Dual Nature of Radiation and Matter

Dual Nature of Radiation :-

Dual nature of Radiation means both Wave nature and Partical nature.

Milikan's Experiment :-

(i) He conducted oil-droplet experiment for the measurement of charge or an electron ($-1.602 \times 10^{-19} C$).

(ii) He Established that electric charge is quantised.

(iii) He calculated the value of e/m.

Electron Emission :-

When the light of sutable frequency incident on metallic plate than electron is emitted from the metallic c Surface, this phenomenom is called electron Emission.

Or,

The phenomenom of Emission of electrons from the metallic Surface is called Electron Emission.

The electron Emission can be done by the following process:—

(i) Thermionic emission
(ii) field emission
(iii) photoelectric emission

(1) Thermionic emission:—

The type of emission in which electrons are emitted from the metallic plate by using sufficient heat energy is called thermionic emission.

or,

When emission of electron from the metallic plate is done by using heat energy is called thermionic emission.

Field emission:—

When emission of electron from the metallic plate is done by using stronge electric and Magnetic field is called field emission.

Hertz's observations:-

(i) The phenomenom of electric emission is discovered by Heinrich Hertz during his electromagnetic wave experiment.

(ii) His experimental investigation on the products of electromagnetic waves by means of spark discharge.

(iii) When emitter plate was illuminated by UV light the speak across the detector loop get increase.

Hallwach's and lenard's observations:-

lenard's observed that when UV radiation where fall on emitter plate then current flows but as soon as UV Radiation were stoped then current flows also stopped.

These observation indicate that when UV radiations fall on the emitter plate then electrons are ejected from it.

Experimental study of photoelectric effect

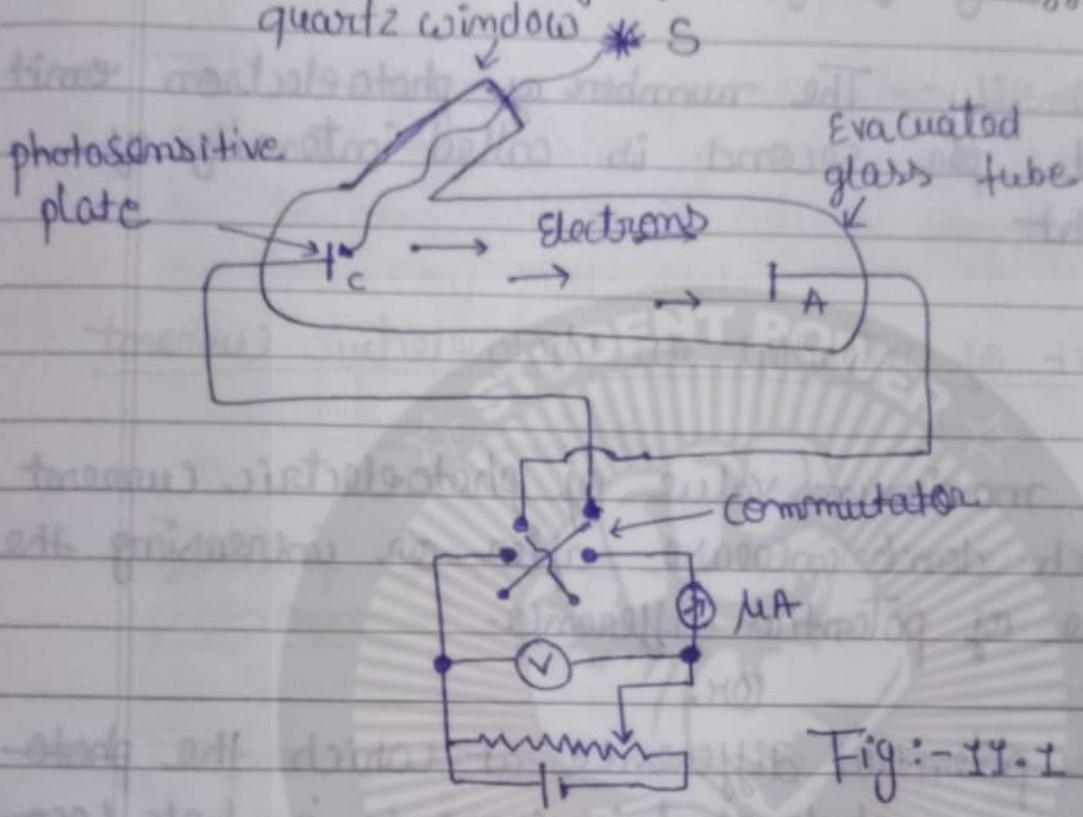

Fig:- 11.1

Study of the varition of photocurrent with :—

(I) intensity of Radiation
(II) Frequency of incident Radiation
(III) potential difference between the plates
(IV) Nature of the material of the plate

Effect of intensity of light on photocurrent

The photocurrent is directly proportional to the

* Stopping potential or cut-off potential

The minimum negative potential or retarding potential at which photocurrent will stoped or become zero is called stopping potential or cut-off potential.

$$K_{max} = eV_0$$

Effect of frequency of incident radiation on photocurrent potential:-

Frequency of radiation is directly proportional to the photocurrent

Effect of frequency of incident radiation on Stopping potential:-

- The greater the frequency of incident radiation then more negative will be stopping potential.

$$K.E = h(\nu - \nu_0)$$

$$\boxed{\frac{1}{2}mv^2 = h(\nu - \nu_0)}$$

properties of electromagnetic Radiation or light :-

(i) In interaction of radiation with matter, radiation behaves as if it is made up of particles called photons.

(ii) Each photon has energy $E (= h\nu)$ and momentum $p (= h\nu/c)$, and speed c, the speed of light.

(iii) photons are electrically neutral and are not deflected by electric and magnetic fields.

(iv) In a photon - particle collision, the total energy and total momentum are conserved.

(i) The Kinetic energy of photoelectron varies linearly with frequency but independent of intensity of the incident Radiation.

(ii) Stopping potential If the frequency of incident Radiation is lower then cut-off frequency or threshold frequency. then their is no emission photoelectric current.

Photoelectric Effect and wave theory of light

photoelectric Effect

The phenomenon of emission of electrons from the surface of metal when light of suitable frequency is falled on it is called photoelectric Effect.

Einstein's photoelectric equation : Or particle Nature

Total energy = Threshold energy + Kinetic energy

$$\phi = \phi_0 + K \cdot \varepsilon$$

$$h\nu = h\nu_0 + K \cdot \varepsilon$$

VVI

Wave Nature of the metal

From Einstein's equation

$$E = mc^2 \quad \text{——(i)}$$

From plank's equation

$$E = h\nu \quad \text{——(ii)}$$

From eq (i) and (ii), we get

$$mc^2 = h\nu$$

$$mc^2 = h\frac{c}{\lambda}$$

$$\lambda = \frac{hc}{mc^2}$$

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

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

λ = wave length
h = plank constant
$h = 6.63 \times 10^{-34}$ Js
p = ~~momentum~~ momentum.

a potential (V), The kinetic energy is equal to (~~electrical energy~~). (is equal to work-done. (eV) on it. by the electric energy.

K.E = electrical energy

$$\frac{1}{2} mv^2 = eV \quad \text{——— (1)}$$

(by mutiple $\frac{m}{m}$, we, get)

$$K.E = \frac{1}{2} mv^2 \times \frac{m}{m}$$

$$= \frac{mv^2}{2m}$$

$$= \frac{p^2}{2m}$$

$$\frac{p^2}{2m} = eV \quad \text{——— (10)}$$

$$p^2 = 2meV$$

$$p = \sqrt{2meV} \quad \text{——— (11)}$$

As we know that

From de-Broglie equation

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

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$\boxed{\lambda = \frac{1.227}{\sqrt{V}}\ nm} \quad \text{or} \quad \boxed{\lambda = \frac{12.27}{\sqrt{V}}\ A^\circ}$$

where as,

$$\frac{h}{\sqrt{2me}} = 1.227$$

$\sqrt{V}$ = potential

physical quantity	Symbol	Dimensions	unit	Remarks
planck's constant	h	$[ML^2T^{-1}]$	Js	$E = h\nu$
stopping potential	V_0	$[ML^2T^{-3}A^{-1}]$	V	$eV_0 = K_{max}$
work function	ϕ_0	$[ML^2T^{-2}]$	J; eV	$K_{max} = E - \phi_0$
Threshold frequency	ν_0	$[T^{-1}]$	Hz	$\nu_0 = \phi_0/h$
de-Broglie wavelength	λ	$[L]$	m	$\lambda = h/p$

$$\lambda = 2d \sin\theta$$
$$\lambda = 2 \times 2.15 \sin 50^\circ$$
$$= 1.65 A^\circ \quad \text{---} (1)$$

From de - Broglie equation

$$\lambda = \frac{1.227}{\sqrt{V}} \text{ nm}$$

$$\lambda = \frac{12.27}{\sqrt{V}} A^\circ$$

$$\lambda = \frac{12.27}{\sqrt{54}} A^\circ$$

$$\lambda = 1.67 A^\circ$$

where as
$A^\circ = 10^{-10}$ m
$\theta = 50$
$V = 54$

From eqn (1) and (11). we can conclude that de Broglie equation is correct and minor ~~eqtat~~ Davisson due to Exprimental defect.

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

Here, λ is de Broglie wavelength.

De - Broglie Wavelength

The wavelength associated with a matter is called De Broglie wavelength.

- photocell

photocell is an arrangement which converts light energy into electric energy.

It works on the principle of photoelectric Effect.

It is used to produces sound.

VVI

Relationship between wave length and potential difference.

Consisted an electron of mass (m) and change (e) is ~~accelated~~ from rest to accelerated

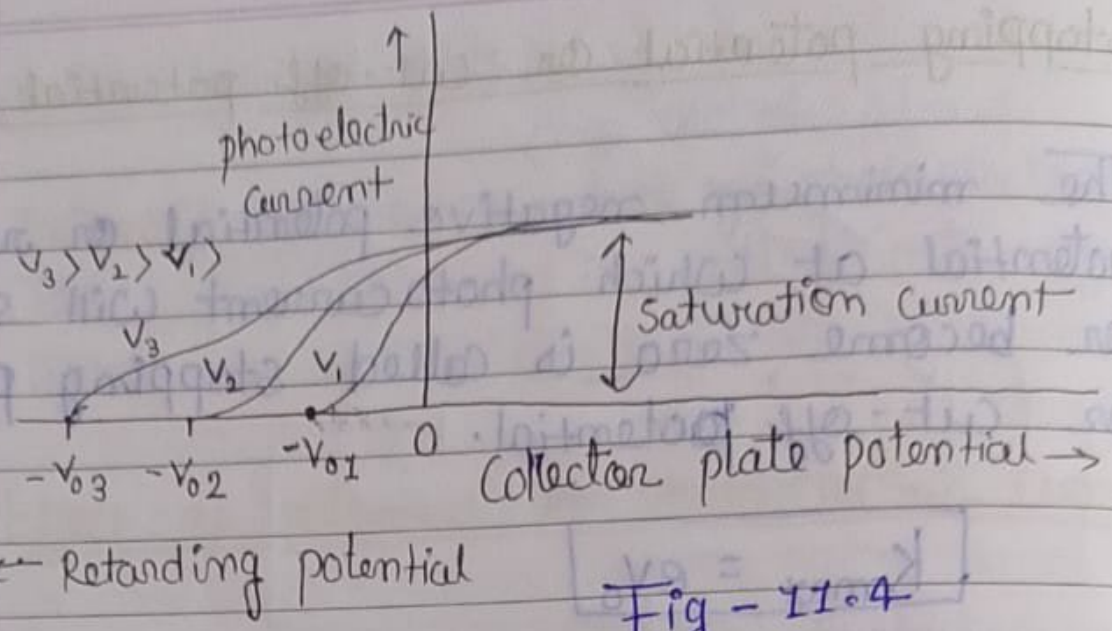

Fig - 11.4

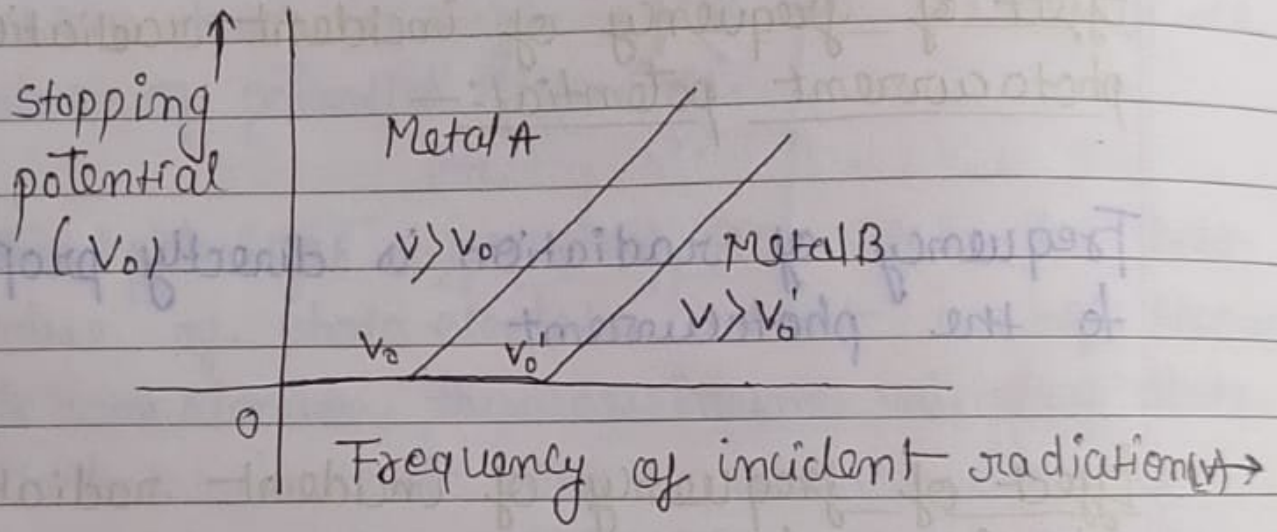

Fig 11.5

The stopping potential (V_0) is varies linearly with frequency of incidents radiation.

These observation have two implications :-

VVI

photo electric emission:—

When the light of suitable frequency falls on the metallic plate, then electrons are emitted from the metallic surface which is called photo-electric emission. And the emitted electron's are called photoelectrons.

VVI

* Work function (ϕ_0):—

The minimum amount of energy required for the emission of electron from the metallic surface is called work function.

VVI

Note:—

* Caesium [CS] has work function 2.14 ev and metal platinum [Pt] has work function 5.65 ev.

VVI

photo electric effect:—

The phenomenom of emission of electrons from the surface of metal when light of suitable frequency is falled on it is called photoelectric Effect.

intensity of light.

Intensity:- The number of photoelectron emitted per second is called intensity of light

Effect of potential on photoelectric current

The maximum value of photoelectric current which don't increase after or increasing the value of potential difference.

Or,

The potential difference at which the ~~photo~~ value of photoelectric current is ~~bef~~ become its maximum, this maximum value of photoelectric current which connot increase in further is called Saturation Current.

Or,

The photoelectric current which connot be increased after increasing the amount of potential difference is called saturation current.