Chapter-11

Dual Nature of Matter And Radiation

Photo-electric effect :

The minimum amount of energy required by an electron to just escaped from the metal surface is called work function of the metal.

Electron Emission : The phenomenon of emission of electrons from a metal surface is called electron emission.

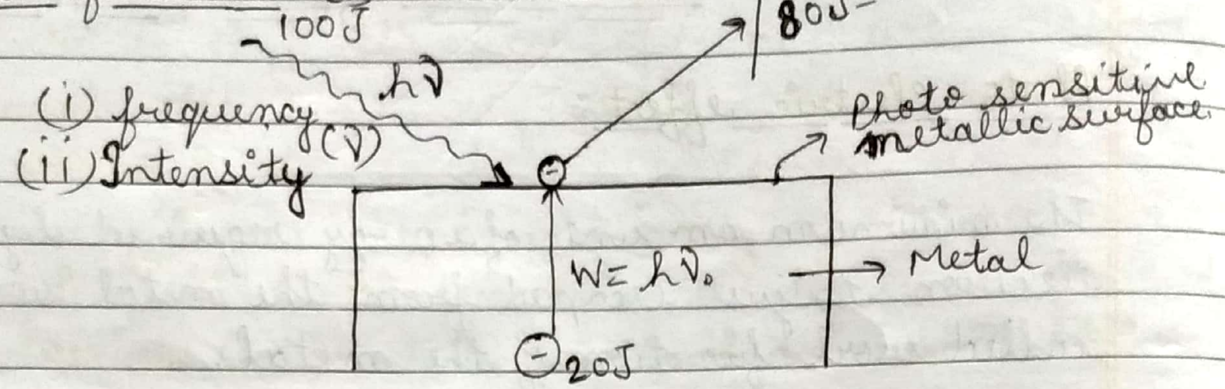
Methods by which an electron used to supply the required amount of energy are :

(i) Thermionic emission
(ii) Feild emission or cold cathode emission.
(iii) Photo-electric emission
(IV) Secondary emission.

$-ve$ C Stopping potent. $i = \frac{Ne}{t}$

(i) Effect of intensity of light on photoelectric current

Work function :- (I)



$E = h\nu$

$E_{min} = h\nu$

$h\nu = h\nu_0 + \frac{1}{2} m v^2_{max}$

$h\nu = h\nu_0 + eV_0$

$eV_0 = h\nu - h\nu_0$

$V_0 = \frac{h\nu}{e} - \frac{h\nu_0}{e}$

$E = h\nu$

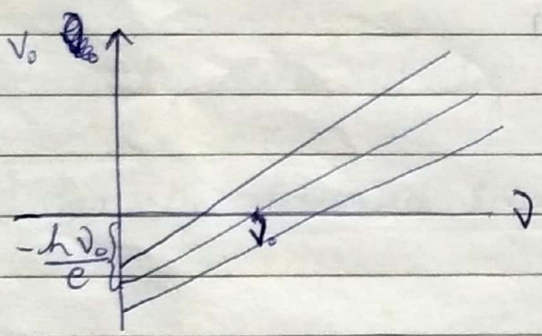
$E_{minimum} = h\nu_{minimum}$ → threshold frequency

$h\nu = h\nu_0 + \frac{1}{2} m v^2_{max}$

$h\nu = h\nu_0 + eV_0$

$eV_0 = h\nu - h\nu_0$

$V_0 = \frac{h\nu}{e} - \frac{h\nu_0}{e}$



(ii) Effect of Potential :- Photoelectric current increases with the increase in acclerating potential till a stage is reached when the photoelectric current becomes maximum and does not increase further with the increase in the acclerating potential. This maximum value of photoelectric current is called the saturation current.

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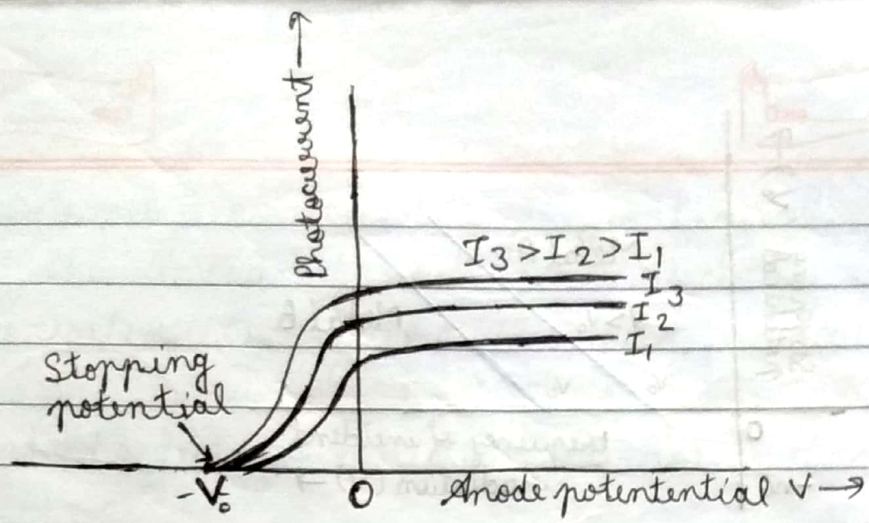


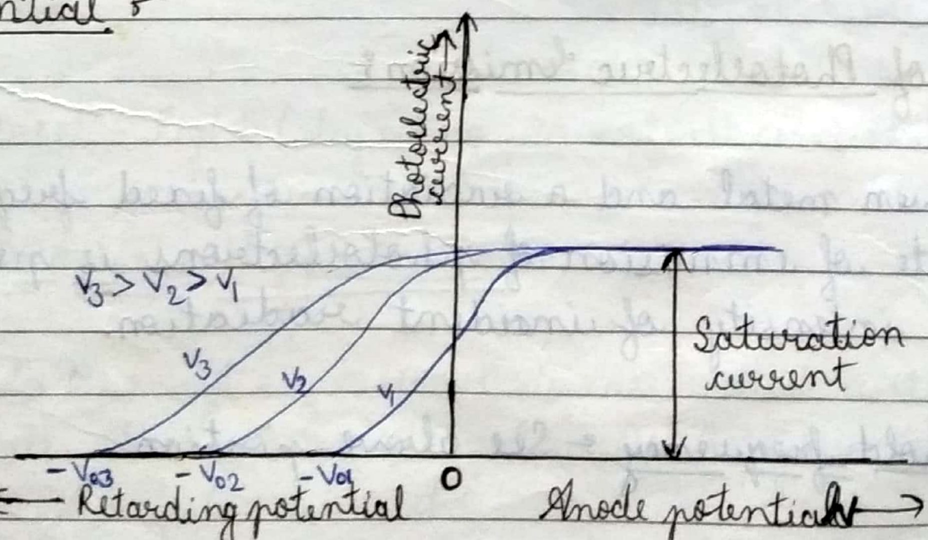
The value of the retarding potential at which the photoelectric ~~effect~~ current becomes zero is called cut off or stopping potential for given frequency of the incident radiation.

$$\boxed{K_{max.} = \frac{1}{2} m v^2_{max} = eV_0}$$

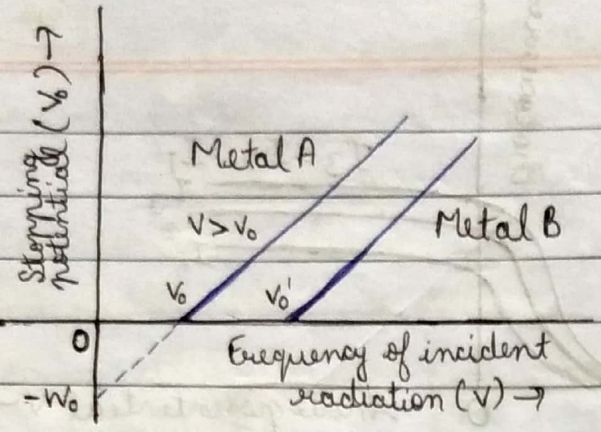
∴ where, v_{max} = max. Velocity
V_0 = stopping potential.

For given frequency of incident radiation the stopping potential is independent of its intensity.

Effect of frequency of Incident radiation on stopping potential :



Variations of photoelectric current with anode potential for different frequencies for incident radiation.



Variation of stopping potential with frequency of incident radiation.

The above or beyond graph imply two important facts:-

(i) The max. kinetic energy of photoelectrons increases linearly with the frequency of the incident radiation, but is independent of it's intensity.

(ii) For a frequency V of the incident radiation less than the threshold frequency V_0, no photoelectric emmision is possible, howsoever large is the intensity of incident radiation.

Threshold frequency :- The minimum value of the frequency of incident radiation below which the photoelectric emission stops all together is called threshold frequency.

Laws of Photoelectric Emission :-

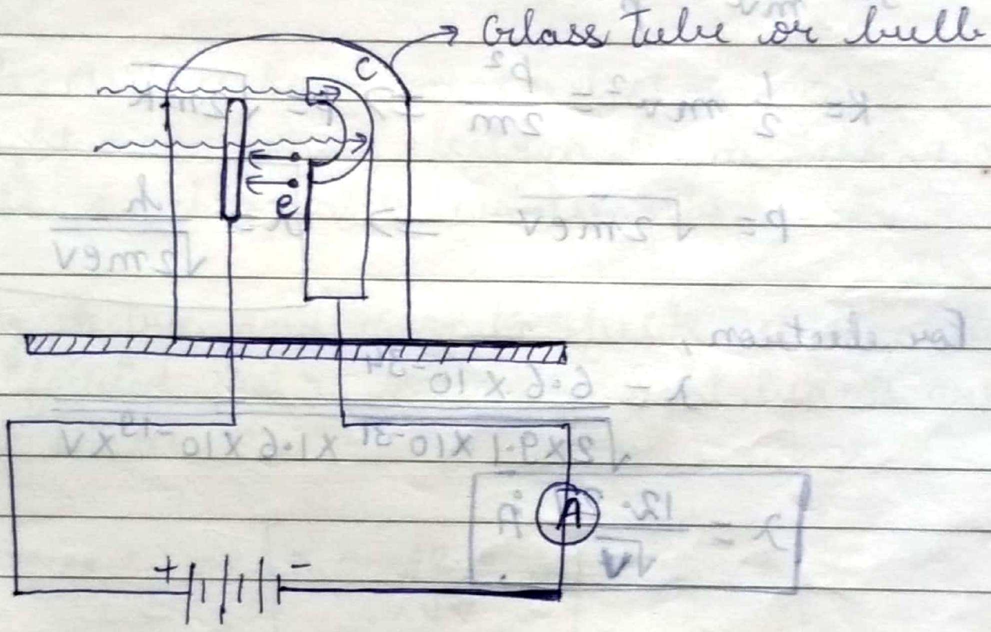
(i) For a given metal and a radiation of fixed frequency, the rate of emmision of photoelectrons is proportional to the intensity of incident radiation.

(ii) Threshold frequency :- See above portion.

(iii) For the radiation of frequency higher than the threshold frequency, the max. kinetic energy of photoelectrons is directly proportional to the frequency of the incident radiation and is independent of the intensity of the incident radiation.

(iv) The photoelectric emission is an instantaneous process.

Photoemissive cell :-



Applications of photoemissive cell :-

(i) In stadiums or other places where no. of people are counted.

(ii) In street-light (by using inverter circuit & bulb.

De-Broglie's hypothesis :-

Acc. to De Broglie, a wave is associated with every moving particle. These waves are called De Broglie waves or matter waves.

$E = h\nu = \frac{hc}{\lambda}$

$\phi = mc$

$\therefore E = mc^2 = pc \Rightarrow \frac{h\cancel{c}}{\lambda} = p\cancel{c} \Rightarrow \boxed{\lambda = \frac{h}{p}}$

For ordinary material particle

$p = mv$, where $v < c$

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

This is called de Broglie relation

De-Broglie's wavelength associated with an electron :-

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

$$K = \frac{1}{2} m v^2 = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mK}$$

$$p = \sqrt{2meV} \Rightarrow \boxed{\lambda = \frac{h}{\sqrt{2meV}}}$$

For electron,

$$\lambda = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times V}}$$

$$\boxed{\lambda = \frac{12.27}{\sqrt{V}} \mathring{A}}$$

Conclusion of Davisson and Germer's experiment :-

$2d \sin\theta = n\lambda$ ...... eq. Bragg's condition

For nickle crystal

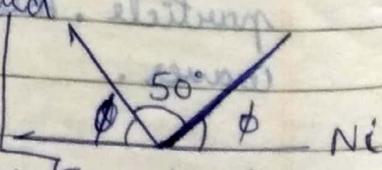
$d = 0.91 \mathring{A}$, $n = 1$, $\theta = 65°$

$2 \times 0.91 \sin 65° = 1\lambda$

$\boxed{\lambda = 1.65 \mathring{A}}$ (Experimentally)

Theoretically , $\boxed{\lambda = 1.66 \mathring{A}}$

Theoritical value is eqial to experimental value. Hence Davission and Germer's experiment proved.



Thus theoretically & experimentally the value of λ coincides. Thus Davission & German experiment proves the existance of De - Broglie waves.

$50 + \phi + \phi = 180$

$\phi = 65°$

Electron Microscope :-

It is an imp. application of De-Broglie wave designed.

Electron Microscope ~~are~~ is designed to study very minute objects like viruses, microbes and the crystal structure of the solids.

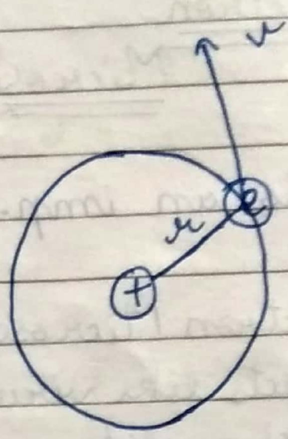
Principle :- It is based on the fact :-

(i) Like light radiations, electron beam behave as waves but with much smaller wavelengths.

(ii) By using electric and magnetic fields, electron beams can be focussed just as ordinary light beams are focussed by glass lenses.

$$\boxed{\lambda = \frac{12.3}{\sqrt{V}} \text{ Å}}$$

Bohr's Theory of Hydrogen atom :-



$$\frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2} = \frac{mv^2}{r}$$

$$r = \frac{e^2}{4\pi\epsilon_0 mv^2} \rightarrow (1)$$

Also, $mvr = n\cdot\frac{h}{2\pi}$

$$r = \frac{nh}{2\pi mv} \rightarrow (2)$$

Equating (1) & (2)

$$\frac{e^2}{4\pi\epsilon_0 \cancel{m} v^{\cancel{2}}} = \frac{nh}{2\pi \cancel{mv}}$$

$$v = \frac{2\pi ke^2}{nh}$$

$$\therefore r = \frac{nh \times nh}{2\pi m \times 2\pi ke^2}$$ [Subsititiong value of v in eq. (2)]

$$= \frac{n^2h^2}{4\pi^2 mke^2} \approx 0.53\,\mathring{A}$$, where $n = 1$. for H_2 atom

$$E = K + P$$

$$= \frac{1}{2}mv^2 + \left[\frac{-Ke^2}{r}\right]$$

$$= \left[\frac{1}{2}\cdot\frac{Ke^2}{r}\right] - \frac{Ke^2}{r}$$

$$E = -\frac{Ke^2}{2r}$$

$$= -\frac{Ke^2 \times 4\pi^2 m Ke^2}{2 \times n^2h^2}$$

$$= -\frac{2\pi^2 m K^2 e^4}{n^2h^2}$$

$$E_n = -\frac{13.6}{n^2}\, eV$$

Spectral Series of Hydrogen :

$$E_n = \frac{-13.6}{n^2}\, eV$$

$$E_2 - E_1 = h\nu$$

$$E_{n_2} - E_{n_1} = h\nu$$

$$h\nu = \frac{2\pi^2 m k^2 e^4}{h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$h\frac{c}{\lambda} = 2\pi^2 m k$$