A-LEVEL PHYSICS • EXERCISE SHEET

22.2 Photoelectric effect

Name: _____ Class: _____ Date: _____ **Total: 17 marks**

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

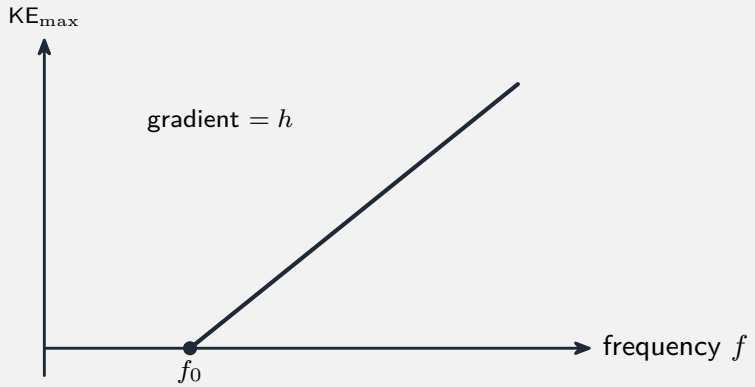
1 Worked examples

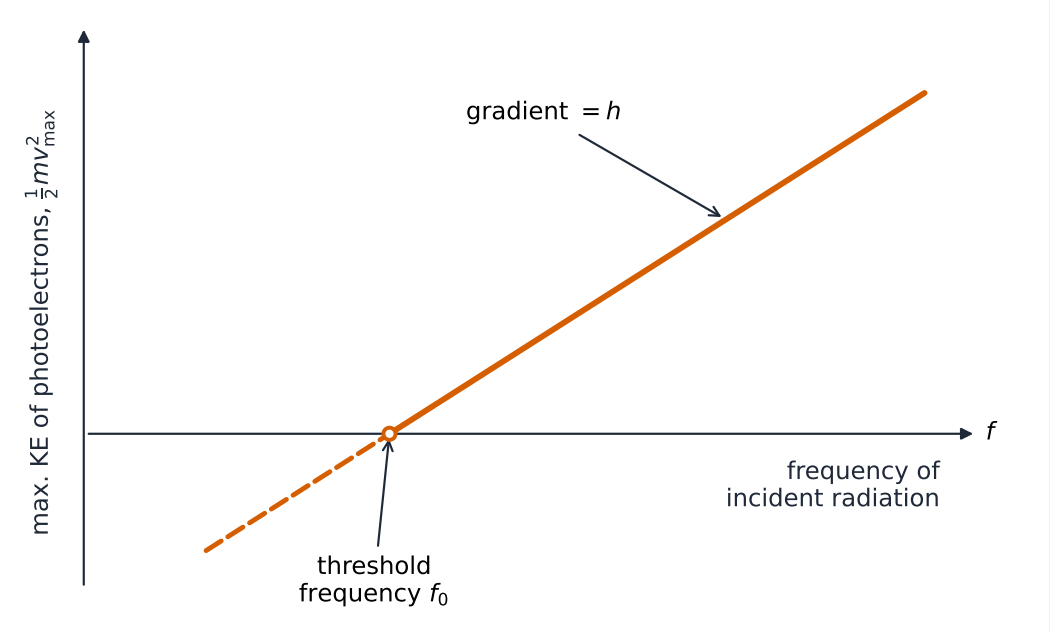
Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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:

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





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** 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 $\mathrm{KE}_{\max}$ 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]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **22.2 Photoelectric effect** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/44 N25 —Q9 (photoelectric effect, KE–f graph)
- 9702/42 J25 —Q9 (work function and threshold frequency)

Solutions

2.1 The **lowest frequency** of radiation that will release electrons from the metal.

2.2 The **minimum energy** needed to free an electron from the surface.

2.3 $hf = \Phi + \frac{1}{2}mv_{\max}^2$.

2.4 Each photon has energy $hf < \Phi$, so it **cannot supply** enough energy to free an electron (and energy is one-photon-per-electron).

3.1 C —no electrons.

3.2 $\mathrm{KE}_{\max} = hf - \Phi = 3.5 - 2.0 = 1.5$ eV.

3.3 Each electron absorbs **one photon**, so its max KE depends only on the **photon energy (hf)**, set by frequency; higher intensity means **more photons per second**, so more electrons per second —a larger current, but the same energy per electron.

3.4 $f_0 = \Phi/h = (3.2 \times 10^{-19})/(6.63 \times 10^{-34}) = 4.8 \times 10^{14}$ Hz.

3.5 (a) The **Planck constant** h.

3.5 (b) A line with the **same gradient** (parallel to the first), but shifted to the **right** —a **higher threshold frequency** f_0 (and a more negative y-intercept $-\Phi$).