Photoelectric effect

Photoelectric effect can be defined as the process of emission of electrons from the surface of metals when electromagnetic radiation of suitable frequency falls on the surface of metal. These electrons are termed as **photoelectrons** and the current so produced is known as **photoelectric current**.

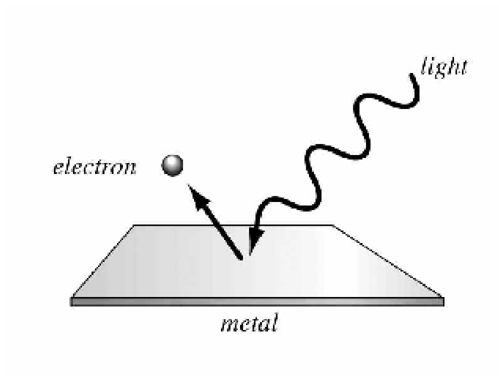

Figure 1: Photoelectric effect

Einstein's photoelectric equation

On the basis of Planck's idea of quantum of energy, Einstein explained photoelectric emission. According to this theory, the light radiations consist of discrete packets of energy called quanta. Each photon travels with the speed of light and has the energy

$$E = hf \tag{1}$$

where, $h = 6.63 \times 10^{-34} Js$ is the Planck's constant and f is frequency of photon.
Einstein proposed that one electron is emitted from the metal surface if one photon of suitable frequency falls on it. Let us consider that a photon of light having frequency falls on the metal surface. Then the energy of the photon (hf) will be shared in two ways.

(a) A part of energy of the photon is used in overcoming the force that binds the electron with the metal surface. This energy is known as the work function (ϕ) of the metal which is the minimum energy required to liberate an electron from the surface of metal without imparting any kinetic energy to it.

(b) The rest of the energy of photon is used to impart kinetic energy to the emitted photoelectron.
Now, kinetic energy of the photoelectron $(E_k) = \frac{1}{2}mv^2$
where, v is the velocity and m is the mass of the emitted photoelectron. So, we can write,
Energy of photon = work function + kinetic energy of emitted electron

$$\text{or,} \quad hf = \phi + E_k$$

$$hf = \phi + \frac{1}{2}mv^2 \tag{2}$$

Equation (2) represents the Einstein's photoelectric equation. If the incident photon of energy is the minimum energy called the threshold energy and the corresponding frequency of the light is f_0, then the incident energy hf_0 will just sufficient to eject the photoelectron out of the metal surface without imparting any kinetic energy to the photoelectron. Hence, we can write

$$hf_0 = \phi$$

Substituting in equation (2), we have,

$$hf = hf_0 + E_k \tag{3}$$

$$E_k = h(f - f_0) \tag{4}$$

Explanation of laws of photoelectric emission

The laws of photoelectric emission can be explained as follows:

(i) Each photoelectron, emitted from the metal surface, is imparted the necessary energy by a single photon. This means no photoelectron absorbs energy from more than one photon to gain the energy required to leave the surface of the metal. However, this also supports the linear relation between the number of photoelectron emitted and the intensity of the incident radiation (number of photons falling on the metal surface per second).

(ii) If $f < f_0$, kinetic energy of the photoelectron will be negative, which is impossible. Thus, the photoelectric emission does not take place for the radiation having the frequency below the threshold value.

(iii) If $f > f_0$, kinetic energy of the photoelectron is found to be proportional to the frequency of the incident light. If the intensity of the incident radiation is increased under this condition, the number of electrons emitted from the surface of the metal increases proportionately.

(iv) The photoelectric emission is due to an effect of elastic collision between a photon and an electron inside the surface of the metal. This collision results in the absorption of photon's energy at an instant and the transfer of energy is almost instantaneous. This explains the time lag between the incident photon and the emission of the photoelectrons being less than 10^{-9} seconds.

Thus, it can be said that the photoelectric effect is feasible only if the incident light is in the form of quanta of energy; each packet has energy, more than the work function of the metal surface. It reveals the fact that light is not of wave nature but of particle nature. This is why, laws of photoelectric emission was accounted by quantum theory of light.

Photons

The light radiations consist of discrete packets of energy called **Photons or quanta**. These photons are the bundles (packets) of energy, which are emitted by a source of radiation.

Important characteristics of photons

1. According to Planck's quantum theory, a source of radiation radiates energy in the form of photons, which travel in a straight line.
2. The energy of photon is $E = hf = \frac{hc}{\lambda}$, where $h = 6.63 \times 10^{-34} Js$, $f =$ frequency of photon and $\lambda =$ wavelength of photon.
3. There is a change in velocity of a photon in different media, due to change in its wavelength.
4. The frequency of photon gives the radiation, a definite energy (or colour), which does not change when photon travels through different media.
5. They are electrically neutral and are not deflected by electric and magnetic fields.
6. They travel with the speed of light (c).

Applications of photoelectric effect

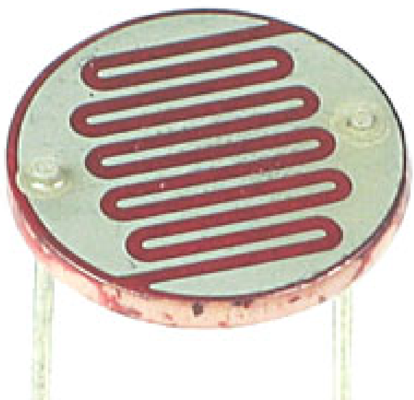

Figure 2: Photocell

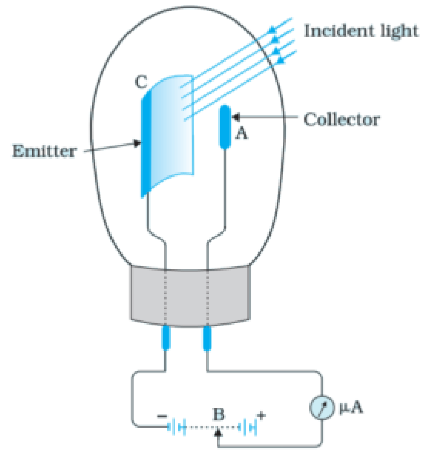

Figure 3: Schematic representation of a photocell

Photocells work on the principle of photoelectric effect. A photocell is a device which converts light energy into electric energy. It is used in the reproduction of sound which is recorded on a movie film. It is used in the exposure meter while taking a photograph by camera to know the correct time of exposure. It is used in lux-meter to measure the intensity of light and it is also used in a burglar alarm.