B.Sc Part II Physics (Hons) ①

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Q Establish the Einstein's equation $\frac{1}{2}mv^2 = h(\nu - \nu_0)$ and Explain the laws of P.E.E. ?

Ans P.E.E :- Einstein in 1905 explained the phenomenon of photo electric effect on the basis of planck's quantum theory. According to this theory, light travell in the form of small bundles of energy called photons. The energy of each photon is $h\nu$, Here ν = frequency of light wave, h = planck's constant. The intensity of light depends on the number of these photons.

When a photon falls on a metal, it transferes whole of its energy $h\nu$ to any one of the electrons present in the metal and its own existence is vanished. A part of this energy is used in ejecting the electron from the metal and rest is given to the ejected electron as K.E. All the electrons are not ejected from the surface of metal. The electrons emitted from the surface of metal, or the electrons which are ejected from within the metal, they expand some of their acquired energy in collisions with the atom on their way to the surfaces, Thus electrons will different energies are emitted from the metal. The electron emitted from the surface of the metal have maximum K.E because their energy is not lost by collisions.

Let the maximum K.E of photo electron emitted from metal surface is E_K and W is the energy required to eject a photo electron from metal. W is the work function of metal.

from conservation of energy,

$$h\nu = E_K + W$$

$$\therefore E_K = K.E = h\nu - W \quad \text{.........} \quad (1)$$

where $h\nu'$ be the energy of photon absorbed by the electron in the metal. ③

If the energy of photon absorbed by the electron is less than the work function W of metal, then the electron will not be emitted. Therefore for the given metal ν_0 be the threshold frequency.

The amount of energy $h\nu_0$ of the photon of light will be spent in ejecting the electron out of metal, it will be equal to the work function W. Hence $W = h\nu_0$ we get

$$E_K = h\nu - h\nu_0$$

$$\therefore E_K = h(\nu - \nu_0) \quad \text{--- ②}$$

Let the maximum velocity of the emitted photoelectron be V_{max}, then $E_K = \frac{1}{2} m V_{max}^2$

$$\therefore \frac{1}{2} m V_{max}^2 = h(\nu - \nu_0) \quad \text{--- ③}$$

$$\because \nu = \frac{c}{\lambda}, \quad \lambda_0 \rightarrow \text{Threshold wavelength}$$

$$\therefore \frac{1}{2} m V_{max}^2 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) \quad \text{--- ④}$$

These equations ①, ②, ③ & ④ are called Einstein's photo electric equation.

Explanations of laws of P.E.E :→

laws of P.E.E can be explained by the Lenard & Millikan on basic of above equation as follows :—

If the intensity of light of a given frequency ν is increased, then the number of photons striking the surface per second will increase in the same ratio but the energy $h\nu$ of each photon will remain the same. Hence the number of photoelectrons will correspondingly increase but their maximum K.E (E_K) will remain the same, As it is clear from Einstein's equation. Thus law (I) and (II) of P.E.E are explained.

It is also seen that from Einstein's equation that the maximum K.E (E_K) of the photoelectrons will increases almost linearly but increase in the frequency ν of the incident light. This is the law of P.E.E.

If $\nu < \nu_0$, Then the K.E of electron would be negative which is impossible. This means If the frequency ν of the incident light is less than threshold frequency ν_0, photo electron can not be emitted whatever be the intensity of light. This is law (IV) of P.E.E.

As soon as the first photon falls on the metal one of the electron in the metal absorb it as such and is ejected. There is no time lag between incident of light (Photon) on the metal and the emission of electron. This is the law (V) of P.E.E.