PLANCK'S QUANTUM THEORY

$$E = h\nu$$

where, **E** = energy of a quantum of radiation,

h = Plank constant = 6.627×10^{-27} erg sec

or 6.627×10^{-27} Joule sec,

ν = frequency of radiation

➤**PLANCK'S QUANTUM THEORY**- Light always moves in the form of small energy packets , these energy packets are known as photons or quanta. Energy of one photon can be hv,2hv,3hv……..nhv .

Here

v=frequency of photon

h= planck's constant .(h=6.626× 10^{-34} $j.sec$)

n=1.2,3,4……

➤The **Planck constant** compares the sum of energy a photon bears with its electromagnetic wave frequency. It is named after Max Planck, the physicist. In quantum mechanics, it is an essential quantity.

Working function or threshold energy -Minimum energy required by an electron to reach the metal surface is known as working function. It is also known as threshold energy.

Delhi frequency or threshold frequency - Minimum frequency of a proton that can provide the energy equal to working function is known as Delhi frequency.

Delhi wavelength or threshold wavelength- Maximum wavelength of a Photon that can provide the energy equal to working function to the elections is known as Delhi wavelength.

PHOTOELECTRIC EFFECT-

The **photoelectric effect** is a phenomenon in which electrons are ejected from the surface of a metal when light is incident on it. These ejected electrons are called **photoelectrons**

The ***photoelectric effect*** was first introduced by Wilhelm Ludwig Franz Hallwachs in the year 1887, and the experimental verification was done by Heinrich Rudolf Hertz. They observed that when a surface is exposed to electromagnetic radiation at a higher threshold frequency, the radiation is absorbed, and the electrons are emitted. Today, we study the photoelectric effect as a phenomenon that involves a material absorbing electromagnetic radiation and releasing electrically charged particles.

To be more precise, light incident on the surface of a metal in the photoelectric effect causes electrons to be ejected. The electron ejected due to the photoelectric effect is called a photoelectron and is denoted by e^-. The current produced as a result of the ejected electrons is called ***photoelectric current.***

Properties of the Photon

- For a photon, all the quantum numbers are zero.
- A photon does not have any mass or charge, and they are not reflected in a magnetic and electric field.
- The photon moves at the speed of light in empty space.
- During the interaction of matter with radiation, radiation behaves as it is made up of small particles called photons.
- Photons are virtual particles. The photon energy is directly proportional to its frequency and inversely proportional to its wavelength.
- The momentum and energy of the photons are related, as given below

EINSTEIN'S PHOTOELECTRIC EQUATION-

If energy of photon is E and work function is w then

Kinetic energy of electron = energy of photon - work function

K.E.= E - ϕ [$\phi = work\ function$]

$E = \phi + K$

$\therefore \quad \boxed{K = E - \phi}$

But, $E = h\nu$ ...(2)

$\phi = h\nu_0$

Using in Eqn (2) ...(3)

$$\boxed{K = h(\nu - \nu_0)}$$ ...(4)

But, $K = eVs = \frac{1}{2}mv^2$ ...(5)

$\therefore \quad \boxed{eVs = h(\nu - \nu_0)}$ ...(6)

and, $\boxed{\frac{1}{2}mv^2 = h(\nu - \nu_0)}$ ...(7)

But $\nu = \frac{c}{\lambda}$ ...(8)

and $\nu_0 = \frac{c}{\lambda}$

So **½ m** $v^2 = hc\,(\frac{1}{\lambda} - \frac{1}{\lambda 0})$

Applications of the Photoelectric Effect-

- Used to generate electricity in solar panels. These panels contain metal combinations that allow electricity generation from a wide range of wavelengths.
- Motion and Position Sensors: In this case, a photoelectric material is placed in front of a UV or IR LED. When an object is placed in between the Light-emitting diode (LED) and sensor, light is cut off, and the electronic circuit registers a change in potential difference
- Lighting sensors, such as the ones used in smartphones, enable automatic adjustment of screen brightness according to the lighting. This is because the amount of current generated via the photoelectric effect is dependent on the intensity of light hitting the sensor.
- Digital cameras can detect and record light because they have photoelectric sensors that respond to different colors of light.
- X-Ray Photoelectron Spectroscopy (XPS): This technique uses X-rays to irradiate a surface and measure the kinetic energies of the emitted electrons. Important aspects of the chemistry of a surface can be

obtained, such as elemental composition, chemical composition, the empirical formula of compounds and chemical state.

- Photoelectric cells are used in burglar alarms.
- Used in photomultipliers to detect low levels of light.
- Used in video camera tubes in the early days of television.
- Night vision devices are based on this effect.
- The photoelectric effect also contributes to the study of certain nuclear processes. It takes part in the chemical analysis of materials since emitted electrons tend to carry specific energy that is characteristic of the atomic source.

Laws of Photoelectric Effect:-

➢There is no time lag between incident radiation (photon) and ejected photoelectron.

➢ The rate of photo-emission is directly proportional to intensity of incident radiation (light).

➢The velocity and hence the kinetic energy of photo-electrons is independent of intensity of incident light.

➢The velocity and hence the kinetic energy of photo-electrons is directly proportional to frequency of incident radiation.

➢The emission of electron take place above a certain frequency known as threshold frequency. This frequency is characteristic frequency of photo-metal used.

Important Points to Remember-

- If we consider the light with any given frequency, the photoelectric current is generally directly proportional to the intensity of light. However, the frequency should be above the threshold frequency in such a case.
- Below threshold frequency, the emission of photoelectrons completely stops despite the high intensity of incident light.
- A photoelectron's maximum kinetic energy increases with an increase in the frequency of incident light. In this case, the frequency should exceed the threshold limit. Maximum kinetic energy is not affected by the intensity of light.
- Stopping potential is the negative potential of the opposite electrode when the photo-electric current falls to zero.
- The threshold frequency is described as the frequency when the photoelectric current stops below a particular frequency of incident light.
- The photoelectric effect establishes the quantum nature of radiation. This has been taken into account to be proof in favor of the particle nature of light.