Chapter 16 – Corpuscular Aspect of Light (Photoelectric Effect)

Photoelectric Effect: is the phenomenon of the emission of electrons from the surface of a body (generally a metal) when illuminated by suitable radiation.

Plank's postulate: the exchange of energy between matter and radiation is quantized.

Einstein's postulate: radiation itself is quantized: light is composed of particles called photons. These photons are of zero mass and zero charge and travel in vacuum at the speed of light.

All photons of a monochromatic radiation of frequency ν have same energy:

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

where h is a fundamental constant called Plank's constant.
Photon energy is usually excessed in eV.

To extract an electron from a metal, we have to supply it with a minimum energy called work function W_0.

For a pure metal, photoelectric emission takes place only if the frequency of the incident radiation is greater than or equal to a minimum frequency ν_0, characteristic of the metal, called threshold frequency.
To this threshold frequency ν_0 corresponds a wavelength in vacuum called threshold wavelength λ_0 where:

$$\boldsymbol{\lambda_0 = \frac{c}{\nu_0}}$$

If $E < W_0$ or $\nu < \nu_0$ or $\lambda > \lambda_0 \Longrightarrow$ Electrons are not extracted.
If $E = W_0$ or $\nu = \nu_0$ or $\lambda = \lambda_0 \Longrightarrow$ Electrons are extracted with a zero speed.
If $E > W_0$ or $\nu > \nu_0$ or $\lambda < \lambda_0 \Longrightarrow$ Electrons are extracted with a maximum kinetic energy $K.E = \frac{1}{2}mV^2$ where:

$$\boldsymbol{E = W_0 + K.E}$$

$$\boldsymbol{h\nu = h\nu_0 + \frac{1}{2}mV^2 \Longrightarrow \frac{hc}{\lambda} = \frac{hc}{\lambda_0} + \frac{1}{2}mV^2}$$

Notes:

- Photoelectric emission is quasi-instantaneous whatever the intensity of the incident radiation.
- The kinetic energy depends on the frequency of the incident radiation and independent of its intensity.
- When the intensity of the radiations increases, the number of the emitted electrons (photocurrent) increases.
- The intensity of the electric current is: $I = \frac{Q}{t} = \frac{Ne}{t}$.
- The energy of N photons is $E = Nh\nu$.
- For a source of power P: $E = P \times t \Longrightarrow Nh\nu = Pt \Longrightarrow N = \frac{Pt}{h\nu}$
- The quantum efficiency: $r = \frac{N_{eff}}{N}$.