Nishant Jindal

$$\boxed{K.E_{max} = h\nu - \psi}$$

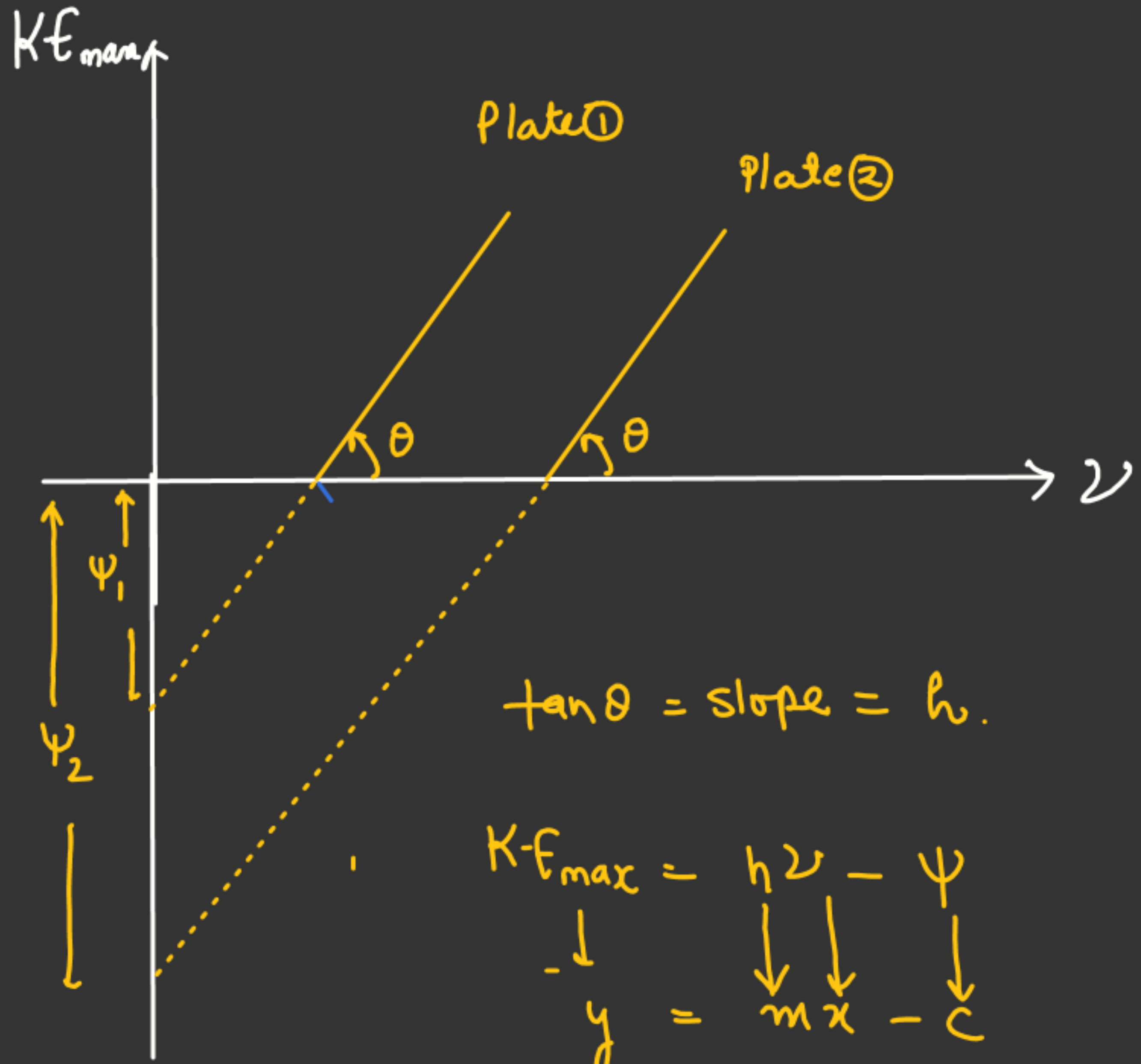
$$\boxed{\psi = \frac{hc}{\lambda_0}}$$

$\nu = \frac{c}{\lambda}$
$\Downarrow$
Frequency.

$$K.E_{max} = eV_0$$

V_0 = Stopping Potential

$$\boxed{eV_0 = h\nu - \psi}$$



$\tan\theta$ = slope = h.

$$K.E_{max} = h\nu - \psi$$
$$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$$
$$y = mx - c$$

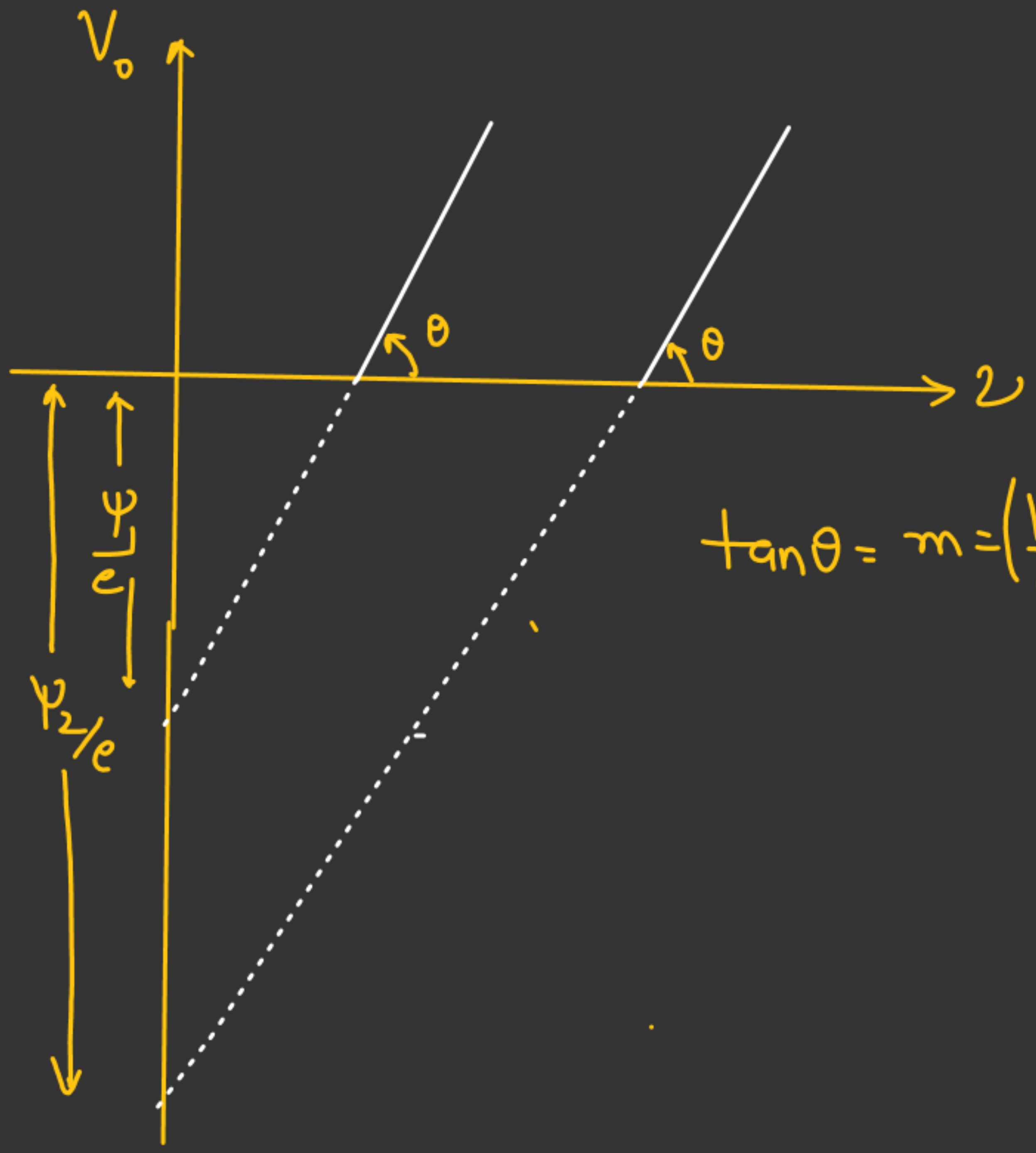
Intercept = ψ

Nishant Jindal

$$eV_0 = h\nu - \psi$$

$$V_0 = \left(\frac{h}{e}\right)\nu - \left(\frac{\psi}{e}\right)$$

$$y = mx - c$$



$$\tan\theta = m = \left(\frac{h}{e}\right)$$

PHOTOELECTRIC EFFECT

Q.1 In a photoemission experiment, the maximum kinetic energies of photoelectrons from metals P, Q and R are E_P, E_Q and E_R respectively, and they are related by $E_P = 2E_Q = 2E_R$. In this experiment, the same source of monochromatic light is used for metals P and Q while a different source of monochromatic light is used for the metal R. The work functions for metals P, Q and R are $4.0eV, 4.5eV$ and $5.5eV$, respectively. The energy of the incident photon used for metal R, in eV, is **(2021)**

$E_p = 2E_Q$

$K.E_{max} = h\nu - \psi$

$(h\nu - \psi_p) = 2(h\nu - \psi_Q)$

$h\nu = 2\psi_Q - \psi_p = 4.5 \times 2 - 4$

$(h\nu) = 5 e.V$

$E_p = (5-4)$

$= 1 e.V$

K.E max of plate R $\rightarrow E_R = h\nu' - \psi_R$

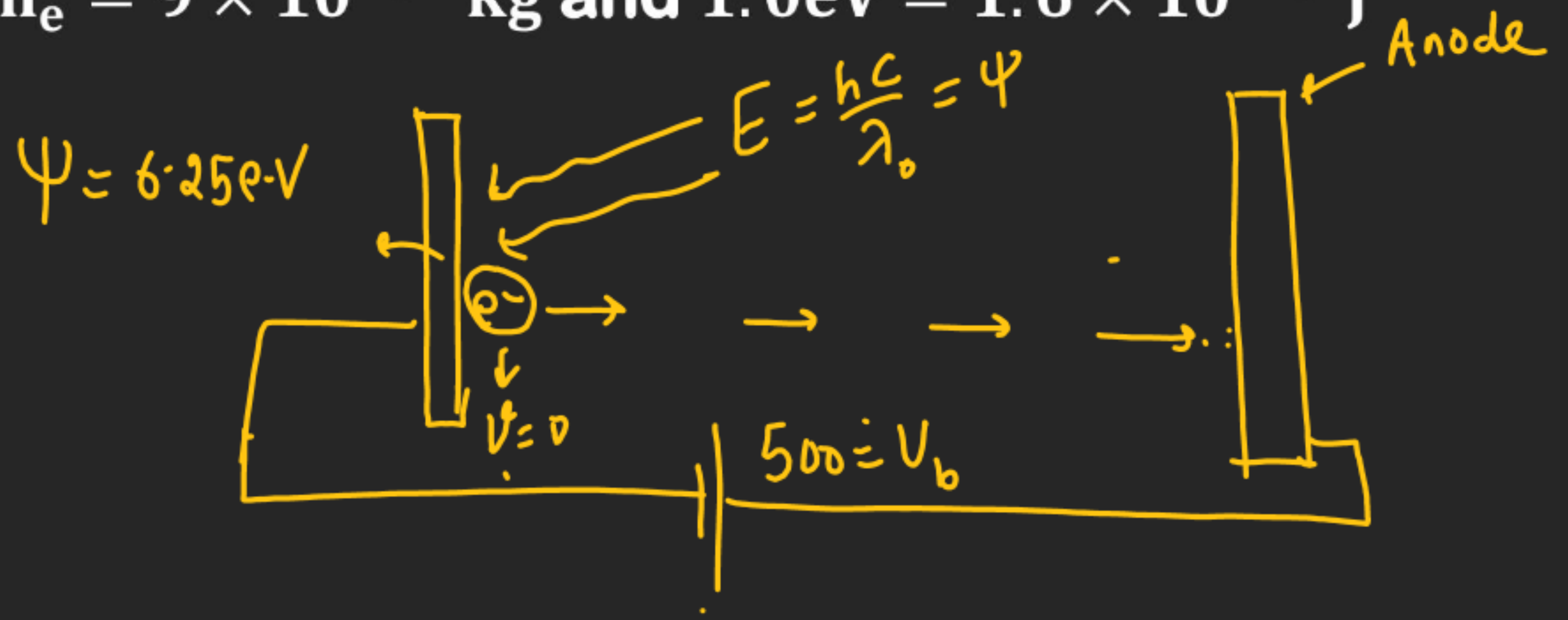
$\frac{E_p}{2} = h\nu' - \psi_R$

$\frac{1}{2} + \psi_R = h\nu'$

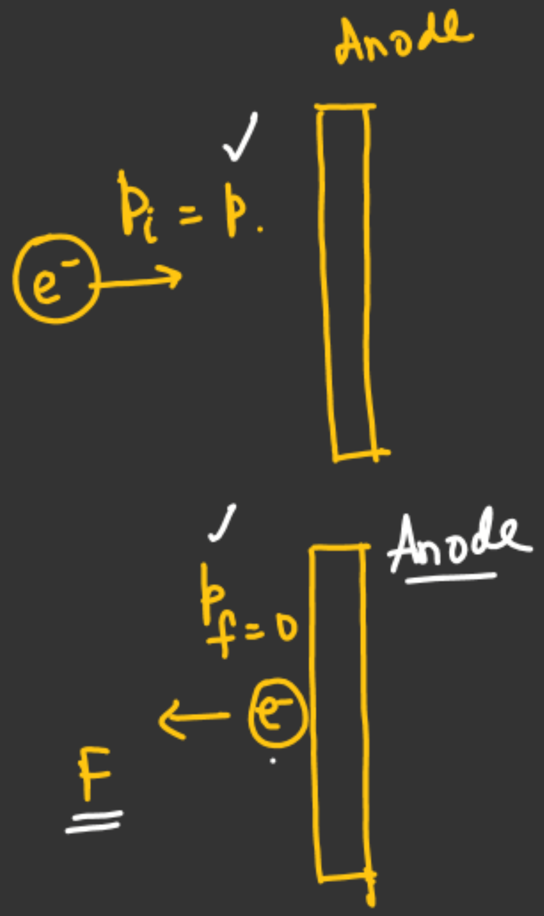
$h\nu' = \frac{1}{2} + 5.5 = 6 e.V$ ✓

PHOTOELECTRIC EFFECT

Q.2 In a photoelectric experiment a parallel beam of monochromatic light with power of $200\ \mathrm{W}$ is incident on a perfectly absorbing cathode of work function $6.25\mathrm{eV}$. ψ The frequency of light is just above the threshold frequency so that the photoelectrons are emitted with negligible kinetic energy. Assume that the photoelectron emission efficiency is 100%. A potential difference of $500\ \mathrm{V}$ is V_b applied between the cathode and the anode. All the emitted electrons are incident normally on the anode and are absorbed. The anode experiences a force $\mathrm{F} = \mathrm{n} \times 10^{-4}\ \mathrm{N}$ due to the impact of the electrons. The value of n is__. Mass of the electron $\mathrm{m_e} = 9 \times 10^{-31}\ \mathrm{kg}$ and $1.0\mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}$ **(2018)**



Nishant Jindal



$$F = \left(\frac{\Delta p}{\Delta t}\right)$$

Force per second $= |\Delta p|$

$$F = p$$

Work done by battery $= (K.E)$ ⇓ (Kinetic energy of electron absorbing on anode plate)

$$eV_b = (K.E)$$

$$p = \sqrt{2m(K.E)}$$

Momentum

$$= \sqrt{2meV_b}$$

$$n \times 10^{-4} = \left(\frac{200}{6.25 \times 1.6 \times 10^{-19}}\right) \times \sqrt{2meV_b}$$

⇓ No of Photoelectrons emitted.

⇓ [Change in Momentum of an electron

Power = $\frac{\text{Energy}}{\text{time}}$

$n = 24$ Ans.

Energy per second of incident beam = 200

Energy of one photoelectron $= \psi = 6.25\,eV$

$= 6.25 \times 1.6 \times 10^{-19}$

Nishant Jindal

PHOTOELECTRIC EFFECT

Q.3 A silver sphere of radius $1\ \mathrm{cm}$ and work function $4.7\mathrm{eV}$ is suspended from an insulating thread in free space. It is under continuous illumination of $200\ \mathrm{nm}$ wavelength light. As photoelectrons are emitted, the sphere gets charged and acquires a potential. The maximum number of photoelectrons emitted from the sphere is $A \times 10^{Z}$ (where $1 < A < 10$). The value of Z is **(2011)**

$h\nu = 1242\ \mathrm{eV\,nm}$

Photoelectric emission stop.
when

$h\nu - 4.7 = (K.E)_{max}$

$h\nu = \frac{hc}{\lambda} = \left(\frac{1242}{200}\right) = 1.51\ \mathrm{e.V}$

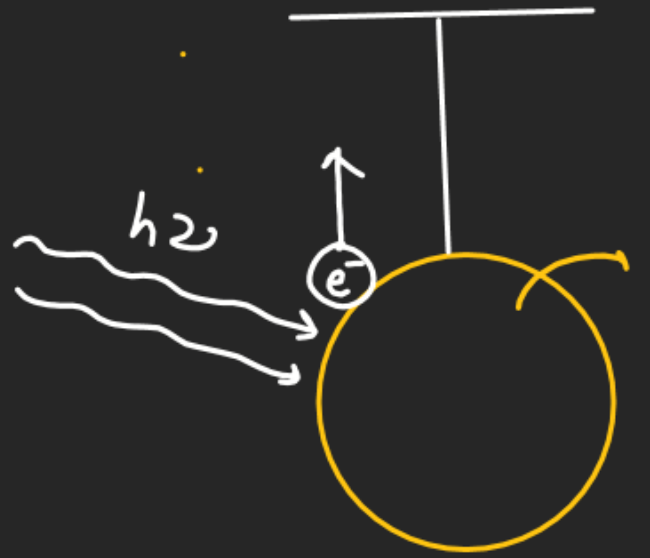
$V = 1.51$ Volt.

$(1.51) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2} \Rightarrow Q = \_\_\_\_$

$ne = \_\_\_\_$

$n =$

$eV_{sphere} = (K.E)_{max}$



PHOTOELECTRIC EFFECT

Q.4 When a beam of 10.6eV photons of intensity $2.0\ \text{W/m}^2$ falls on a platinum surface of area $1.0 \times 10^{-4}\ \text{m}^2$ and work function 5.6eV, 0.53% of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per second and their minimum and maximum energies (in eV) Take $1\text{eV} = 1.6 \times 10^{-19}$ J. **(2000)**

$0 \le (\text{Energy of photoelectrons}) \le (K.E)_{max}$

Energy of one photon = 10.6 eV

Total Energy = $(10.6 \times n)$

n = No of incident photons.

$\text{Intensity} = \left(\dfrac{\text{Energy incident}}{\text{time} \times \text{Area}}\right)$

$\dfrac{10.6 \times n}{t} = 2 \times 10^{-4}$

$K.E_{max} = h\nu - \phi$

$\dfrac{\text{Energy incident}}{\text{Time}} = I \times A = (2 \times 10^{-4})$

$\left(\dfrac{n}{t}\right) = \left(\dfrac{2 \times 10^{-4}}{10.6 \times 1.6 \times 10^{-19}}\right)$

No of Incident photon per second

$\left(\begin{matrix}\text{No. of Photoelectrons} \\ \text{emitted}\end{matrix}\right) = \left(\dfrac{0.53}{100}\right) \times \left(\dfrac{2 \times 10^{-4}}{10.6 \times 1.6 \times 10^{-19}}\right) = 6.25 \times 10^{11}$ ✓

PHOTOELECTRIC EFFECT

Q.6 Electrons in hydrogen like atoms $(Z = 3)$ make transitions from the fifth to the fourth orbit and from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate and eject photoelectrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 volt. Calculate the work function of the metal and the stopping potential for the photoelectrons ejected by the longer wavelength.

(Rydberg constant $= 1.094 \times 10^{7}\ \mathrm{m^{-1}}$)

$V_0 = 3.95$ volt

Stopping potential $= 3.95$ eV

$(K.E)_{max} = 3.95\,eV$ **(1990)**

$$E_{max} = 13.6(3)^2\left[\frac{1}{9} - \frac{1}{16}\right]$$

$$h\nu' = 13.6 \times 9\left(\frac{7}{9 \times 16}\right)$$

$$= \left(\frac{13.6 \times 7}{16}\right) e\text{-}V$$

$$= \underline{5.95\ e\text{-}V}$$

$$\varphi = (5.95 - 3.95)\, e\text{-}V$$

$$= \underline{2\ e\text{-}V}$$

Nishant Jindal

For longer wavelength.

$$h\nu = 13.6(9)\left[\frac{1}{16}-\frac{1}{25}\right]$$

$$= \underline{\qquad\qquad}.$$

$$(K.E)_{max} = \underline{0.754\ eV}$$

$$(h\nu - \psi) = (K.E)_{max}$$

Corresponding to longer Wave length

$$\left[13.6\times 9\left[\frac{1}{16}-\frac{1}{25}\right]\right] - 2 = (K.E)_{max}$$

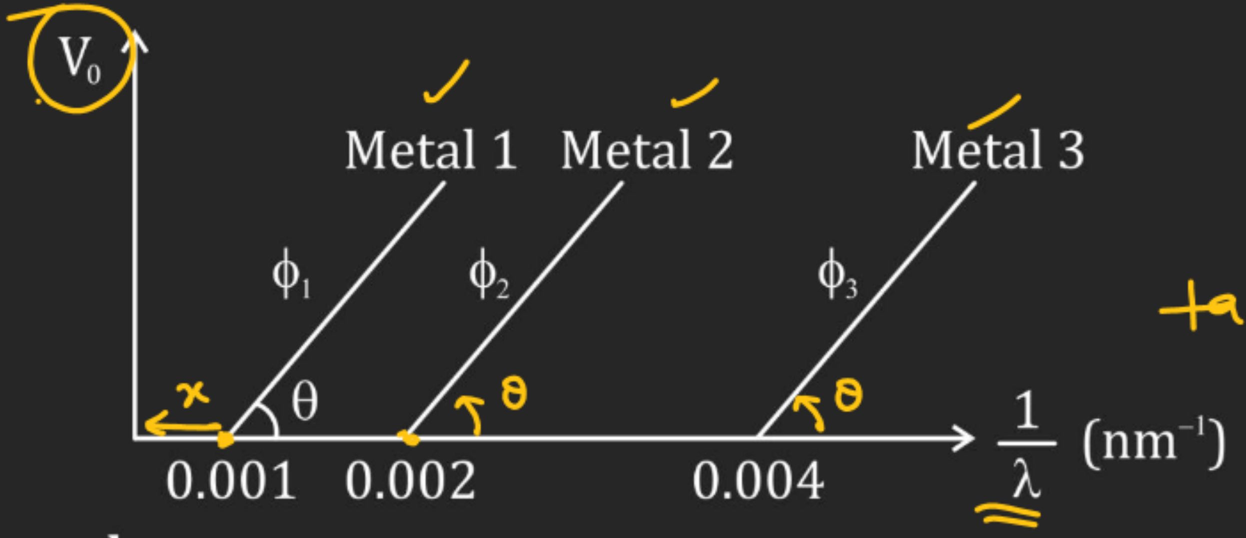
longer wavelength

$$V_0 = \frac{(K.E)_{max}}{e} =$$

Nishant Jindal

PHOTOELECTRIC EFFECT

Q.8 The graph between the stopping potential (V_0) and $(1/\lambda)$ is shown in the figure ϕ_1, ϕ_2 and ϕ_3 are work functions. Which of the following is/are correct? **(2006)**



($\lambda < 400\,nm$ For Ultraviolet)

$\tan\theta = hc$

AC

(A) $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$

(B) $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$

(C) $\tan\theta$ is directly proportional to $\frac{hc}{e}$ where h is Planck's constant and c is the speed of light

(D) Ultra violet light can be used to emit photoelectrons from metal 2 and metal 3 only.

$\frac{1}{\lambda_1} = 0.001$

$\lambda_1 = \frac{1}{1\times10^{-3}} = 10^3\,nm$

$\lambda_2 = \frac{1}{2}\times10^3\,nm =$

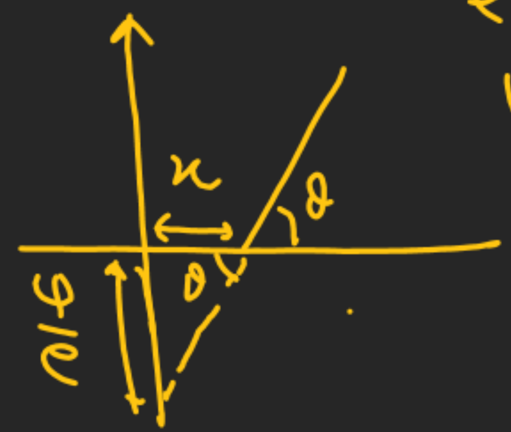
$\phi \propto x$

$\phi_1 : \phi_2 : \phi_3 :: 1 : 2 : 4$

$\tan\theta = \frac{\phi/e}{x}$

$\tan\theta = \left(\frac{\phi}{e}\right)\frac{1}{x}$

$\phi = x(e\tan\theta)$



$eV_0 = h\nu - \psi$

$V_0 = \left(\frac{hc}{e}\right)\frac{1}{\lambda} - \left(\psi/e\right)$

PHOTOELECTRIC EFFECT

Q.9 When light of a given wavelength is incident on a metallic surface, the minimum potential needed to stop the emitted photoelectrons is $6.0\ \mathrm{V}$. This potential drops to $0.6\ \mathrm{V}$ if another source with wavelength four times that of the first one and intensity half of the first one is used. What are the wavelength of the first source and the work function of the metal, respectively? **(2022)**

[Take $\frac{hc}{e} = 1.24 \times 10^{-6}\ \mathrm{J\,mC^{-1}}$.]

(A) $1.72 \times 10^{-7}\ \mathrm{m}, 1.20\mathrm{eV}$ ✓

(B) $1.72 \times 10^{-7}\ \mathrm{m}, 5.60\mathrm{eV}$

(C) $3.78 \times 10^{-7}\ \mathrm{m}, 5.60\mathrm{eV}$

(D) $3.78 \times 10^{-7}\ \mathrm{m}, 1.20\mathrm{eV}$

$eV_0 = (K.E)_{max} = 6\,e\text{-}V.$

$h\nu - \psi = 6\text{-}eV.$

$\left(\frac{hc}{e}\right)\frac{1}{\lambda} - \frac{\psi}{e} = 6.\ V$ — (1)

$\left(\frac{hc}{e}\right)\frac{1}{4\lambda} - \frac{\psi}{e} = 0.6\ V.$ — (2)

(1) − (2)

$\frac{hc}{e}\left(\frac{3}{4}\right)\frac{1}{\lambda} = 5.4$

$\lambda = ??$

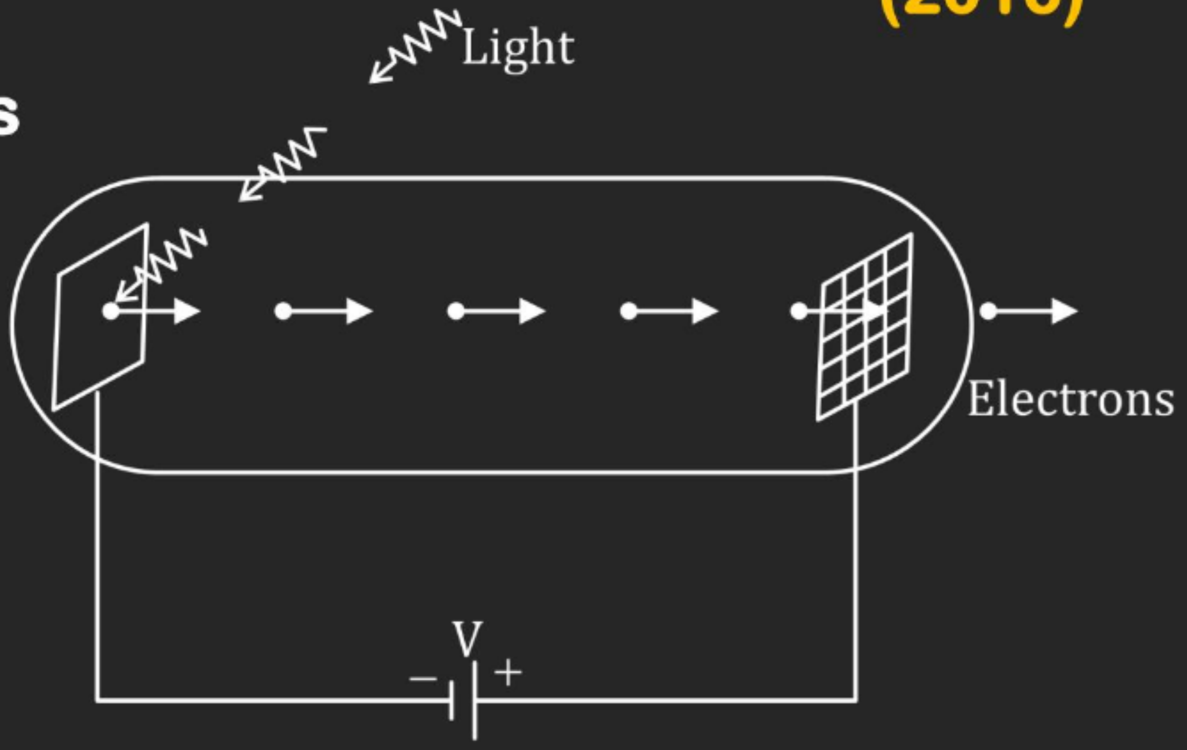
$\lambda = ?$

$\psi = ?$ ✓

PHOTOELECTRIC EFFECT

H-W

Q.7 Light of wavelength λ_{ph} falls on a cathode plate inside a vacuum tube as shown in the figure. The work function of the cathode surface is ϕ and the anode is a wire mesh of conducting material kept at a distance d from the cathode. A potential difference V is maintained between the electrodes. If the minimum de Broglie wavelength of the electrons passing through the anode is λ_e, which of the following statement(s) is(are) true? **(2016)**



(A) For large potential difference $(V >> \phi/e)$, λ_e is approximately halved if V is made four times

(B) λ_e decreases with increase in ϕ and λ_{ph}

(C) λ_e increases at the same rate as λ_{ph} for $\lambda_{ph} < hc/\phi$

(D) λ_e is approximately halved, if d is doubled

Nishant Jindal

H.W

PHOTOELECTRIC EFFECT

Q.5 Photoelectrons are emitted when $400\ \mathrm{nm}$ radiation is incident on a surface of work function $1.9\mathrm{eV}$. These photoelectrons pass through a region containing α-particles. A maximum energy electron combines with an a-particle to form a He^{+}ion, emitting a single photon in this process. He^{+}ions thus formed are in their fourth excited state. Find the energies in eV of the photons, lying in the 2 to $4\mathrm{eV}$ range, that are likely to be emitted during and after the combination. [Take $\mathrm{h} = 4.14 \times 10^{-15}$ eV.s.] (1999)

PHOTOELECTRIC EFFECT

H.W

Q.10 In a historical experiment to determine Planck's constant, a metal surface was irradiated with light of different wavelengths. The emitted photoelectron energies were measured by applying a stopping potential. The relevant data for the wavelength (λ) of incident light and the corresponding stopping potential (V_0) are given below: (2016)

$\lambda(\mu m)$	V_0 (Volt)
0.3	2.0
0.4	1.0
0.5	0.4

Given that $c = 3 \times 10^8 \text{ m s}^{-1}$ and $e = 1.6 \times 10^{-19} C$, Planck's constant (in units of $J\ s$) found from such an experiment is

(A) 6.0×10^{-34} (B) 6.4×10^{-34}

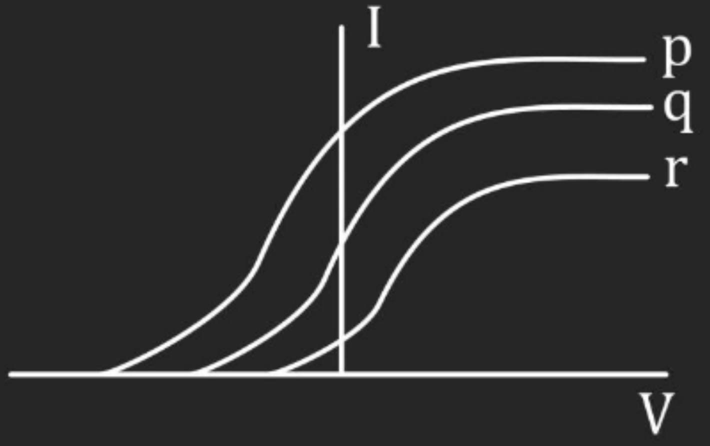
(C) 6.6×10^{-34} (D) 6.8×10^{-34}

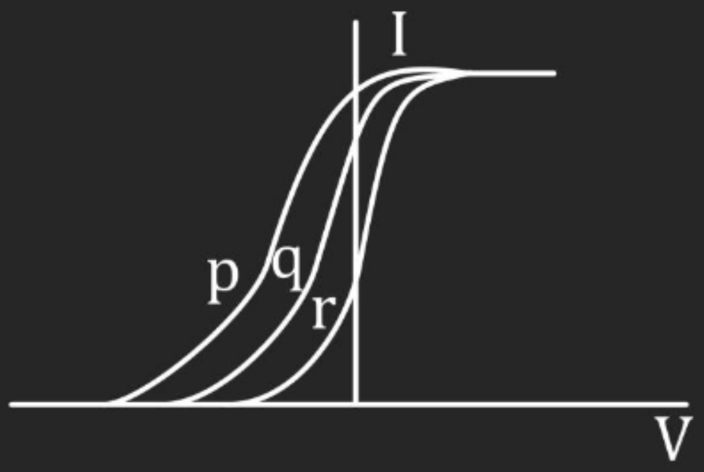
Nishant Jindal

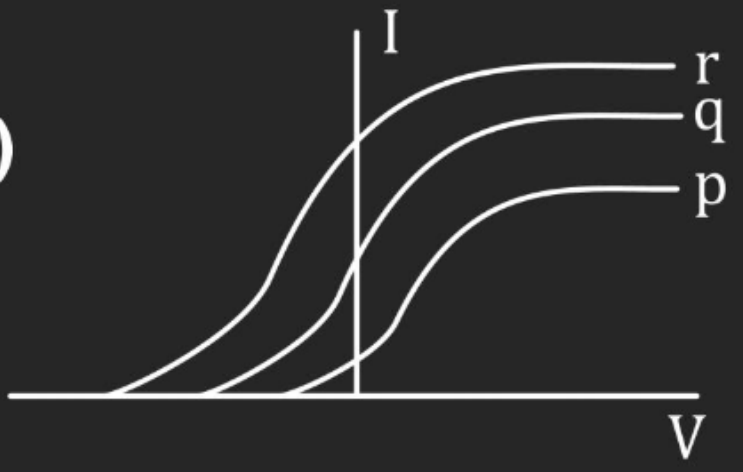
H.W

PHOTOELECTRIC EFFECT

Q.11 Photoelectric effect experiments are performed using three different metal plates p, q and r having work functions $\phi_p = 2.0\text{eV}, \phi_q = 2.5\text{eV}$ and $\phi_r = 3.0\text{eV}$, respectively. A light beam containing wavelengths of $550\text{ nm}, 450\text{ nm}$ and 350 nm with equal intensities illuminates each of the plates. The correct $I - V$ graph for the experiment is (Take $hc = 1240\text{eVnm}$) **(2009)**

(A)


(B)


(C)


(D)