20CSE1030 Zubin Shah

Aim: To determine
1) The threshold frequency for photoelectric emission
2) Work function of photoemission matter.
3) To calculate the planck's constant.

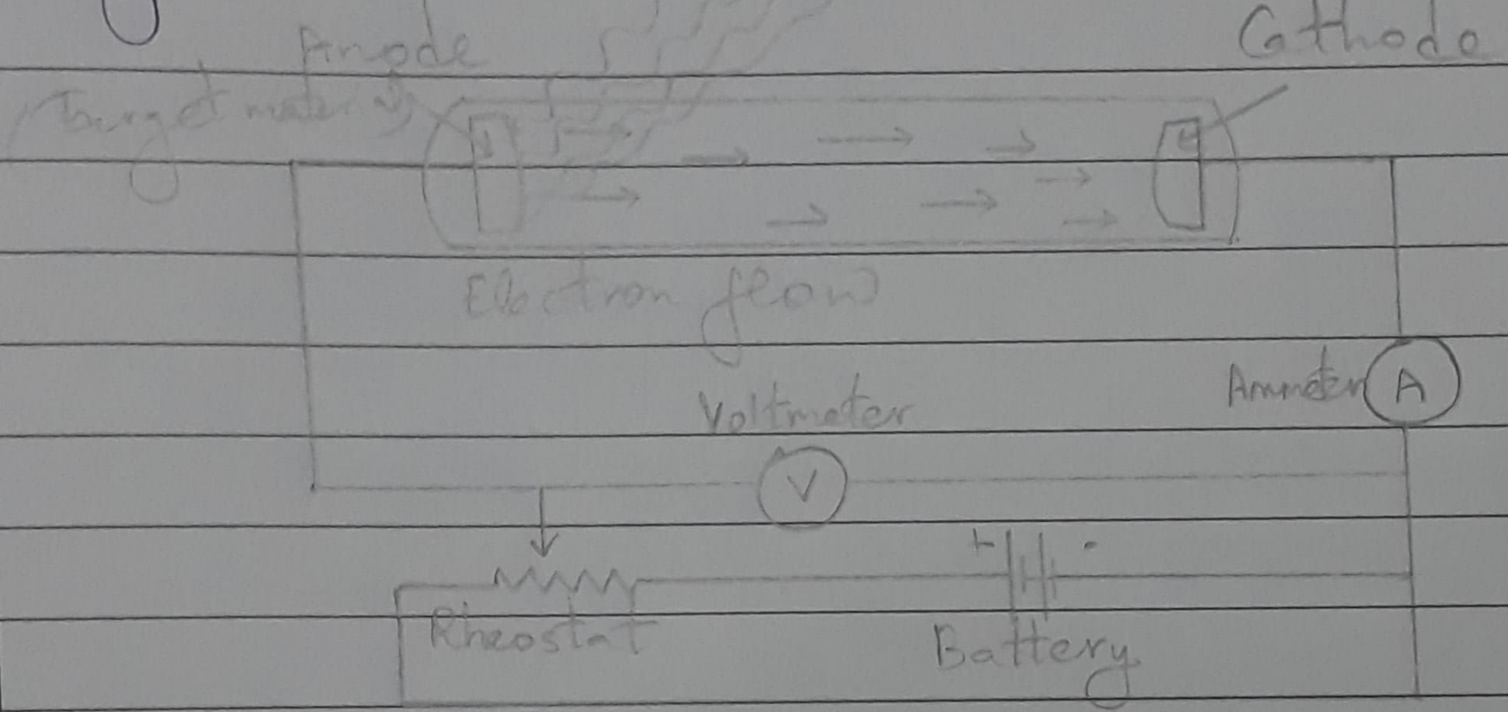
Apparatus: Planck's constant consisting of a photocell
Mercury vapor lamp
DC voltage source
A set of filters

Introduction:
- Photoelectric effect and its experimental verification by Albert Einstein was a major milestone in the history of physics which changed its course from the classical physics to the quantum mechanics.
- Max planck's Quantum theory helped the development of modern physics.
- Planck's constant 'h' & the electronic charge 'e' are generally associated together as ratio 'h/e'.
- There were many attempts even before Einstein to determine this ratio
- In 1901 Max Planck proved that energy contained in the photons emitted by a moving electron is directly proportional to its frequency.
- The proportionality constant, called by him as "Quantum of action", is now known as Planck's constant $h = 6.626 \times 10^{-27}$ ergs/sec.
- Planck recieved the Nobel Proze in Physics in 1918 for this fundamental discovery and it eventually let to many more fundamental discoveries in the field of quantum mechanics.
- The photoelectric effect involves emission of electrons

(photoelectron) from the surface of a material when light impinges on it. It was first observed by Alexander Edmond Bacquerel in 1839.

- Later (1887) Heinrich Hertz & Philipp Lenard (1902) published the first through investigation of photoelectric effect.
- But it was Albert Einstein (1905) who applied quantum mechanics and obtained an expression for the photoelectric effect.
- He showed how the photon energy is used to overcome the potential barrier and release electrons from the outer orbit of an atom and provide them necessary kinetic energy to move out of the surface of the material and reach a collector where they can be counted in terms of electric current.
- For this invention, he was awarded the 1912 Nobel prize in physics.

Diagram:



Experimental setup for photoelectric effect

Theory:

- Emission of electrons from a metal piece when illuminated by light or any other radiation of suitable frequency or wavelength is called photoelectric effect.

- The ejected electrons are called photoelectrons and the directed motions of photoelectrons constitute photoelectric current.

- The magnitude of photoelectric current is directly proportional to the intensity of the incident light.

- The photocell shown in fig 1 consists of a photosensitive surface called emitter, a collector in an evacuated quartz bulb.

- According to Einstein, when a single photon is incident on the metal surface, it is ~~compl~~ completely observed and import its energy is a single electron during collision. The photon energy is utilized for the two purposes.

1. Partly for getting the electron free from the atom and away from the metal surface. This energy is known as photoelectric work function(ϕ) of the metal.
2. The balance of the photon energy is used up ~~is~~ in giving the electron a kinetic energy. Therefore Einstein photoelectric equation can be written as :-

$$h\nu = \phi + \frac{1}{2}mv^2 \quad \text{—— (i)}$$

Note: In case the photon energy is just ~~e~~ sufficient to liberate the electron on then

$$h\nu_0 = \phi_0 \quad \text{—— (ii)}$$

from both eq. $KE = \frac{1}{2}mv^2_{max} = h(\nu - \nu_0)$ —— (iii)

Increase in frequency of incident light increase the velocity with which photoelectrons are ejected. Now when the voltage is reverse i.e. when the emitter is made positive with respect to collector photoelectric current does not immediately drop to zero provided that emitter.

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- The retarding potential difference between the two electrodes at which the photoelectric current reduced to zero is known as stopping potentials.

- Now V_{max} is maximum velocity of emission of a photoelectron and V_0 is stoping potential then
  $\frac{1}{2} m v^2_{max} = eV_0$

- Therefore, Einstein photoelectric equation may be expressed in terms of stopping potential as:

$$h\nu = \phi + eV_0 \quad \text{or} \quad h\nu = h\nu_0 + eV_0$$

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

The graph of the equation(4) shown in fig. is a straight line with slope h/e when $V_0 = 0$

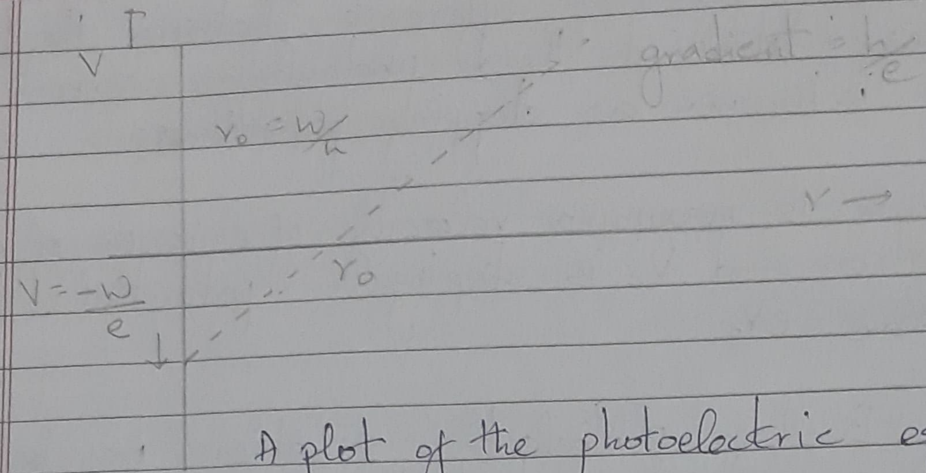
$$\frac{h\nu}{e} = \frac{h\nu_0}{e}$$

$$\nu = \nu_0$$

Therefore, Planck's constant $h = e * slope$

Work function $\phi_0 = \frac{h}{e} * \nu_0$

or $\phi_0 = slope * \nu_0$ (eV)



A plot of the photoelectric equation.

- The x-axis intercept would represent the reciprocal of the threshold wavelength
- The slope would equal the expression $\frac{hc}{q}$ &
- The y-axis intercept would represent the work function divided by the fundamental charge of an electron

Procedure:

1. The mode of the swith is kept in reverse position.
2. Filters are arranged in the order of decreasing wavelength
3. Filters with maximum wavelength is inserted in the slot.
4. The lamp is situated on.
5. When slowly increase the negative voltage required to reduce the photocurrent to zero value and is known as stopping potential.
6. The experiment is repeatedly done for other filters and values for corresponding stopping potentials are tabulated.

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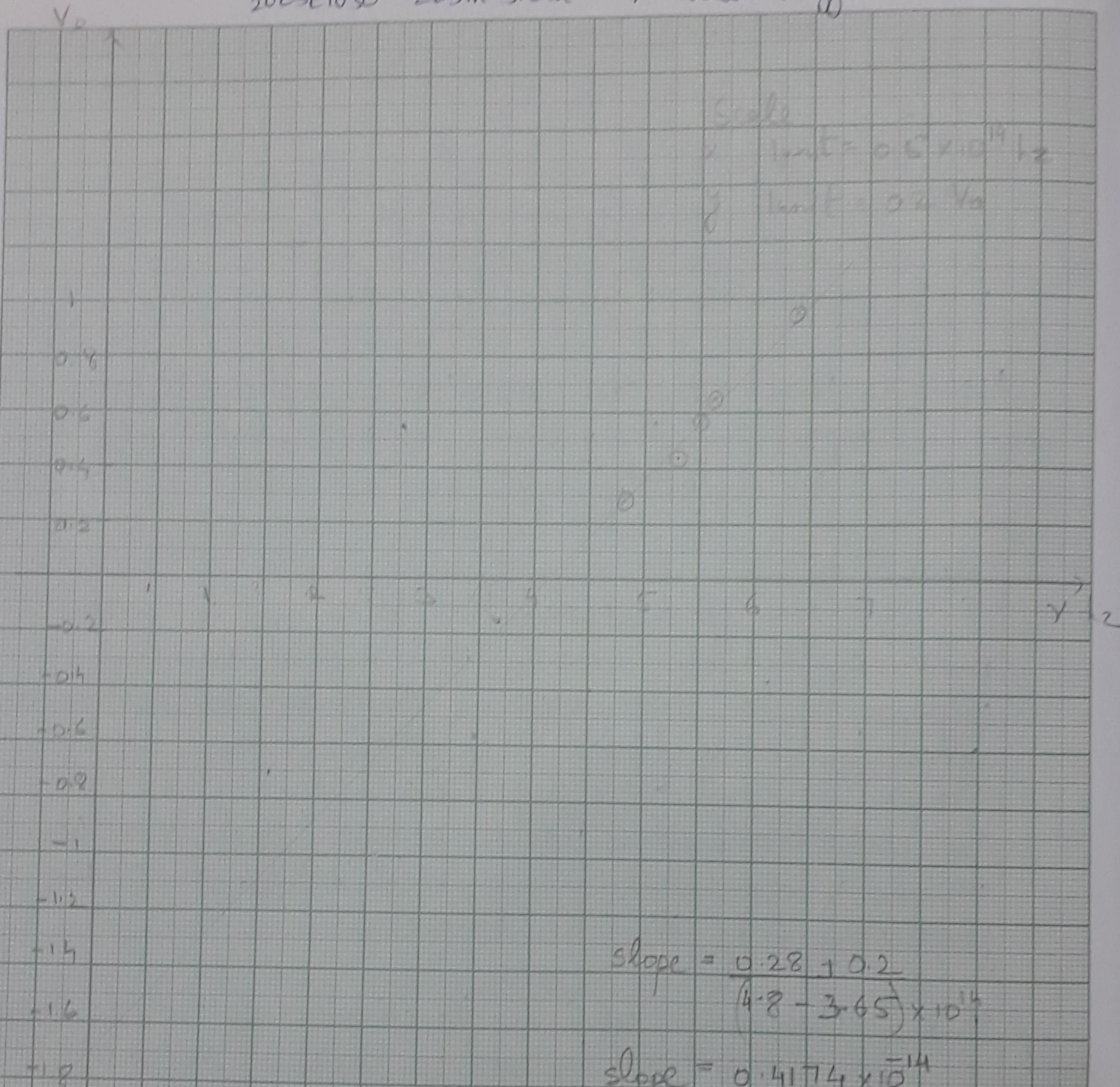

$$\text{slope} = \frac{0.28 + 0.2}{(4.8 - 3.65) \times 10^{14}}$$

$$\text{slope} = 0.4174 \times 10^{-14}$$

~~Observer~~

Calculations:

Slope of graph $= 0.4174 \times 10^{-14}$

Y-intercept $= -1.7$

from Equation $V_0 = \frac{h}{e}\nu - \frac{h\nu_0}{e}$

slope : $\frac{h}{e} = 0.4174 \times 10^{-14}$

$h = 1.6 \times 10^{-19} \times 0.4174 \times 10^{-14}$

$h = 6.6875 \times 10^{-34}$ Js from graph

Y intercept $-\frac{h\nu_0}{e} = -1.7$

$\nu_0 = \frac{1.7 \times 1.6 \times 10^{-19}}{6.6875 \times 10^{-34}}$

$\nu_0 = 4.0728 \times 10^{14}$ Hz

Work function $= \phi_0 = h\nu_0$

$= 6.6875 \times 10^{-34} \times 4.0728 \times 10^{14}$

$\phi = 1.649$ eV

Observation table:

Sr. No.	Wavelength nm	Frequency Hz	T_1 Volts	T_2 volts	T_{avg} Volts	h $\times 10^{-34}$ Js
1	625	4.8×10^{14}	0.27	0.29	0.28	6.169
2	565	5.31×10^{14}	0.43	0.45	0.44	5.698
3	545	5.504×10^{14}	0.56	0.58	0.57	6.381
4	530	5.66×10^{14}	0.64	0.66	0.65	6.561
5	470	6.383×10^{14}	0.97	0.94	0.95	6.6231

$h_{avg} = \frac{h_1 + h_2 + h_3 + h_4 + h_5}{5} = 6.2864 \times 10^{-34}$ Js

Planck constant $h = \dfrac{h_{avg(calc)} + h_{graph}}{2}$

$= \dfrac{6.2864 \times 10^{-34} + 6.6875 \times 10^{-34}}{2}$

$= 6.48695 \times 10^{-34}$ Js

$$\text{Percentage error} = \left(\frac{6.626 \times 10^{-34} - h}{6.626 \times 10^{-34}}\right) \times 100$$

$$= \left(\frac{6.626 - 6.48695}{6.626}\right) \times 100$$

$$= 2.099\%$$

Result:

1. The threshold frequency $\nu_0 = 4.0728 \times 10^{14}$ hz.
2. Work function $\phi_0 = h\nu_0 = 1.649eV$.
3. Planck's constant $h = 6.48695 \times 10^{-34}$ Js

Conclusion: The planck's constant ~~kw~~ was found to be 6.48695 Js which has a percentage error of 2.099% from the true planck's constant $h = 6.626 \times 10^{-34}$ Js.

Precautions:

1. The source of light should be very intense.
2. The distance between source and photocell should beconstant for one set of reading.
3. The experiment should be performed in a dark room

Applications of photoelectric effect.

1. Photo cell in solar panels.
2. Sensors.
3. Used in photography.