1.4.PHOTOELECTRIC EFFECT

Introduction:

In 1887, Hertz discovered that electrons are emitted when ultraviolet radiation strikes on a metal surface.

- Hertz explained the photoelectric effect based on wave theory of light was unsuccessful.
- In 1905, Einstein successfully explained the photoelectric effect based on the stream of photons.

Definition:

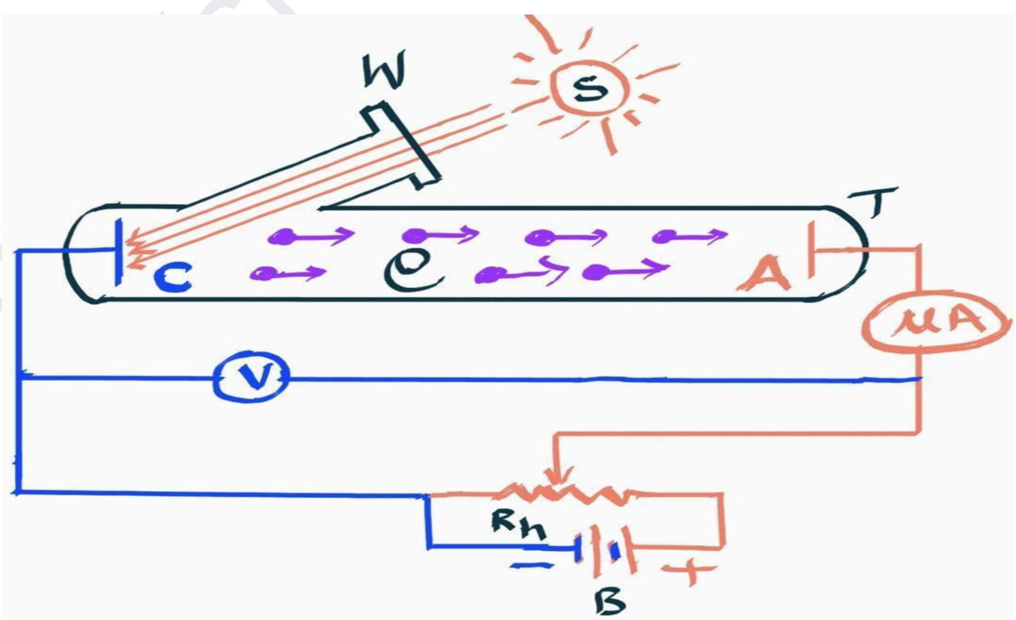
- The phenomenon in which electrons are emitted from a metal surface when light of a certain frequency strikes on it is called photoelectric effect.
- The metal surface which emitted electrons is photosensitive material and the emitted electrons are called photoelectrons & these electrons constitute the photoelectric current.

Experimental study:

- A simple experimental arrangement to study the photoelectric effect has the following apparatus shown in the figure.

1.Source of Light(S) 2.Quartz window(W) 3.Emitter (Cathode)(C)

4.collector (Anode)(A) 5.Quartz glass tube(T)



- It consists of two photosensitive metal plates C&A enclosed in an evacuated quartz glass tube.
- These two plates are connected to the battery through a microammeter (μA) & Rheostat (Rh).
- In the absence of light, there is no flow of current and hence no reading in μA.
- When monochromatic light radiation of sufficiently high frequency passes through a quartz window (w) and falls on a photosensitive metal plate (C) which acts as cathode and emits photoelectrons, it is called emitter.
- These emitted electrons are collected by plate A which acts as anode and is called collector.
- The potential difference between C & A can be varied by a Rheostat (Rh).
- The emission of photoelectrons out of 'C' gives rise to a flow of current in the outer circuit and this photoelectric current is measured by the microammeter (μA).
- Light of different wavelengths can be used by placing appropriate filters in the path of light.

Observations (or) Conditions (or) Factors affecting photoelectric effect:

Factors affecting no. of electrons emitted and their kinetic energy (or) P.E. current.

(i)The potential difference between two electrodes

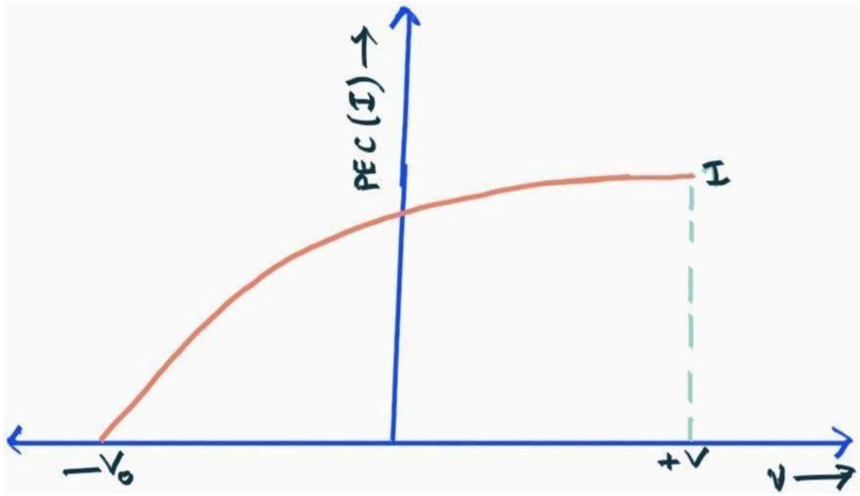
(ii)The intensity of incident radiation

(iii)The frequency of incident radiation

(iv)The photo metal used

(i)Effect of Potential difference:

(a)Collector (A) at +ve potential(+v):

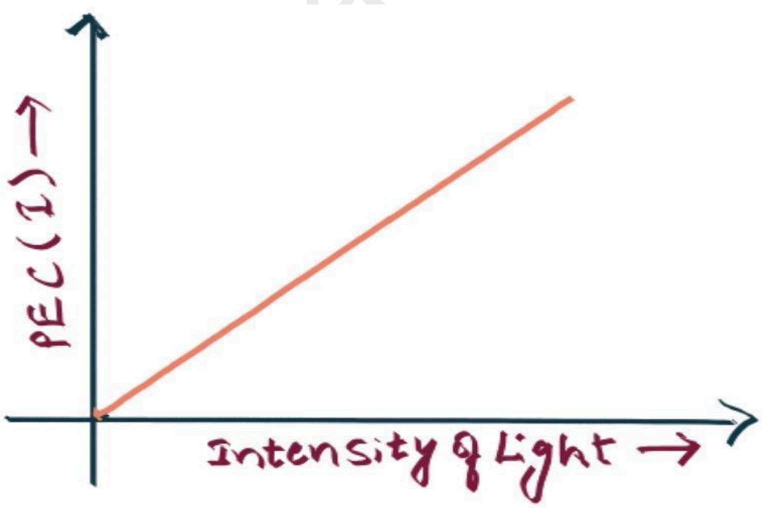


- In this case, photoelectric current (I) gradually increases with increase of potential and reaches a maximum saturation & this current is called saturation current.

(b)Collector (A) at -ve potential(-v):

- In this case, Photoelectric current (I) decreases rapidly with increase of potential and becomes zero at a certain -ve potential (-Vo) & this potential is called stopping potential (or) cut-off potential (Vo).

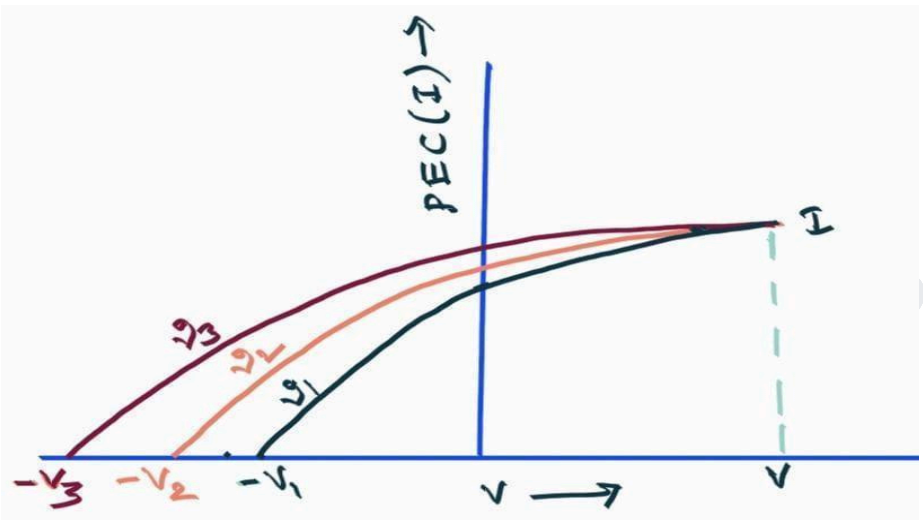
(ii)Effect of intensity of radiation:



- The photoelectric current (I) increases linearly with increase in intensity of incident light.
- From the graph, Saturation current is proportional to the intensity of incident radiation. i.e., higher is the intensity of incident radiation, higher is the saturation current.

(iii)Effect of Frequency of incident radiation:

- The values of the stopping potential will be different for different frequencies of incident light (radiation) But the values of saturation photoelectric current (I) is the same for different frequencies of incident radiation.



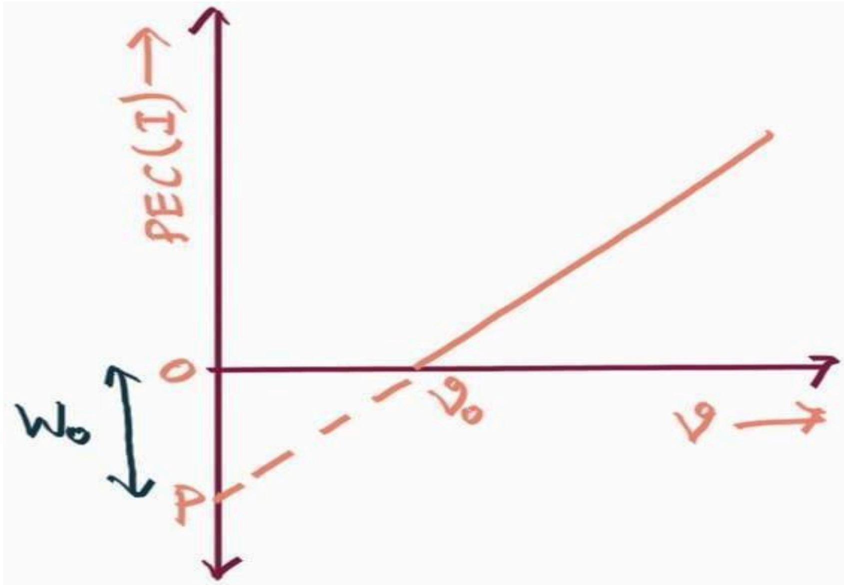
- **When $\nu = \nu_0$,** photoelectrons get emitted from the surface. This minimum value of frequency (ν_0) to get photo electrons emitted from a metal surface is called **Threshold frequency.**

That is, ν_0 = c / λo

→**where: λo** → Threshold wavelength

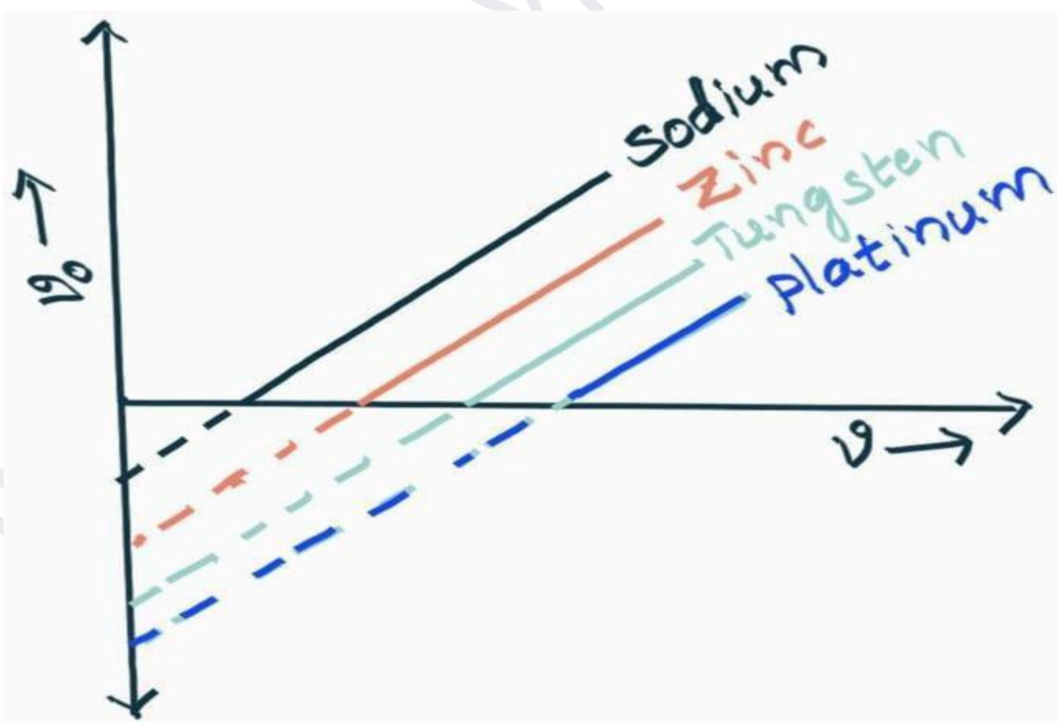
ν_0→ Threshold frequency

ν→ Frequency



The intercept 'op' on the y-axis gives the minimum energy of the incident light required to raise photo electrons from the given metal and is called the work function of the given metal (Wo).

(iv)Effect of photo metal:



- It is clear from the v versus Vo graph, that all the lines have the same slope but their interaction with the frequency axis are different. Thus, threshold frequency depends on the nature of photo metal.

Einstein's photoelectric equation:

In 1905, Einstein successfully explained the photoelectric effect on the basis of the stream of photons.

- Out of the total energy 'hν', a small portion of work function 'Wo' is spent on overcoming the potential barrier and the balance energy hν - Wo' is given to the electron as maximum kinetic energy.

$$K_{max} = h\nu - Wo \text{ --------- } (1)$$

$$h\nu = K_{max} + Wo$$

(or)

$$h\nu = 1/2\ mVmax^2 + Wo \text{---------}(3)$$

This is known as the Einstein photoelectric equation.

- **But** $W_O = h\nu_0$ & $Kmax = e\nu_S$

$$e\ \nu_s = h\nu + h\nu_0$$

$$e\ \nu_s = h\ (\nu - \nu_0)$$

$$\nu_s = h/e\ (\nu - \nu_0) \text{ --------------}(4)$$

Where: $\nu_s \rightarrow$ Stopping Potential

$\nu_0 \rightarrow$ Threshold frequency

Laws of photoelectric effect:

- The following are the laws of photoelectric effect
- The electrons will not be emitted to the metal surface unless the frequency of incident radiation is above the threshold frequency.

- The photoelectric current is independent of frequency of incident radiation]
- The photoelectric current is directly proportional to the intensity of incident radiation.
- The K.E. of photoelectrons depends on the frequency of incident radiation.
- A photoelectric field is an instantaneous process.

Applications of photoelectric effect:

- It helps to study the nuclear phenomenon
- It helps in Imaging technology in the television camera tubes & image intensifiers.
- It is used in spectroscopy, which breaks the light rays into different wavelengths.
- It is used in photoelectric cells for different purposes.