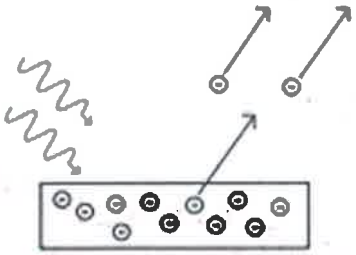
Quantum Phenomena Revision Questions

1. When electrons are incident on the surface of a metal electrons are produced.



a) What is the name of this phenomenon?

The Photoelectric Effect ..... *(1 mark)*

The properties of the incoming photons and the emitted electrons are related by the following equation:

$$hf = \phi + E_k$$

b) For each term in the equation state what the term represents and its units.

h ..... Plank's constant ..... unit ..... Js .....

f ..... Frequency ..... unit ..... Hz .....

ϕ ..... Work function ..... unit ..... J .....

E_K ..... (Max) kinetic energy of electron ..... unit ..... J .....

(4 marks)

2. Quantum mechanics includes the observations that electrons exhibit wave-like properties.

a) Describe an observation which demonstrates this phenomenon. Details are not required.

The diffraction of electrons

(1 mark)

b) Calculate the de Broglie wavelength of an electron travelling at 3.2×10^5 ms^{-1}.

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 3.2 \times 10^5}$$

$$= 2.28 \times 10^{-9} m$$

(2 marks)

c) Calculate the kinetic energy of the above electron.

$$E_k = \frac{1}{2} mv^2$$

$$= \frac{1}{2} \times 9.11 \times 10^{-31} \times (3.2 \times 10^5)^2$$

$$= 4.66 \times 10^{-20} J$$

$$(0.29 eV)$$

(2 marks)

3. One piece of evidence for the quantum behaviour of electrons is that of line spectra. The two images below show a continuous spectrum a light source and the spectrum of a similar light source shone through mercury vapour.

Continuous Spectrum

Mercury vapour lamp

a) Explain how the spectrum for mercury demonstrates a quantum phenomenon.

- Only absorbs at particular wavelengths/frequencies
- Which correspond to particular atomic energies
- Due to electrons moving between discrete energy levels in the atom. *(3 marks)*

b) Mercury produces a sharp absorption line at 436 nm. Calculate the energy of this photon.

$$E = hf = \frac{hc}{\lambda} = 4.56 \times 10^{-19}\ \text{J}$$

(2 marks)

4. In an experiment to measure the photoelectric effect, light of wavelength λ is incident on a metal surface and a current is produced. The current is suppressed by supplying a potential difference *V* between the metal surface and the collecting plate.

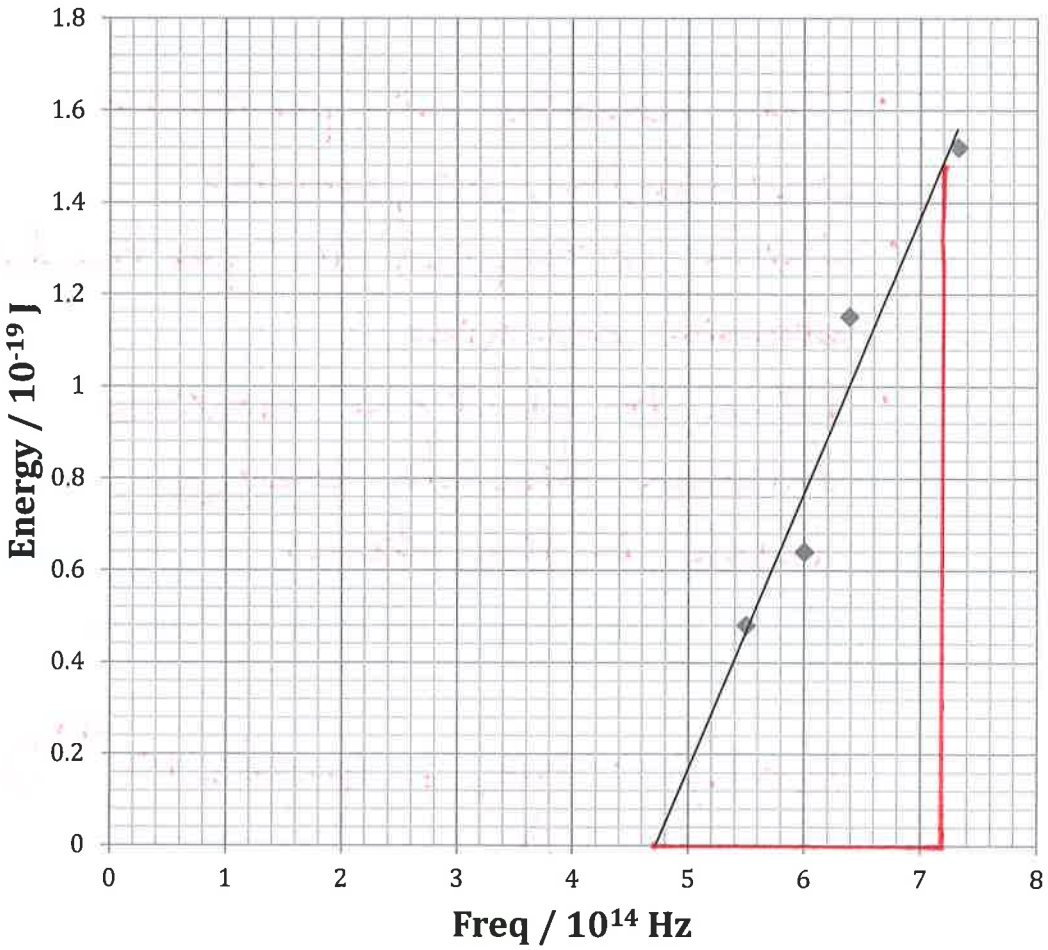
   a) Derive, with explanation, and equation relating λ, *V* and the work function, φ, of the metal.

Max KE of electron = energy of photon − work function

$\Rightarrow eV = hf - \phi$

$eV = \frac{hc}{\lambda} - \phi$ *(2 marks)*

The results of this experiment are shown below.



b) Using the graph opposite,

i. Determine h and the threshold frequency, f_0, from the graph. Include correct units.

h = gradient

$= \frac{1.48 \times 10^{-19}}{2.5 \times 10^{14}} = 5.92 \times 10^{-34}$ Js

$f_0 = 4.7 \times 10^{14}$ Hz

(3 marks)

ii. Calculate the work function, φ, of the metal.

$\phi - hf = 0$

$\phi = hf_0 = 3.12 \times 10^{19}$ J

$= 1.95$ eV

(3 marks)

c) State and explain the effect of doubling the intensity of the radiation while keeping the frequency constant.

· No effect on E_k / Stopping voltage

· Will effect current when voltage is not suppressed.

(2 marks)