F**ORM 5 SPM PHYSICS** **SHORTHAND NOTES**

Chapter 7 Quantum Physics

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7.1 Quantum Theory of Light

In classical wave theory, electromagnetic (EM) radiation is assumed to behave as a wave.

This is supported in that EM radiation exhibit wave like phenomena's such as diffraction, interference, refraction and interpolation.

However, quantum mechanics also assumes that EM radiation behave as particles.

An example of this is the photoelectric effect.
Photons are fundamental particles which make up all forms of EM radiation.

A photon is a massless "packet" or a "quantum" of EM energy

Each photon carries a specific amount of energy, and transfers this energy all in one go.

A photon's energy (E in Joules) can be calculated with the following equation

$$E = hf$$

Here h is Planck's constant (6.63×10^{-34} Js) and f is the frequency (Hz)

Einstein showed that a photon travelling in a vacuum has momentum (even though photos have no mass!)

The momentum (p) of a photon is given by

$$p = \frac{h}{\lambda}$$

Where h is Planck's constant and λ is the wavelength of the photon.

De Broglie states that particles such as electrons can also exhibit wave properties.

Rearranging the above equation, we get

$$\lambda = \frac{h}{mv}$$

Here m is the mass and v the velocity of the particle.

From the equation above we can see that the bigger the mass of the particle, the smaller it's wavelength.

Hence it will be very hard to detect the wavelength of a large mass particle (since its wavelength will be very small!)

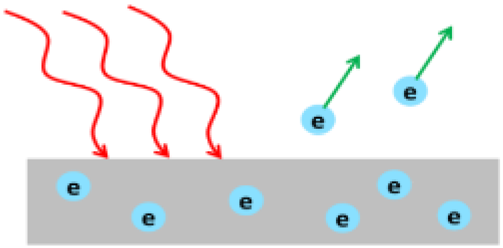
The power (P) of an EM wave is dependent on the number of photons emitted per second (n)

$$P = nhf$$

Which can also be rewritten as

$$P = nh\frac{c}{\lambda}$$

7.2 Photoelectric Effect



Photoelectric effect, is a phenomenon in which electrons are released from the metal surface when it absorbs EM radiation.

Electrons released from photoelectric effect is called photoelectrons.

Photoelectric effect is evidence that light is quantised (discrete) because each electron can only absorb a single photon and only at frequencies above a threshold frequency.

The threshold frequency (f_o) is the minimum frequency of the EM radiation that is needed to remove a photoelectron from the surface of a metal.

7.3 Einstein's Photoelectric Theory

Threshold energy (Φ) is the minimum energy for photoelectrons to be released from the surface of a metal. It is given by

$$\Phi = hf_o$$

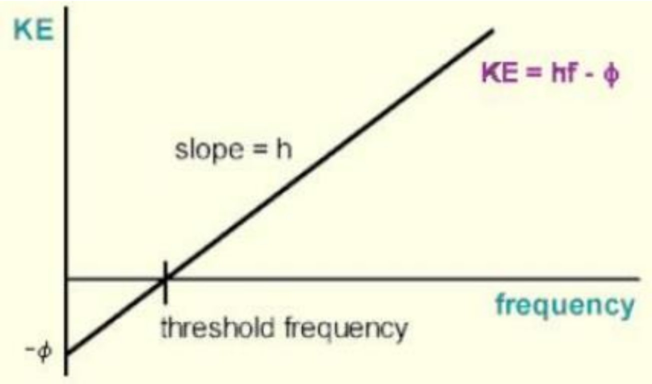
Since energy is conserved, total energy of a photon hitting the surface of the metal (hf) is equal to the sum of the threshold energy (Φ) with the KE of the photoelectron ($1/2mv^2$ or KE)

$$hf = \Phi + 1/2mv2$$

rearranging you get

$$KE = hf - \Phi$$

If you plot the above equation out you get



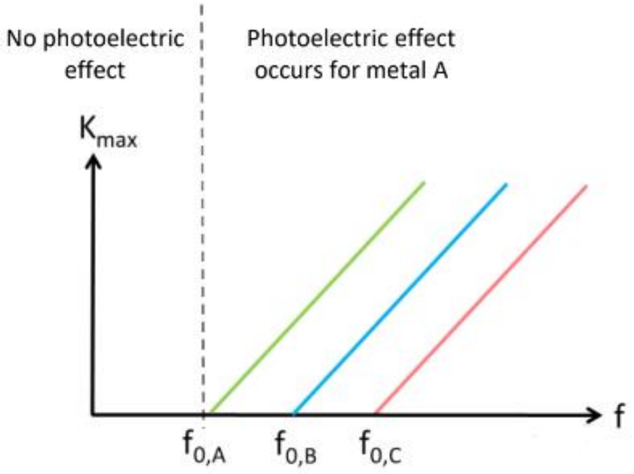
From the graph -the x-axis intercept would represent the reciprocal of the threshold wavelength -the slope would equal h -the y-axis intercept would represent the work function

If the incident photons do not have a high enough frequency (f) and energy to overcome the work function (Φ), then no electrons will be emitted

When hf0 = Φ and f0 = threshold frequency, photoelectric emission just occurs.

KE depends only on the frequency of the incident photon and not on the intensity of the radiation (number of photons striking the metal).

This is because each electron can only absorb one photon to escape the surface of the metal (if the photon has an energy equal to Φ or higher).



Different metals will have different Φ.

Hence KE is independent of intensity.

Photoelectric current on the other hand is dependent on intensity.

This is because when more photos strike the metal surface, more photoelectrons are emitted.

This is due to each electron absorbing a single photon.

Hence, an increase number of photons increases the current.

Photoelectric current is directly proportional to intensity.