1}{2}mv_{\max}^2.$$





photoelectric: $KE_{max} = hf - \phi$ · threshold $f_0 = \phi/h$

Maximum KE against frequency in the photoelectric effect

Reading the KE–frequency graph

Rearranging gives $\mathrm{KE}_{\max} = hf - \Phi$, the equation of a straight line:

- **gradient** $= h$ (the Planck constant — the **same for every metal**);
- the line meets the f-axis at the **threshold frequency** f_0 (where $\mathrm{KE}_{\max} = 0$);
- extending it back, the y**-intercept** is $-\Phi$.

So two different metals give **parallel** lines (same gradient h); the one with the **larger** work function has the **larger** f_0 (its line is further to the right).

- **max KE** depends only on **frequency** (one photon → one electron), not intensity;
- the **current** (number of electrons per second) depends on **intensity**.

2 Practice

Now apply the methods above.

2.1 Define **threshold frequency**. [1]

2.2 Define the **work function** of a metal. [1]

2.3 Write the **photoelectric equation**. [1]

2.4 State why **no** electrons are emitted below the threshold frequency. [1]

3 Exam-style questions

3.1 Below the threshold frequency, increasing the **intensity** of the light: [1]

A	B
C	D

A emits more electrons
B emits faster electrons
C emits no electrons
D lowers the threshold frequency

3.2 A metal has a work function of 2.0 eV. Photons of energy 3.5 eV strike it. Find the **maximum kinetic energy** of the photoelectrons. [2]

3.3 Explain why the **maximum KE** of the photoelectrons is independent of intensity, while the **current** is proportional to intensity. [3]

3.4 A metal has a work function of 3.2×10^{-19} J. Calculate its **threshold frequency**. [2]

3.5 In a photoelectric experiment, the maximum kinetic energy KE_{max} of the photoelectrons is plotted against the frequency f of the incident light, giving a straight line.

(a) The line has gradient 6.6×10^{-34} J s. State the quantity this gradient represents. [1]

(b) The experiment is repeated with a metal of **larger** work function. On the same axes, describe how the new line compares with the first. [2]

3.6 Light of wavelength 410 nm falls on a clean metal surface in a vacuum photocell. The work function of the metal is 2.3 eV. Take $h = 6.63 \times 10^{-34}$ J s, $c = 3.00 \times 10^{8}$ m s^{-1}, $e = 1.60 \times 10^{-19}$ C and the electron mass as 9.11×10^{-31} kg.

(a) **State** what is meant by the **work function** of a metal. [1]

(b) **Determine** the energy of one photon, in joules and in electronvolts. [3]

(c) **Determine** the maximum kinetic energy of an emitted electron, and its maximum speed. [3]

(d) **Determine** the threshold wavelength for this metal. [2]

(e) The **intensity** of the light is doubled, at the same wavelength. **State and explain** the effect on (i) the maximum kinetic energy of the emitted electrons and (ii) the rate at which electrons are emitted. [3]

(f) **Explain** why the existence of a threshold wavelength cannot be explained by a **wave** model of light. [2]