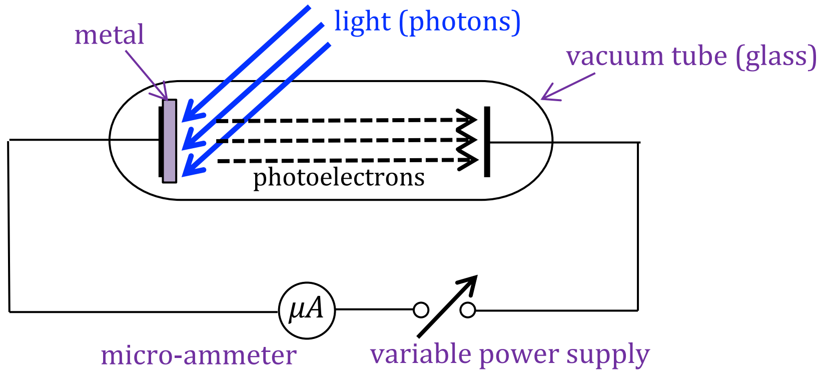
2.8.2 More on the photoelectric effect

videos

The vacuum photocell

The photoelectric effect can be demonstrated using a piece of equipment called a vacuum photocell.



Light is shone on a metal attached to one electrode (called the photocathode). Electrons are emitted, some of which travel through the vacuum to the other electrode (the anode). The net effect is that the photocathode loses electrons and the anode gains electrons. This sets up a potential difference between the two electrodes. If the two electrodes are connected by an external circuit, electrons will flow from the anode and back to the cathode. This small current can be measured using a sensitive micro-ammeter.

A variable power supply can be used to apply a potential difference across the photocell, effectively repelling photoelectrons from the 'anode' on the right-hand side. In order to stop the photoelectrons with the greatest kinetic energy ($E_{k(max)}$) making it to the 'anode', a potential called the stopping potential, needs to be applied. At this point, no electrons will arrive at the 'anode' and so no current will flow in the circuit.

The stopping potential (V_{stop}) is related to the maximum kinetic energy ($E_{k(max)}$) of the photoelectrons. As an electron gains 1 electron-volt (1.6×10^{-19}J) of kinetic energy when it is accelerated through a potential of 1 volt, to decelerate the fastest photoelectron we need to apply a stopping potential:

$$V_{stop} = \frac{E_{k(\max)}}{1.6 \times 10^{-19}}$$

(1)✎Light with a frequency of 3×10^{15}Hz is shone on a vacuum photocell containing zinc metal (work function $\phi=6.93 \times 10^{-19}$J). What is the maximum kinetic energy $E_{k(max)}$ of the emitted photoelectrons? What stopping potential V_{stop} would need to be applied to reduce the external circuit current to zero? (The Planck Constant $h=6.63 \times 10^{-34}$Js).

$E_{k(max)}$ versus frequency graphs

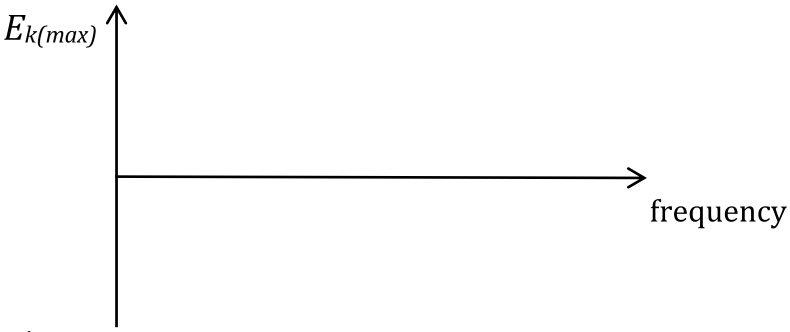
If we change the frequency of the incident light and measure the maximum kinetic energy of the emitted photoelectrons (by measuring the stopping potential - discussed above), we can construct a graph of $E_{k(max)}$ versus frequency.

If we rearrange the formula $hf = \phi + E_{k(\max)}$, to make $E_{k(\max)}$ the subject we get:

$$E_{k(\max)} = hf - \phi$$

This is in the form $y = mx + c$.

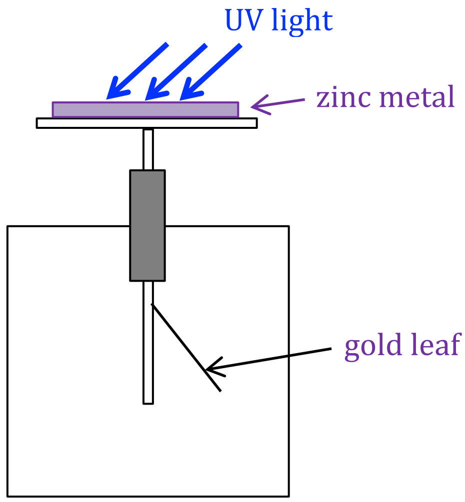
(2) Sketch the graph of $E_{k(max)}$ versus frequency:



(3) What is the gradient of the line? What is the y-intercept?

The gold leaf electroscope

One method of demonstrating the photoelectric effect is to use a gold leaf electroscope. When ultraviolet light with a frequency above the threshold frequency is shone on the zinc metal, the gold leaf is seen to rise.



(4) Explain in as much detail as you can why the gold leaf rises. You may need to research the workings of the gold leaf electroscope for this.