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Expt. No. 8: ..... Photoelectric effect :- Advanced Material analysis through Quantum Physics Page No. .....

Aim :- (i) Determination of Planck's constant
(ii) Determination of 'work function' of given material
(iii) Study of photoelectric effect

Apparatus :- (i) Photo electric equipments
(ii) filters

Theory :- Hertz noticed a spark between the two metallic balls when a high frequency radiation incident on it. This is called photoelectric effect. It is the emission of electrons when electromagnetic radiations having sufficient frequency incident on certain metal surfaces. We call the emitted electrons as photoelectrons and the current they constitute as photo current. The phenomenon was first observed by Heinrich Hertz in 1880 and explained by Albert Einstein in 1905 using Max Planck's ~~eqn~~ experiment which demonstrated the quantum theory of energy levels, photoelectric effect experiment is of great historical importance. It has been observed that there must be a minimum energy needed for electrons to escape from a particular metal surface and is called work function 'W' for that metal. The work function can be expressed in terms of frequency as,

$$W = h\nu_0$$

where h is the Planck's constant and ν_0 is the threshold frequency (minimum frequency for photoelectric effect).

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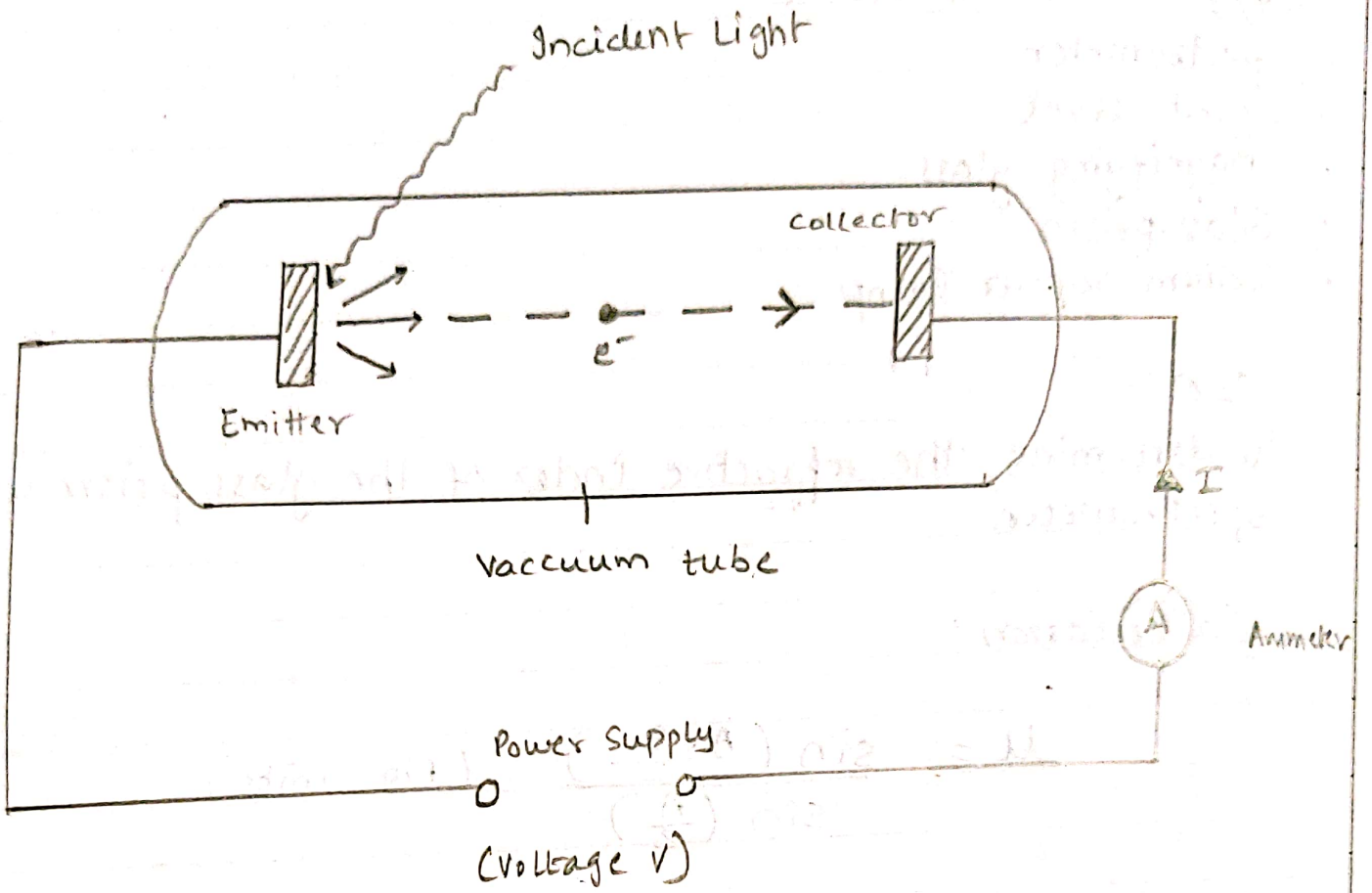
Incident Light
collector
e⁻
Emitter
I
Vacuum tube
A
Ammeter
Power Supply
(Voltage V)

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The work function for some metals are listed in the table

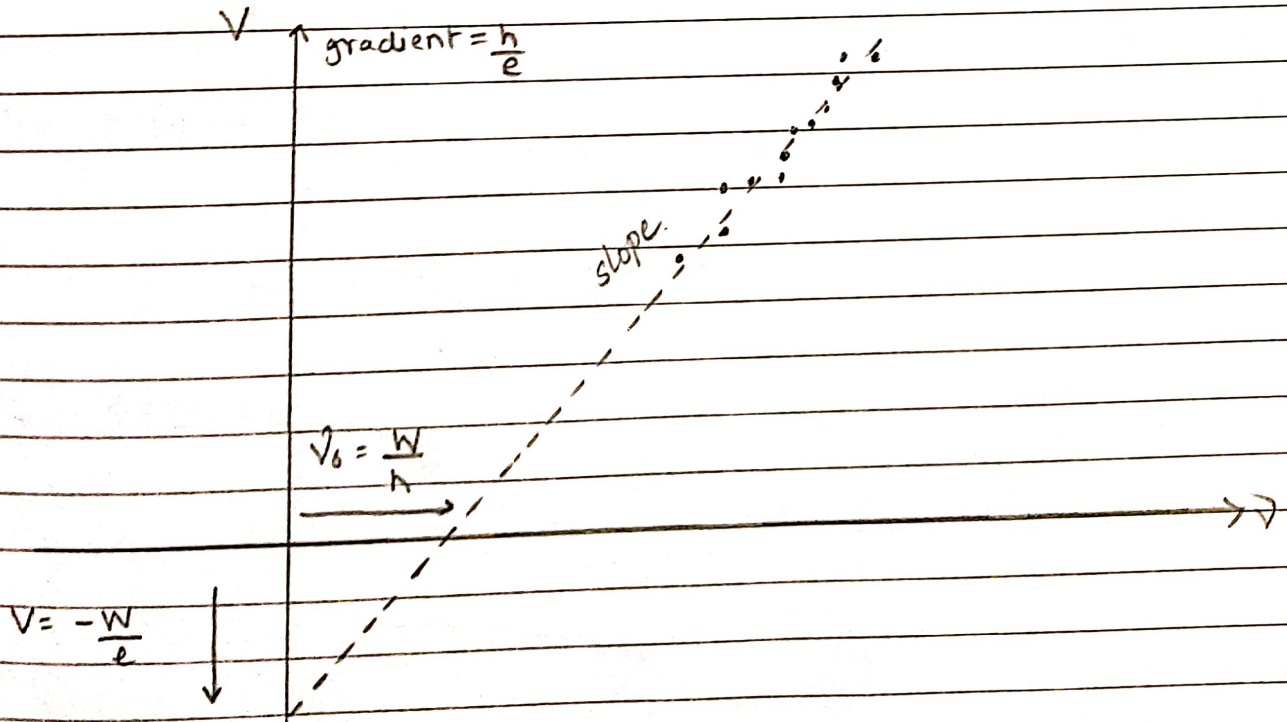
METAL	WORK Fn (eV)
Pt	6.4
Ag	4.7
Na	2.3
K	2.2
Cs	1.9

According to Einstein, the photoelectric effect should obey the equation :-

$$h\nu = KE + W$$

$$h\nu = eV_s + W \qquad \left[\nu = \frac{c}{\lambda}\right]$$

$$V_s = \frac{h\nu}{e} - \frac{W}{e}$$



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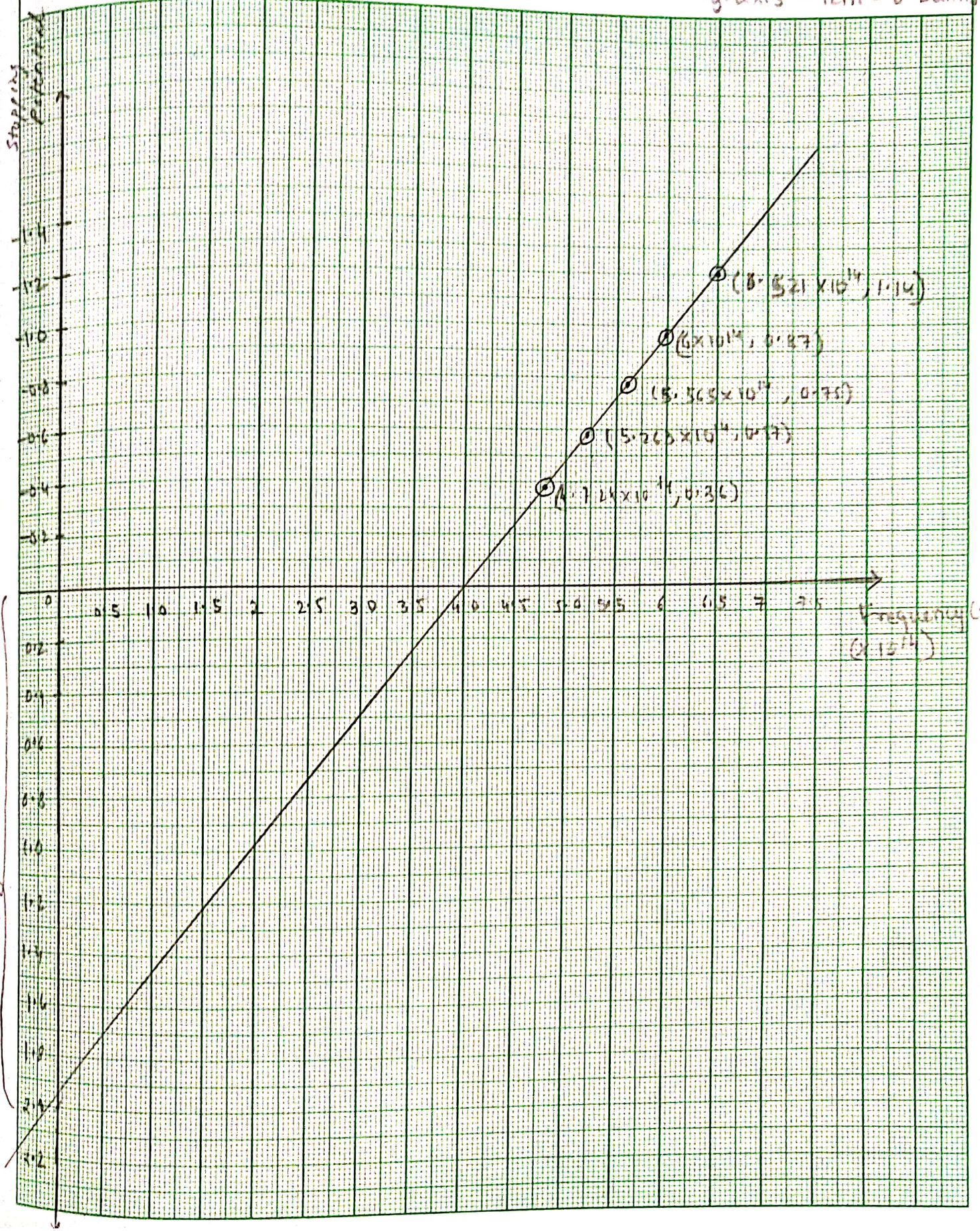
Observation Table

S. No.	Incident photon wavelength (nm)	Incident photon frequency (sec^{-1})	Stopping voltage (V_s)
1.	460	6.521×10^{14}	−1.14
2.	500	6×10^{14}	−0.87
3.	540	5.555×10^{14}	−0.75
4.	570	5.263×10^{14}	−0.57
5.	635	4.724×10^{14}	−0.36

Slope = 0.389×10^{-14} $\left(\frac{h}{e} = \frac{0.21}{0.539 \times 10^{14}}\right)$

Scale:- x-axis - 1cm = 0.5unit

y-axis - 1cm = 0.2units



Calculation :-

$$\nu = \frac{c}{\lambda}$$

For 460 nm $= \frac{3 \times 10^8}{460 \times 10^{-19}}$

$$\nu_1 = 6.521 \times 10^{14}\ s^{-1}$$

For 500 nm $= \frac{3 \times 10^8}{500 \times 10^{-9}}$

$$\nu_2 = 6 \times 10^{4}\ s^{-1}$$

For 540 nm $= \frac{3 \times 10^8}{540 \times 10^{-9}}$

$$\nu_3 = 5.555 \times 10^{14}\ s^{-1}$$

For 570 nm $= \frac{3 \times 10^8}{570 \times 10^{-9}}$

$$\nu_4 = 5.263 \times 10^{14}\ s^{-1}$$

For 635 nm $= \frac{3 \times 10^8}{635 \times 10^{-9}}$

$$\nu_5 = 4.724 \times 10^{4}\ s^{-1}$$

Slope of graph :- $\frac{h}{e} = -\frac{[V_1 - V_2]}{\nu_2 - \nu_1} = \frac{0.57 - 0.36}{(5.263 - 4.724) \times 10^{14}}$

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$\frac{h}{e} = 6.389 \times 10^{-14}$ Vs

h = slope $\times e = 6.233 \times 10^{-34}$ Js

From the graph, work function $\phi = 1.95$ eV

Result :- The value of Planck's constant from given graph & calculations $= 6.233 \times 10^{-34}$ Js
Work function $= 1.95$ eV

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