SEM-IV

PHYH-C IX: ELEMENTS OF MODERN PHYSICS

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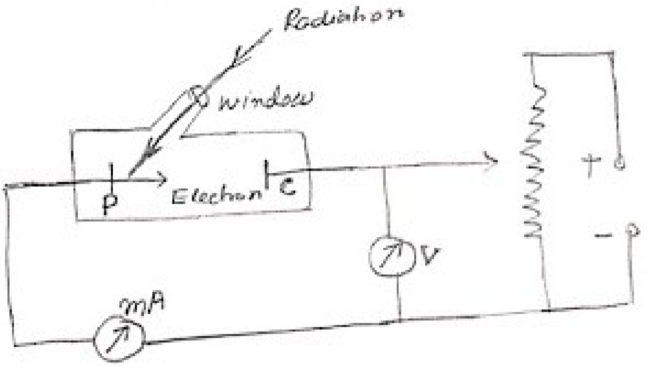
PHOTOELECTRIC EFFECT:

Photoelectric Effect: (1)

When electromagnetic radiations of sufficiently high frequencies (Such as u.v ray or X-ray) fall on some metal surface, electrons are emitted from the metal surface. This phenomenon is Knocon as **photoelectric effect.**

The emitted electrons from the metal surface due to photoelectric effect called **photoelectrons**

The current produced in a circuit due to emission of electrons from metal surface by the effect of light is Knocon as **photocurrent.**



When a suitable radiation is incident on the electrode P, electrons are ejected from it. If C is at a positive potential with respect to P, photoelectrons emitted from P are accelerated towards C. As a result photoelectric current I flowing through the circuit and it can be measured with the help of milliammeter. The accelerating potential difference can be measured with the help of voltmeter V.

If the potential difference between two electrodes is revised i.e C is at negative potential, the electrons are retarded to overcome retarding potential. As a result photocurrent is reduced.

Stoping Potential:

The minimum retarding potential for which photocurrent will be zero is called stopping potential (V_0)

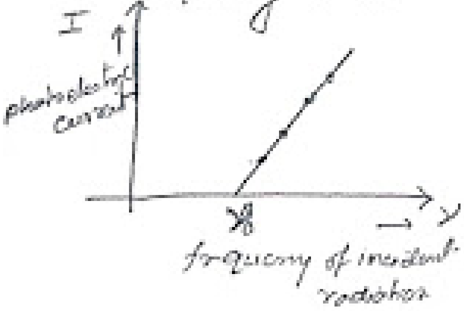
In this case, the work done by stoping potential is equal to the maximum kinetic energy ($\frac{1}{2} m v_{max}^2$) of the electron i.e.

$$eV_0 = \frac{1}{2} m v_{max}^2$$

Thus, stoping potential gives the estimate of the maximum kinetic energy of the emitted photoelectrons.

⊛ Important Results from experimental study of photoelectric effect:

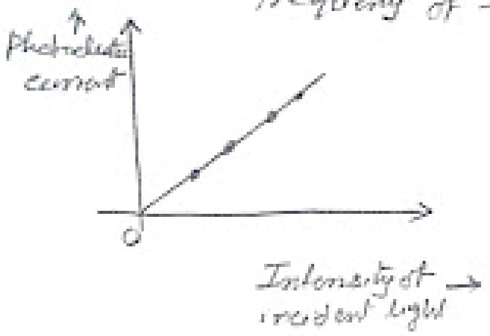
1. when the frequency of incident radiation is above a certain critical value (ν_0) depending on the nature of the metal plates, emission of photoelectrons takes place. This critical frequency is called threshold frequency



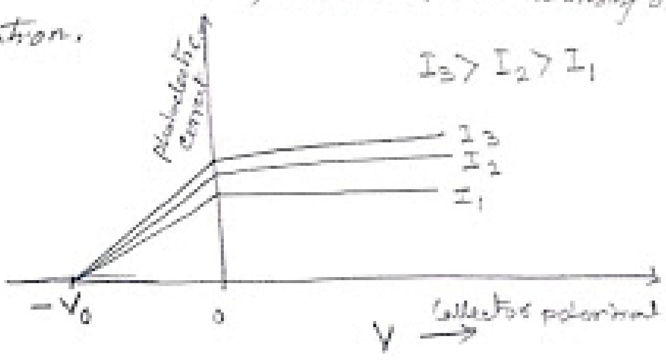
2. The emission of photoelectrons start at the same instant of the light with appropriate frequency fall on the metal plate. It has been observed that the time lag between the incident photon and emission of photoelectron is less than 10^{-8} s. so the photoelectric emission is almost instantaneous

3. The maximum K.E of emitted electrons of a particular metal plate, is directly proportional to the frequency of the incident light. It is independent of the intensity of the incident light.

4. The strength of the photoelectric current is directly proportional to the intensity of the incident light. It is independent of the frequency of the incident light.



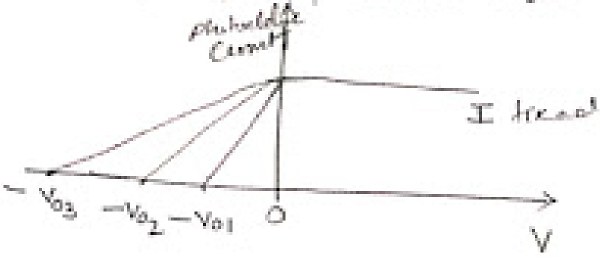
5. Stoping potential (V_0) is independent of the intensity of incident radiation.



If we measure photoelectric current for various values of Collector potential (V) taking Intensity (I) of the incident light as a parameter for a fixed frequency (ν).
Then photoelectric current increase with increase of intensity of incident light. But stoping potential remain same.

(4)

6. The Stoping potential for a given metal increases with the frequency of incident light.



7. The rate of emission of photoelectrons does not depends upon the temperature of the plate. So the photoelectric effect is different from that of thermoelectric emission.

Failure of Electromagnetic theory to explain the experimental results of photoelectric effect:

① The electromagnetic theory fails to explain why photoelectric emission is almost instantaneous emission.

② The electromagnetic theory fails to explain the non-dependance of maximum K.E of a photoelectron on the intensity of incident photon.

③ The electromagnetic theory fails to explain the existance of therhold frequency for any material.

Einstein's Photoelectric equation

In 1905 Einstein applied the quantum theory of light to explain photoelectric effect.
He considered that
1.Light is composed of discrete energy packets called photons that move with velocity of light in space .The energy of photon $= h\nu$, Where $h = 6.627 \times 10^{-}34$ plank constant and ν frequency of incident light.

2. Photoelectric effect is a collision between incident photons and electrons inside the metal. An incident photon of energy $h\nu$ is completely absorbed by the electron during collision.

The minimum energy required to liberate an electron from metal surface is known as work function of an electron of the particular metal surface.The corresponding frequency is known as threshold frequency. Thus , when a photon of energy $h\nu$ is absorbed by an electron , an amount of energy at lest equal to$W_0 = h\nu_0$ is used to liberate the electronfrom the metal surface. the excess energy $h\nu - W_0$ which is absorbed by the outgoing electron of mass m will be appeared as its maximum K.E $= \frac{1}{2}mv_{max}^2$

$$h\nu - W_0 = \frac{1}{2}mv_{max}^2 \tag{0.1}$$

or

$$h\nu = h\nu_0 + \frac{1}{2}mv_{max}^2 \tag{0.2}$$

This equation is known as Einstein photoelectric equation.
Mathematical Problems:
PROBLEM-1 A ray of ultraviolet light of wavelength $3000A^0$ *falls on a surface of a metal whose work function is* 2.28 *ev. This eject an electron . What will be the velocity of emitted electron?*

PROBLEM-2 Ultraviolet light of wavelengths $800A^0$ *and* $700A^0$ *when allowed to fall on hydrogen atoms in their ground state is found to liberate electron with K.E* $1.8ev$ *and* $0.4ev$ *respectively. Find the value of plank constant.*

PROBLEM-3 When radiation of frequency 7.5×10^14 *Hz is incident on a metal surface , electron are emitted with maximum energy* $1.6 \times 10^{-}19$ *Jule. What is the lowest frequency of radiation required for emission of electron from the metal surface?*

PROBLEM-4 If the light of wavelength $6000A^0$ *falls on a metal surface and emits photoelectrons with velocity of* $4 \times 10^5 ms^{-1}$*, What is its threshold wavelength?*