Date : 08-06-2021

Expt. No : 1

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1. PHOTOELECTRIC EFFECT

Aim:

To determine the plank's constant, threshold frequency and work function of the metal by photoelectric effect.

Apparatus Required:

1. Photocell
2. Mercury Lamp
3. DC Voltage Source
4. Digital Voltmeter
5. A set of filters of different wavelengths.

Introduction:

The photoelectric concept was first started by becquerel in 1839. Later many scientist like Hertz, Lenard went on different ~~wo se~~ reasearches and gave different concepts on this Photoelectric effect.

In 1901 plank gave a statement that energy of photon is directly proportional to the frequency.

$$E \propto \nu$$

$$E = h\nu$$

He defined a proportionality constant 'h' which is known as plank's constant. [$h = 6.626 \times 10^{-34}$ Js]

But he just gave qualitative idea on photoelectric effect.

The equation he introduced make a brief change in Physics. We started a new domain in physics called Quantum

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Mechanics.

In 1905, Einsten applied Quantum Mechanics to this photoelectric effect and gave a quantitative analysis. He gave the expression of photoelectric effect

$$h\nu = h\nu_0 + \frac{1}{2} m v_{max}^2$$

Theory:

When light wave of sufficient energy incident on a metal then electrons are ejected from its surface. This phenomenon is known as photoelectric effect.

The emitted electrons are called as photo electrons and the current produced by these electrons is called photo electric current.

The Minimum amount of energy required to eject the electrons from the metal surface is called Workfunction. The Workfunction can be expressed interms of frequency,

$$\phi = h\nu_0$$

where h is the plank's constant

ν_0 is the Threshold frequency

(Minimum frequency for photo electric effect).

According to Einstein,

The incident energy is utilised in 2 ways,

(i) Absorbed by the electron to eject from the metal surface.

(ii) Balance energy is used up in giving the electron a kinetic energy.

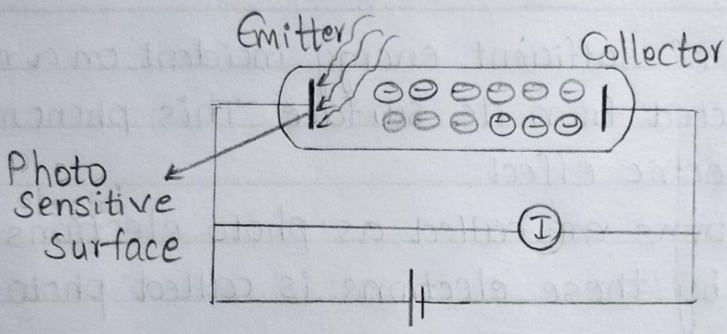


Fig 1

The photoelectric effect equation,

$$E = \phi + KE$$

$$h\nu = h\nu_0 + \frac{1}{2} m v_{max}^2$$

$$\frac{1}{2} m v_{max}^2 = h\nu_0 - h\nu$$

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

where V_{max} is the Maximum velocity of emission of photoelectron.

Laws of photoelectric effect :

(i) Photoelectrons are ejected from the metal surface only when the energy of incident radiation is greater than or equal to the workfunction of the metal.

(ii) If we increase the intensity of light (no. of photons) then more no. of electrons will eject, this implies increase in current

Thus, Intensity of light is directly proportional to the current.

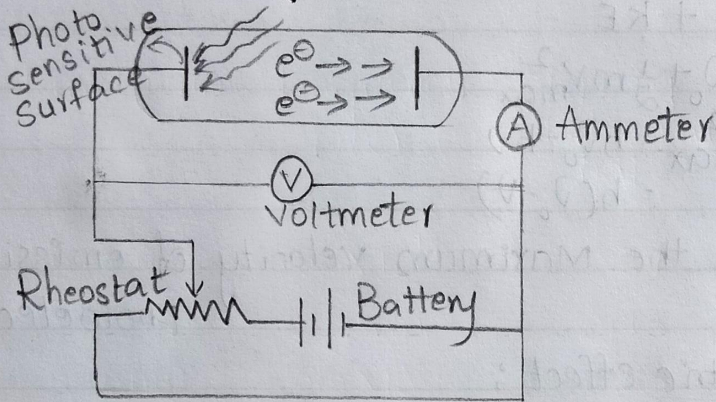
(iii) From the Einstein equation, it is clear that kinetic energy depends on frequency of incident light.

Thus, Frequency of light is directly proportional to the kinetic energy

Now the voltage is connected in such a way that positive terminal with emitter and negative terminal with collector as shown in Fig 1.

when V=0, current will be Maximum.

Experimental Diagram:-



By keeping the intensity of light constant, if we increase the voltage then the current start retarding. For a particular voltage, current will be zero. This voltage is known as stopping potential.

Thus KE can be expressed in the form of stopping potential,

$$\frac{1}{2}mv_{max}^2 = eV_0 \quad \text{where } e = 1.6\times10^{-19} C$$

Einstein equation,

$$\frac{1}{2}mv_{max}^2 = h(\nu-\nu_0)$$

$$eV_0 = h(\nu-\nu_0)$$

$$V_0 = \frac{h}{e}(\nu-\nu_0)$$

If we draw the graph for above equation, then we will get a straight line for stopping potential versus frequency (which will not pass through origin).

From the slope we can calculate the plank's constant and from x-intercept work-function can be calculated.

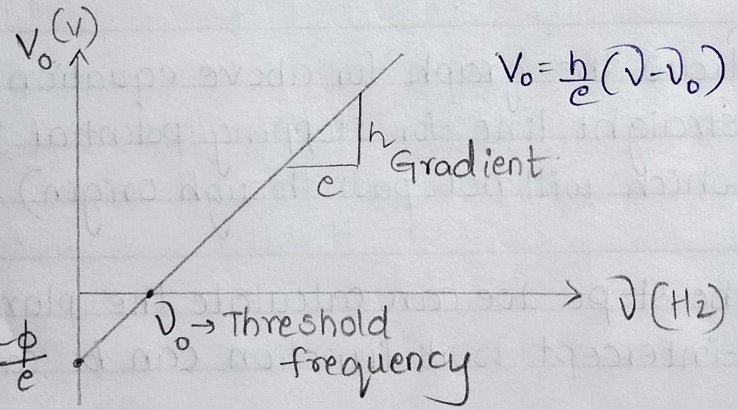
Procedure :

1. Connect the apparatus as shown in experimental diagram.
2. Filters are arranged according to their wavelengths either in increasing or decreasing order
3. The first filter is inserted in the slot.
4. Now switch on the light source.
5. We can observe the value of photoelectric current in ammeter. The slowly increase the voltage value in the

Observation Table :

S.No	Wavelength	frequency (Hz)	Stopping potential (Trail 1)	Stopping potential (Trail 2)	Average
1.	625 nm	4.8×10^{14}	0.27	0.28	0.275
2.	565 nm	5.31×10^{14}	0.43	0.44	0.435
3.	545 nm	5.5×10^{14}	0.53	0.57	0.55
4.	530 nm	5.66×10^{14}	0.63	0.65	0.64
5.	470 nm	5.38×10^{14}	0.97	0.93	0.95

Graph :



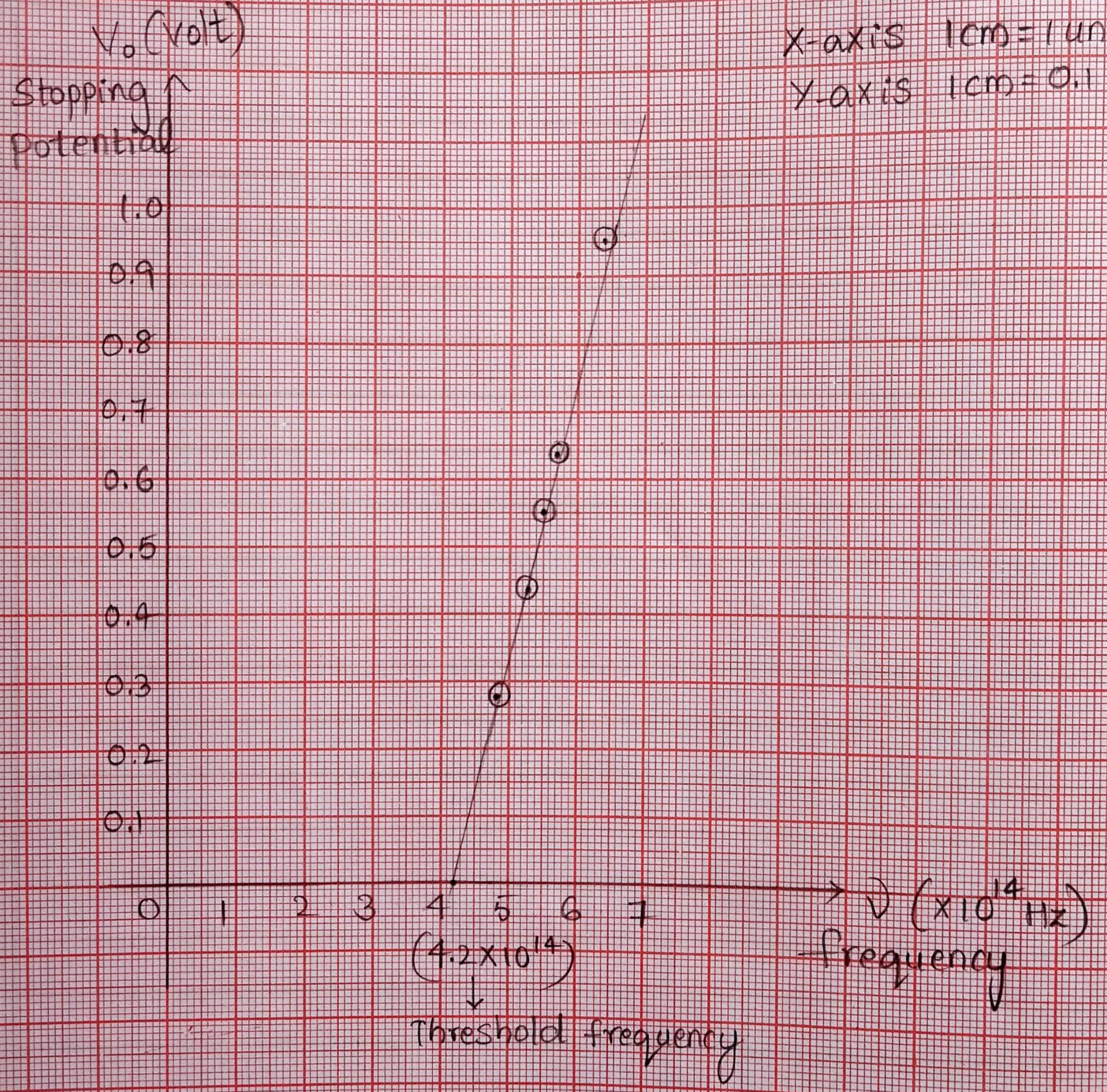
(1) Slope $= \frac{h}{e}$

(2) X-intercept = Threshold frequency (ν_o) $\begin{bmatrix} V_o = 0 \\ \nu = \nu_o \end{bmatrix}$

(3) Y-intercept $= \frac{-h\nu_o}{e} = \frac{-\text{Work function}(\phi)}{e}$ $[\nu = 0]$

Graph for Record book

Scale:
X-axis 1cm = 1 unit
Y-axis 1cm = 0.1 unit



Calculation :

From graph, $slope = \frac{0.95-0}{(6.5-4.2)\times 10^{14}}$

$= \frac{0.95}{2.3} \times 10^{-14}$

$= 0.413 \times 10^{-14}$

$h_{graph} = slope \times 1.6 \times 10^{-19}$
$= 0.6608 \times 10^{-33}$
$= 6.608 \times 10^{-34}$ J S

Threshold frequency $(\nu_0) = 4.2 \times 10^{14}$ Hz

From Table, $V_0 = \frac{h}{e}(\nu - \nu_0)$

$h = \frac{eV_0}{\nu - \nu_0}$

$h_1 = \frac{1.6 \times 10^{-19} \times 0.275}{(4.8-4.2)\, 10^{14}}$

$= 7.33 \times 10^{-34}$ J.S

$h_2 = \frac{1.6 \times 10^{-19} \times 0.435}{(5.31 - 4.2)\, 10^{14}}$

$= 6.27 \times 10^{-34}$ J.S

$h_3 = \frac{1.6 \times 10^{-19} \times 0.55}{(5.5-4.2)\, 10^{14}}$

$= 6.76 \times 10^{-34}$ J.S

$h_4 = \frac{1.6 \times 10^{-19} \times 0.64}{(5.66-4.2)\, 10^{14}}$

$= 7.01 \times 10^{-34}$ JS

$h_5 = \frac{1.6 \times 10^{-19} \times 0.95}{(6.38-4.2)\, 10^{14}} = 6.97 \times 10^{-34}$ J.S

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$$h_{avg} = \frac{h_1 + h_2 + h_3 + h_4 + h_5}{5}$$

$$h_{avg} = 6.868 \times 10^{-34} \text{ J.S}$$

$$\text{Final } h = \frac{h_{avg} + h_{graph}}{2}$$

$$= \frac{(6.868 + 6.608)}{2} \times 10^{-34}$$

$$h = 6.738 \times 10^{-34} \text{ J.S}$$

$$\text{Work function} = h\nu_0$$

$$= 6.738 \times 10^{-34} \times 4.2 \times 10^{14} \text{ J}$$

$$= 28.2996 \times 10^{-20} \text{ J}$$

$$= \frac{28.2996 \times 10^{-20}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\phi = 1.7687 \text{ eV}$$

Error Calculation :

$$\text{error } \% = \left| \frac{h_{theoretical} - h_{experimental}}{h_{theoretical}} \right| \times 100$$

$$= \left| \frac{6.626 \times 10^{-34} - 6.738 \times 10^{-34}}{6.626 \times 10^{-34}} \right| \times 100$$

$$= 1.69 \%$$

$$\simeq 1.7 \%$$

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voltmeter till the current become zero.

6. Note that particular stopping potential value in the table.

7. Repeat the process by placing the other filters

Results :

(i) Plank's constant (h) = 6.738×10^{-34} Js

(ii) Threshold frequency (ν_0) = 4.2×10^{14} Hz

(iii) Work function (ϕ) = 1.7687 eV

Conclusion :

From the experiment, the value of plank's constant was found to be 6.738×10^{-34} Js with an error of 1.7% with the theoretical value of h (6.626×10^{-34} Js).

The work function of the metal was found to be 1.7687 eV.

Applications :

1. In Nuclear processes
2. Chemically analyzing materials based on their emitted electrons
3. Imaging Technology
4. In paper industry to measure the thickness of paper.
5. Automatic switching of street lights