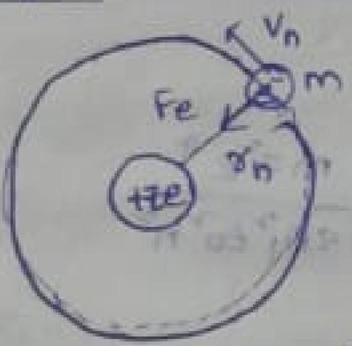
MODERN PHYSICS.

Bohr's Atomic model:

1) e^- revolves in circular orbit around Nucleus
2) Angular momentum of e^- in the orbit is quantized. (integral multiple of $\frac{h}{2\pi}$)
   → Ang. mom of e^- is conserved in a particular orbit.
3) Energy of e^- in a part. orbit is constant. Thus, they are termed as Stationary / stable orbits.

Hydrogen like atom:



centripetal force

$$F_e = \frac{1}{4\pi\epsilon_0}\frac{(Ze)(e)}{r_n^2} = \frac{m v_n^2}{r_n}$$

$$\Rightarrow m v_n^2 r_n = \frac{Ze^2}{4\pi\epsilon_0} \quad \text{---} (1)$$

$$\vec{L} = \vec{r} \times \vec{P} = m(\vec{r} \times \vec{v})$$

$$\text{Ang. momentum}(L) = m v_n r_n = \frac{nh}{2\pi} \quad \text{---} (2)$$

$$(1) \Rightarrow \frac{Ze^2}{4\pi\epsilon_0} = (m v_n r_n) v_n = \left(\frac{nh}{2\pi}\right) v_n$$

$$\Rightarrow \boxed{v_n = \frac{Ze^2}{2nh\epsilon_0}} \quad \Rightarrow v_n \propto \frac{Z}{n}$$

$$m v_n r_n = \frac{nh}{2\pi}$$

$$m\left(\frac{Ze^2}{2nh\epsilon_0}\right) r_n = \frac{nh}{2\pi}$$

$$\rightarrow \boxed{r_n = \frac{n^2 h^2 \epsilon_0}{\pi m Z e^2}} \qquad r_n \propto \frac{n^2}{Z}$$

$$\boxed{r_0 = 0.529 Å}$$

Energy of e^- in n^{th} orbit

$$E_n = \frac{-me^4}{8\epsilon_0^2 n^2 h^2}$$

Energy of e^- in ground state is $(n=1)$

$$E_0 = \frac{-me^4}{8\epsilon_0^2 h^2}$$

$$\boxed{E_0 = -13.6 eV}$$

n=4 ———— −0.85eV

n=3 ———— −1.51eV

n=2 ———— −3.4eV

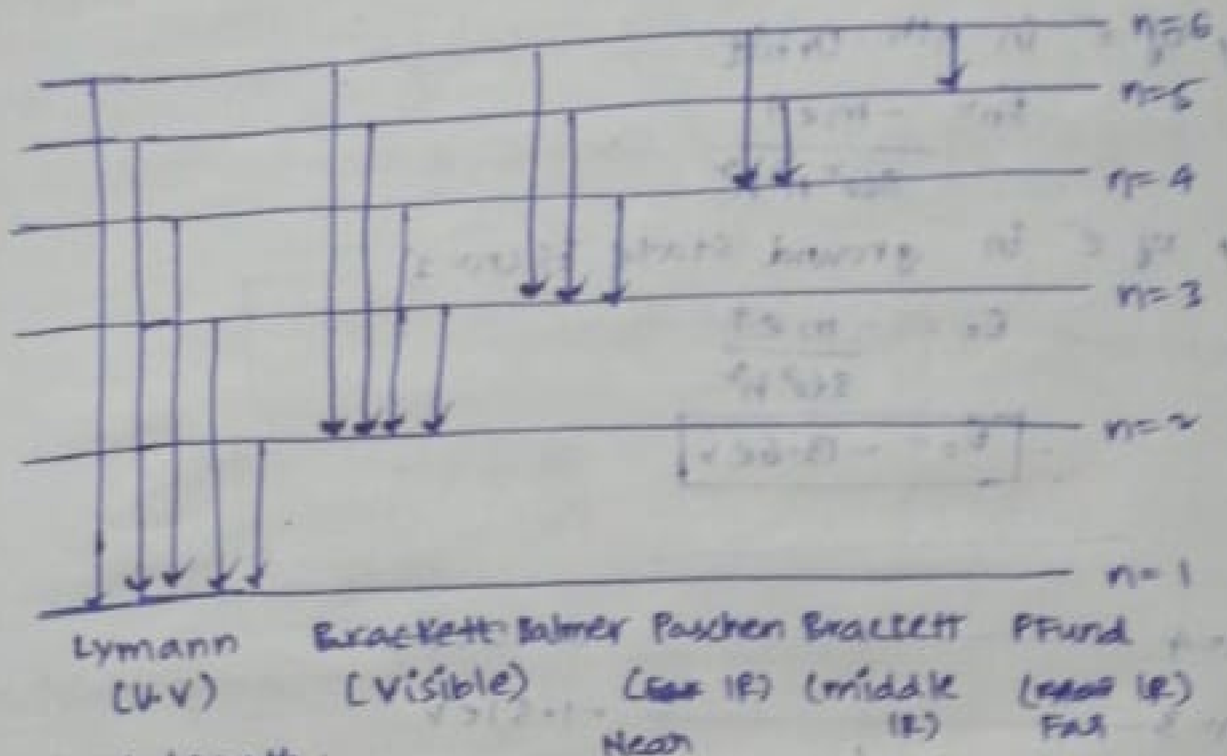
n=1 ———— −13.6eV

In transition, wave length released in H-atom is

$$\boxed{\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}$$

Hydrogen spectra:

Series	Final State (n_1)	Initial State (n_2)	Series Limit	max. wavelength	Region
Lyman	1	2,3,- -	$\frac{1}{R}$	$\frac{4}{3R}$	UV
Balmer	2	3,4,- -	$\frac{4}{R}$	$\frac{36}{5R}$	Visible
Paschen	3	4,5,- -	$\frac{9}{R}$	$\frac{144}{7R}$	near IR
Brackett	4	5,6,- -	$\frac{16}{R}$	$\frac{400}{9R}$	middle IR
Pfund	5	6,7,- -	$\frac{25}{R}$	$\frac{9000}{11R}$	Far IR



Min. wave length:

Lymann: $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{\infty}\right) = R$ $\Rightarrow \lambda = \frac{1}{R}$

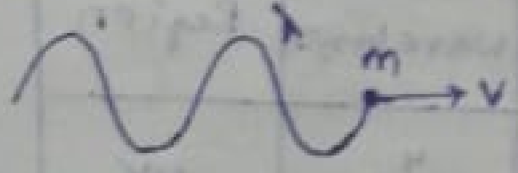
Paschen $= \frac{9}{R}$

Bracket $= \frac{16}{R}$

Balmer: $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{\infty}\right) = \frac{R}{4}$

$\lambda = \frac{4}{R}$

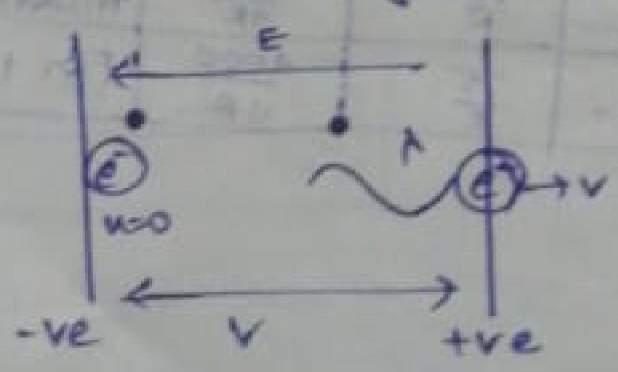
MATTER WAVES:



wavelength of wave is given by

$$\boxed{\lambda = \frac{h}{p} = \frac{h}{mv}} \ast$$

$\left(\lambda = \frac{h}{mv}\right) \rightarrow$ Debroglie's wavelength

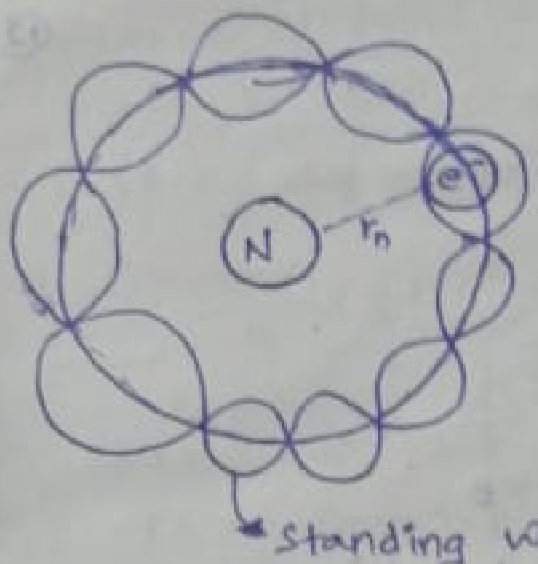


$e \cdot V = \frac{1}{2} mv^2 = \frac{p^2}{2m}$

$P = \sqrt{2meV}$

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

$$\boxed{\lambda = \sqrt{\frac{150}{V}} \, Å} \Rightarrow \boxed{\lambda = \frac{12.25}{\sqrt{V}} \, Å}$$



$L = m \cdot v_n \cdot r_n = \frac{nh}{2\pi}$

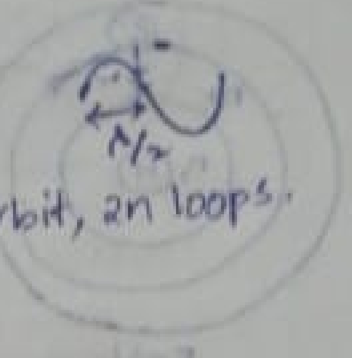
$\Rightarrow \left(\frac{h}{\lambda}\right) r_n = \frac{nh}{2\pi}$

$\Rightarrow \boxed{2\pi r_n = n\lambda}$

$2\pi r_n = (2n)\left(\frac{\lambda}{2}\right)$

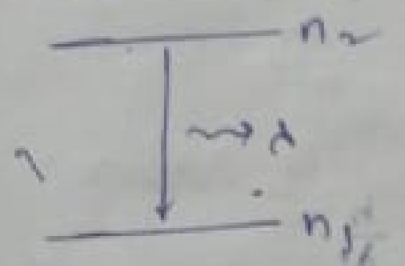
$\lambda = \frac{h}{p}$

$\boxed{p = \frac{h}{\lambda} = m v_n}$



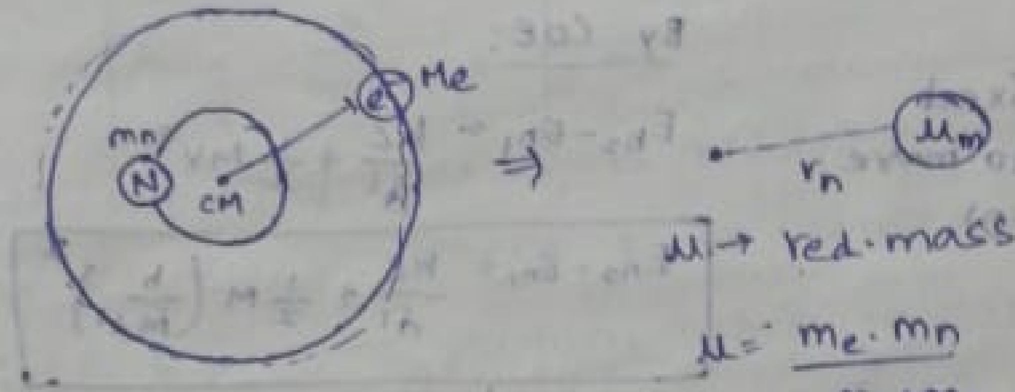
for n^{th} orbit, $2n$ loops.

Correction to wavelength:



$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

By assuming nucl is at rest



$\mu \rightarrow$ red. mass

$\mu = \frac{m_e \cdot m_n}{m_e + m_n}$.

$\frac{1}{\lambda} = z^2\left(\frac{me^4}{8\epsilon_0^2 h^3 c}\right)\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$m_e = 9.11 \times 10^{-31}$ kg

$m_n = 1.67 \times 10^{-27}$ kg

corrected wavelength $-\lambda'$

$\frac{1}{\lambda'} = z^2\left(\frac{\mu e^4}{8\epsilon_0^2 h^3 c}\right)\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$R = \frac{m_e e^4}{8\epsilon_0^2 h^3 c}$

$\frac{\lambda'}{\lambda} = \frac{m_e}{\mu} = \frac{m_e + m_n}{m_n}$

$\Rightarrow \boxed{\lambda' = \left(\frac{m_e + m_n}{m_n}\right)\lambda}$ *

Recoiling of atom:

Light

ν, λ

Photon

Energy of photon

$(E) = h\nu = \frac{hc}{\lambda}$

Q) If an e^- of mass 'm' is revolving around neutron of mass 'M' under gravitational force. Find the minimum possible ~~deg~~ debroglie wave length of e^-?

A) $\frac{-GMm}{R}+\frac{1}{2}mv^2=0$

$F_g = \frac{GM\cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$

$[GMm = (mvr)v]$

$GMm = \left(\frac{nh}{2\pi}\right)v \Rightarrow v = \frac{2\pi GMm}{nh}$

$mvr = \frac{nh}{2\pi} \Rightarrow r = \frac{nh}{2\pi m}\left(\frac{nh}{2\pi GMm}\right) = \frac{n^2h^2}{4\pi^2 GMm^2}$

$\lambda_{min} = \frac{h}{mv} = \frac{h}{mv_{max}} = \frac{h}{m\left(\frac{2\pi GMm}{h}\right)}$ $n=1$

$$\boxed{\lambda_{min} = \frac{h^2}{2\pi GMm^2}}$$

Q2) If an e^- of mass 'm' is revolving around proton under P.E $U = K\log_e r$ where K is constant and 'r' is dist b/w e^- & proton. Bohr's model is valid. Find the allowed radius of orbits?

Soln:- $F = -\frac{dU}{dr} = +\frac{K}{r} = \frac{mv^2}{r}$

$\Rightarrow v = \sqrt{\frac{K}{m}}$ $mvr = \frac{nh}{2\pi}$

$r = \frac{nh}{2\pi mv} = \frac{nh}{2\pi\sqrt{mK}}$

Q3) In a hypothetical atom, particle of mass 2 times the mass of e^- and 2 times the charge of e^- is revolving around the proton. Find the ~~Rydberg constant interms of~~ max λ of Balmer series in terms of R. (Rydberg const.)

Soln: $R = \frac{me^4}{8\epsilon_0^2h^3c}$ $R' = \frac{(2)^{3}me^4}{8\epsilon_0^2h^3c} = 2^3R$

$(ze)^2(2e)^2$ $(4e^2)(4e^2)$

$= \frac{\cancel{36}\, 9}{5(\cancel{4}\!\!\!8 R)} = \frac{9}{40R} \cdot \frac{36}{5(8R)} = \frac{9}{10R}$

Q4) By taking (P.E)$_{1st}$ orbit = 0. Find the total energy of e^- in 1st excited state. (H-atom)

Soln:

n = 2: TE = −3.4ev, PE = −6.8ev, KE = 3.4ev

$\Delta U = -6.8 - (-27.2) = 20.4 eV$

n = 1: TE = −13.6ev, KE = 13.6ev, PE = −27.2ev

n = 2: PE = 20.4ev, KE = 3.4ev } TE = 23.8ev

n = 1: TE = +13.6ev, KE = +13.6ev, PE = 0

Q5) If the diff b/w max. λ of Balmer series and min. λ of Lyman series in a hyd. like atom of atomic no-Z is Δλ

Find the R value in terms of at.no Z, Δλ?

Soln:

$\frac{1}{Z^2}\left[\frac{36}{5R} - \frac{1}{R}\right] = \Delta\lambda$

$\frac{31}{5Z^2R} = \Delta\lambda \Rightarrow \quad \Rightarrow \boxed{R = \frac{31}{5Z^2\Delta\lambda}}$

Q6) COLLISIONS :- (Atomic Collisions)

1) → Shape of particle is not defined. So, no change of shape takes place in collision. [collision is b/w particle & particle]

collision has to be elastic"

2) If collision in b/w particle and atom (or) atom and atom

either collision is elastic/inelastic

→ Collision is inelastic only if loss in K.E of colision should be utilised in excitation

Eg-①:

$\overrightarrow{(n)}\ u$ (P) rest

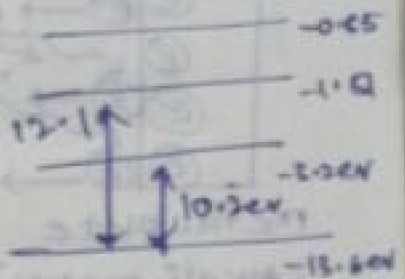
collision is elastic

Eg-②:

$\overrightarrow{(n)}\ u$ (H)

particle atom

collision is either elastic/inelastic.



Eg-③:

Rest

$\overrightarrow{(n)}\ u$ (H) ⇒ $\overrightarrow{(n)}\ v$ $\overrightarrow{(H)}\ v$

m m

collision is perfectly inelastic.

By COLM:

$(m)(u) = 2m(v) \Rightarrow v = \frac{u}{2}$

loss in K.E $= \frac{1}{2}mu^2 - \frac{1}{2}(2m)v^2 = \frac{mu^2}{4}$

$\frac{mu^2}{4} = 10.2eV \Rightarrow \frac{1}{2}mu^2 = 20.4eV$

$\boxed{K.E \text{ of } n = 20.4\ eV}$

* K.E of $n < 20.4eV$
(collision has to be elastic)

* K.E of $n > 20.4eV$ [upto $2(12.1eV)$]
(partially inelastic)

PHOTO-ELECTRIC EFFECT:-

→ Consequence of particle nature of light
→ particle of light is called as photon.
→ Each photon is an energy packet

▨ → energy of photon

$E = h\nu = \frac{hc}{\lambda}$

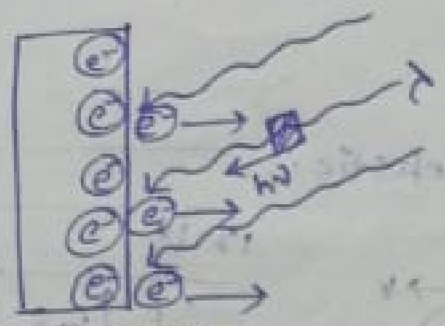
Momentum of Photon ⇒ $\boxed{\frac{E}{c} = P}$

Intensity of Light $(I) = \frac{Power}{Area} = \frac{Energy}{(Area)\times time}$

$$I = \frac{n(h\nu)}{(area)(time)}$$

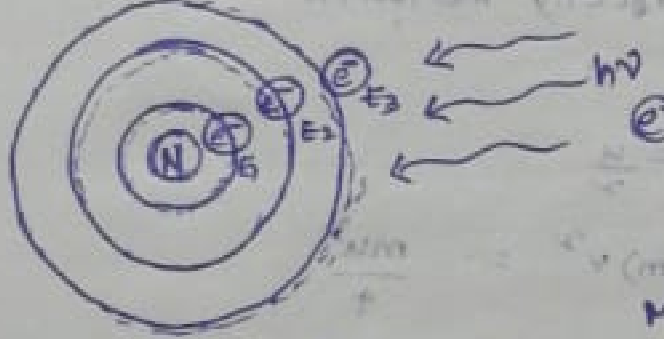
$$\boxed{\frac{n}{(area)(time)} = \frac{I}{h\nu}}$$

→ No-of photons hitting unit area in unit time.



metal plate (Alkali metal)

→ Electrons will be ejected when light of suitable wavelength falls on the metal surface.



e^-_3 $K \cdot E_3 = h\nu - E_3$

$K \cdot E_2 = h\nu - E_2$

$K \cdot E_1 = h\nu - E_1$

Max K·E will be for outermost e^-.

Work function (W)

→ Min. energy required to remove the most loosely bound electron from the metal. [I·E]

$$\boxed{K \cdot E_{max} = h\nu - W}$$

→ K·E of the e^- coming out of the metal target are 0 to $K \cdot E_{max}$.

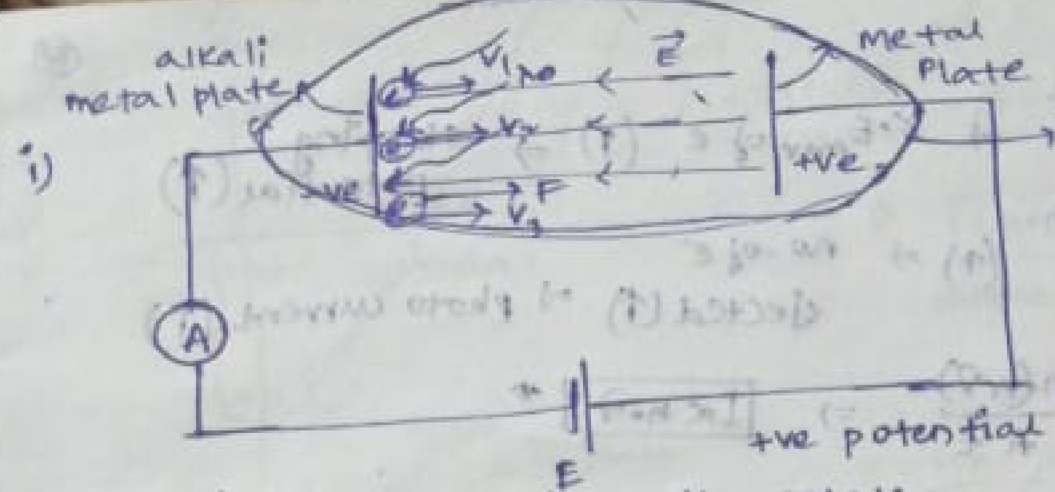
$W = h\nu_{min}$

$\boxed{\nu_{min} = \frac{W}{h}}$ → Threshold frequency

$W = \frac{hc}{\lambda_{max}} \Rightarrow \boxed{\lambda_{max} = \frac{hc}{W}}$ → Threshold wave length.

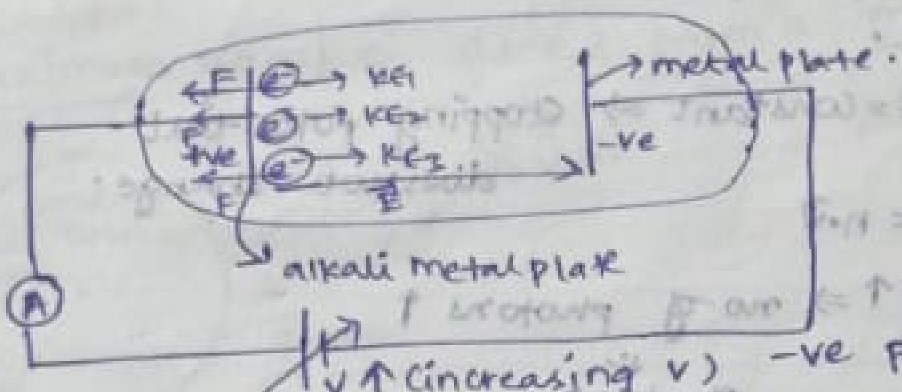
$$\boxed{\begin{aligned} K \cdot E_{max} &= h\nu - h\nu_{min} \\ &= h[\nu - \nu_{min}] \\ K \cdot E_{max} &= hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_{max}}\right] \end{aligned}}$$

i)

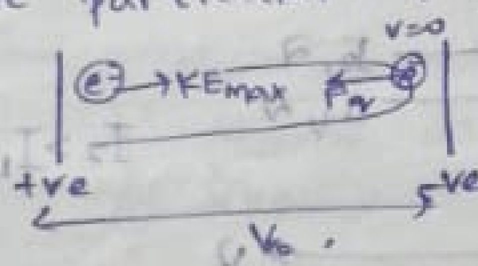


All e^- reach the other plate

ii)



At particular potential V_0' → stopping Potential

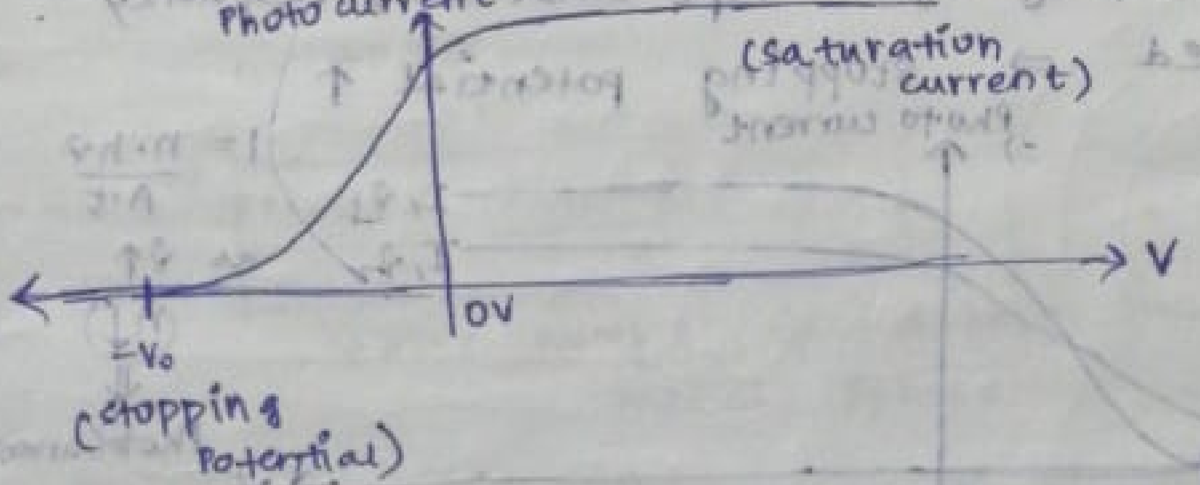


$W = \Delta K.E$

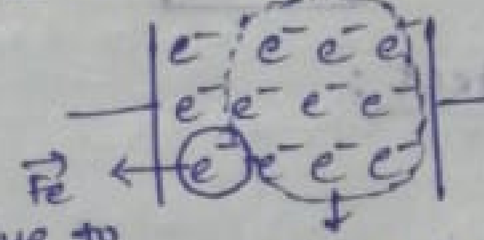
$-eV_0 = 0 - KE_{max}$

$\boxed{KE_{max} = eV_0}$

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



(N*) Note: The small deviation is due to space charge



due to repulsion from space charge.

Hence photo current ↓.

Note:

1) frequency of light (↑) → $K.E_{max}$ of e^- (↑) → stopping potential (↑)

2) No. of photon in light (↑) → no. of e^- ejected (↑) → photo current (↑)

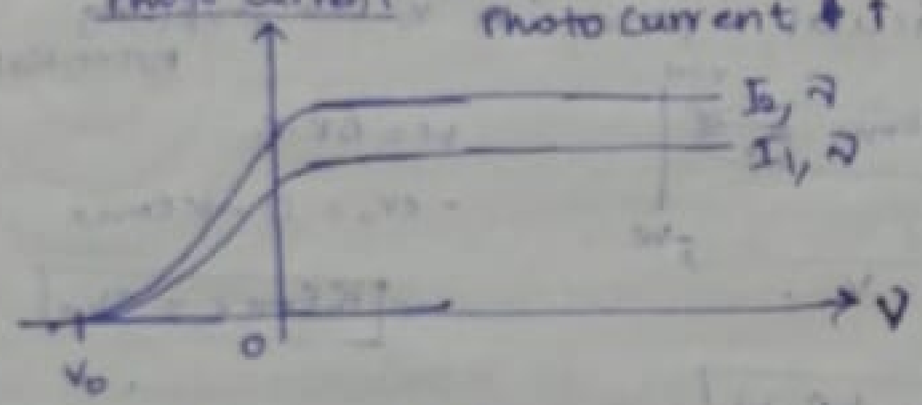
$$I = \frac{n(h\nu)}{A \cdot t} \Rightarrow \boxed{I \propto n \cdot \nu}$$

3) If frequency of light is constant and Intensity is increased.

ν = constant ⇒ stopping potential does not change.

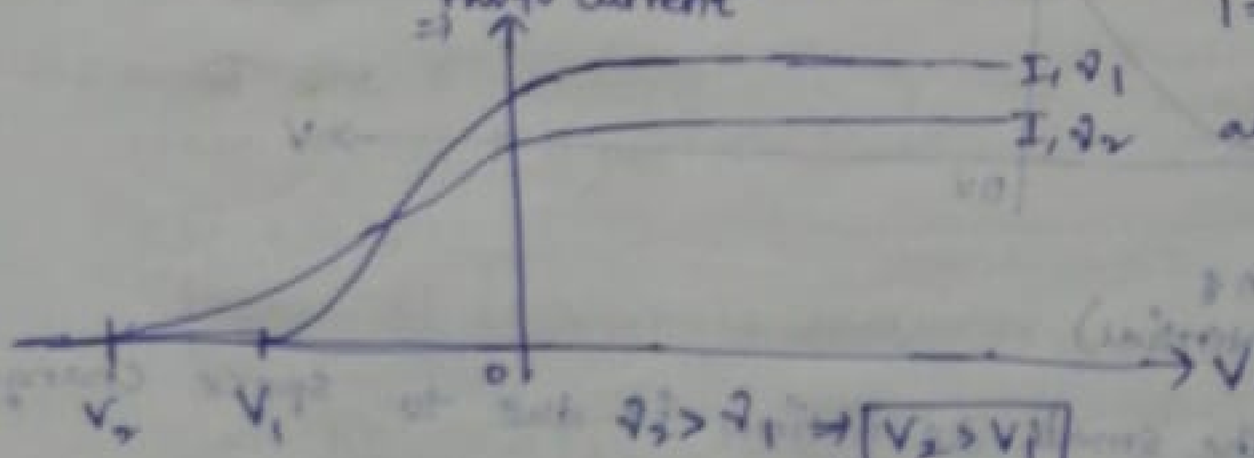
$I \propto n \cdot \nu$

$I \uparrow \Rightarrow$ no. of photons ↑ ⇓ Photo current ↑



$I_2 > I_1$

4) If Intensity of light kept constant & frequency increased ⇒ stopping potential ↑



$I = \frac{n \cdot h\nu}{A \cdot t}$

as $\nu \uparrow$

$n \downarrow$

⇓

Photocurrent ↓

$\nu_2 > \nu_1 \rightarrow \boxed{V_2 > V_1}$

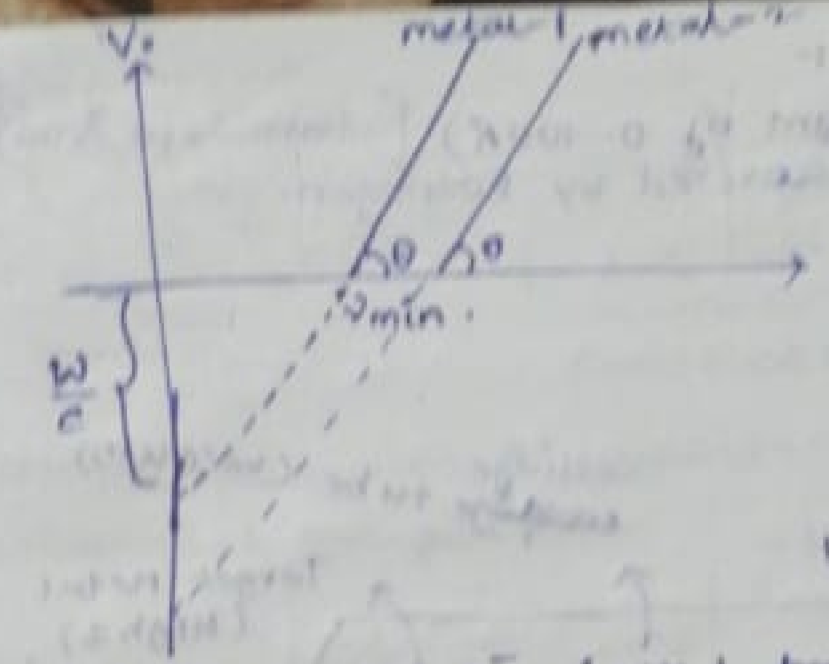
Eqn of photoelectric effect:

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

$e \cdot V_0 = h\nu - W$

$$\Rightarrow \boxed{V_0 = \left(\frac{h}{e}\right)\nu - \frac{W}{e}}$$

$y = mx - c$



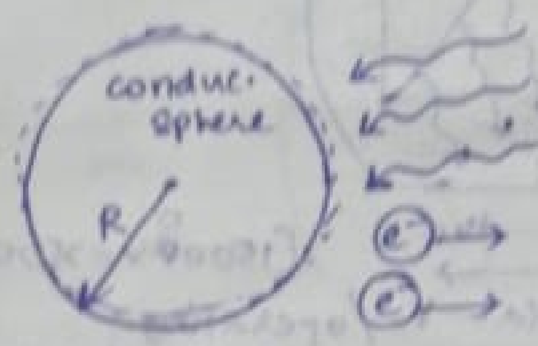
$\tan\theta$ = slope of the graph

$$\boxed{\tan\theta = \frac{h}{e}}$$

where $h = 6.625 \times 10^{-34}\ Js$
$= 4.136 \times 10^{-15}\ eVs$

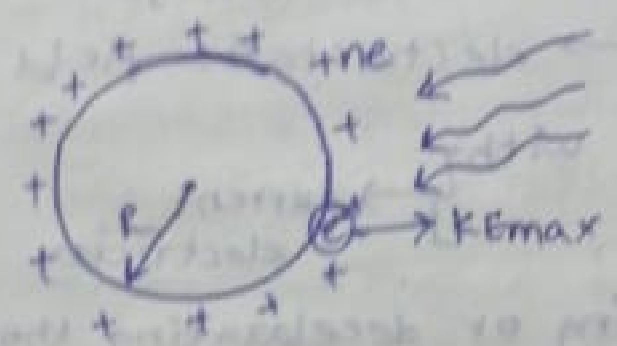
$$E = \frac{hc}{\lambda} = \frac{12400}{\lambda(\text{Å})}\ eV$$

→ **Maximum no. of e^- ejected from a metal sphere:**



$\nu > \nu_{min}$

Not to escape the e^- from metal.



$[TE \text{ of } e^- < 0]$

$KE_{max} + E.P.E < 0.$

$(h\nu - W) - \frac{KQq}{R} < 0.$

$$\boxed{h\nu - W < \frac{ne^2}{4\pi\epsilon_0 R}}$$

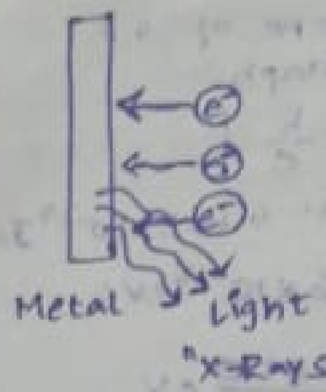
$$n > \frac{4\pi\epsilon_0 R(h\nu - W)}{e^2}$$

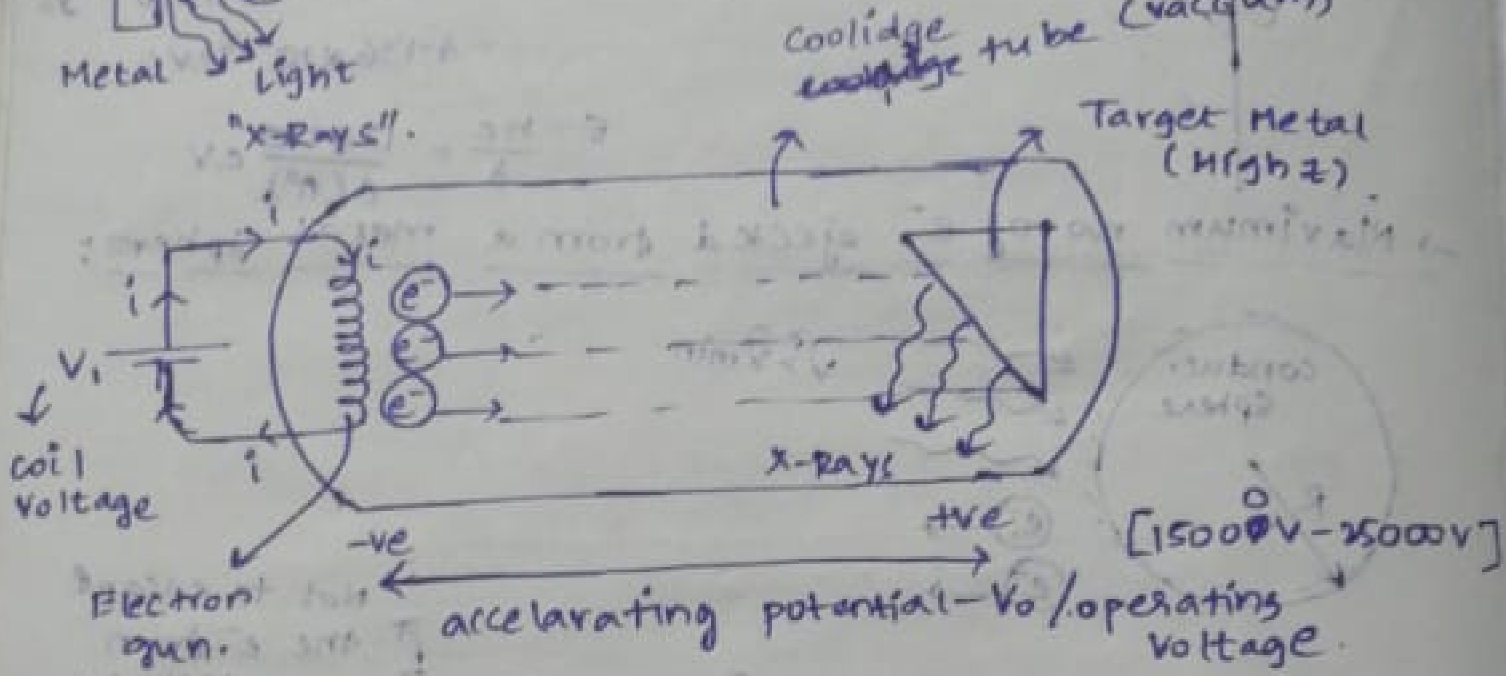
$$\Rightarrow \boxed{n_{max} = \frac{4\pi\epsilon_0 R\,(h\nu - W)}{e^2}}$$

↳ max. no. of e^- ejected from the metal sphere.

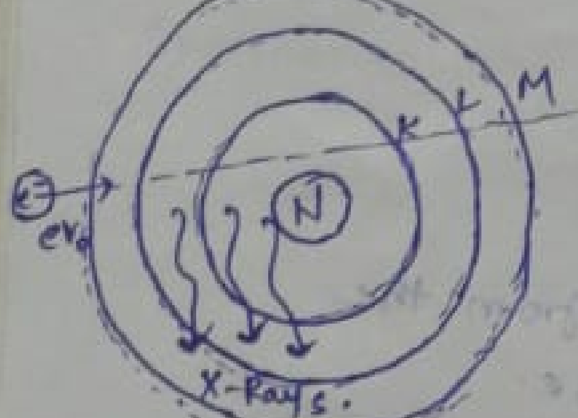
X-Rays:-

(Light of 0–100Å) [1mm → 10^{-3}nm]
→ Discovered by Roentgen.





* when charges are at rest → electrostatic field
* when charges are moving with const. velocity } → current electricity
* when charges are accelarating or decelarating then they exhibit radiation (e.m. waves)



(1) Electron is passing through metal atom without collision with any e^- in the outer orbit.
$\underbrace{\hphantom{xxxxxxxxxxxx}}$
Passing through empty space of atom.

Energy of X-Ray produced → 0 to eV_0.

max. energy of X-Ray produced $= eV_0$.

$$h\nu_{max} = eV_0.$$

$$\frac{hc}{\lambda_{min}} = eV_0 \Rightarrow \boxed{\lambda_{min} = \frac{hc}{eV_0}} \rightarrow \text{cut off wavelength}$$

$\lambda_{min} \longrightarrow \infty$

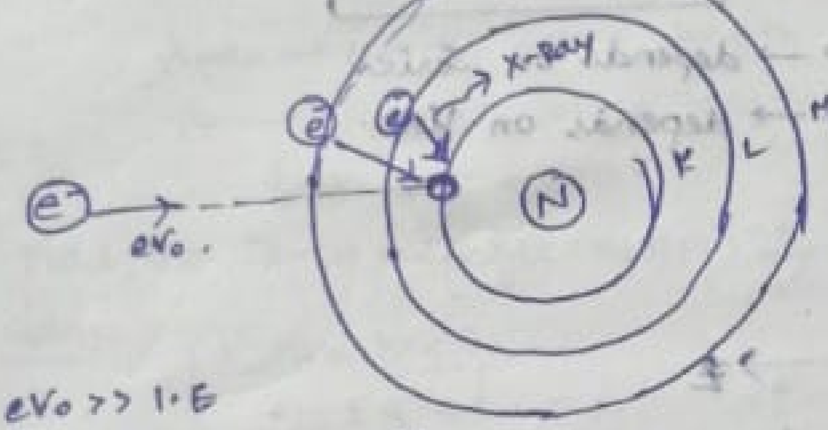
(max. wavelength of X-Ray is not defined) Theoritically

→ All wavelengths of $\lambda_{min} \longrightarrow \infty$ are present in X-Ray spectrum.

Continuos spectrum.

→ cutoff wavelength depends only on operating ~~Potential~~ Voltage

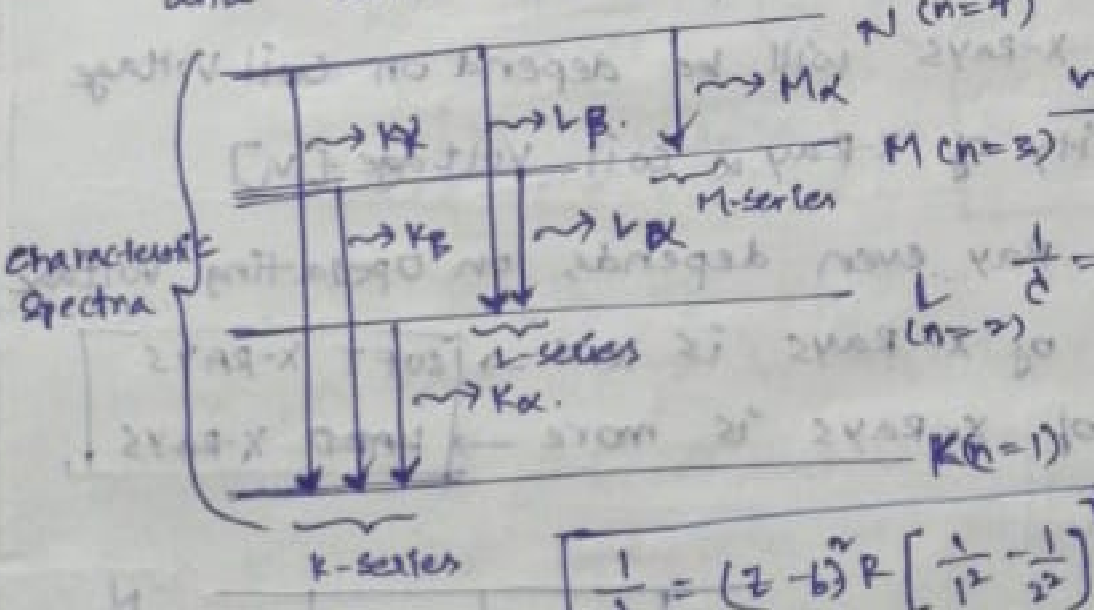
→ prod. of X-rays in coolidge tube is inverse phen. of Phot-elec. effect.



$eV_0 >> I.E$

⇒ the e^- leaves the atom

→ So, the e^- from outer shells transfer to inner shells and emit X-rays.



Wavelength of K_α :-

$$\frac{1}{\lambda} = Z^2 R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

Hyd. like atom

$$\boxed{\frac{1}{\lambda_{K\alpha}} = (Z-b)^2 R\left[\frac{1}{1^2} - \frac{1}{2^2}\right]}$$

b → Screening constant

$$\frac{1}{\lambda_{K\alpha}} = \frac{(Z-b)^2 \, 3R}{4}$$

$$E_L - E_K = \frac{hc}{\lambda_{K\alpha}} \Rightarrow \boxed{\lambda_{K\alpha} = \frac{hc}{E_L - E_K}}$$

$\boxed{b = 1 \text{ for K-shell}}$

Wave length of VIBGYOR

R > Or > Y > G > B > I > V

4000–7000 Å

MOSLEY'S LAW:

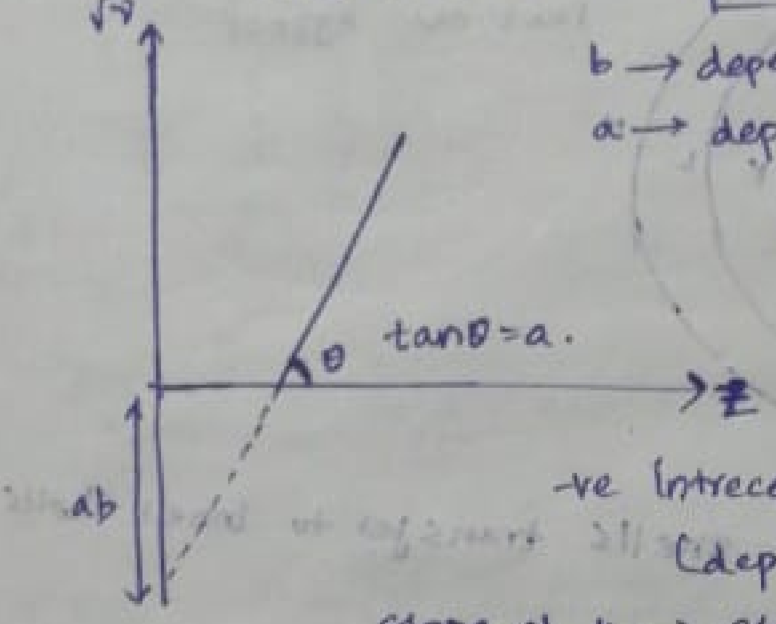
for K_α:

$$\boxed{\frac{1}{\lambda_{K\alpha}} = (z-b)^2 R \left(\frac{3}{4}\right)}$$

$$\nu_{K\alpha} = \frac{3RC}{4}(z-b)^2$$

$$\sqrt{\nu_{K\alpha}} = \sqrt{\frac{3RC}{4}}\,(z-b)$$

$$\sqrt{\nu_{K\alpha}} \propto z-b \Rightarrow \boxed{\sqrt{\nu_{K\alpha}} = a(z-b)}^{*}$$



b → depends on series

a → depends on line.

-ve Intrecept = a·b

(depends on both line & series)

slope of K_β > slope of K_α.

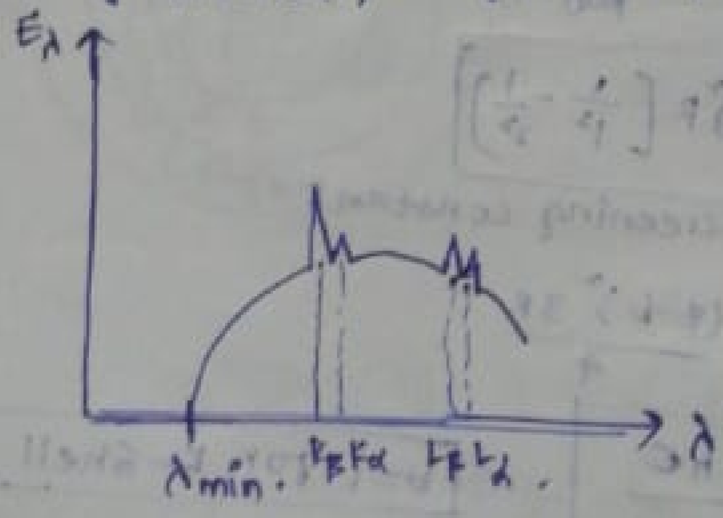
* Intensity of X-RAYS will be depend on coil voltage

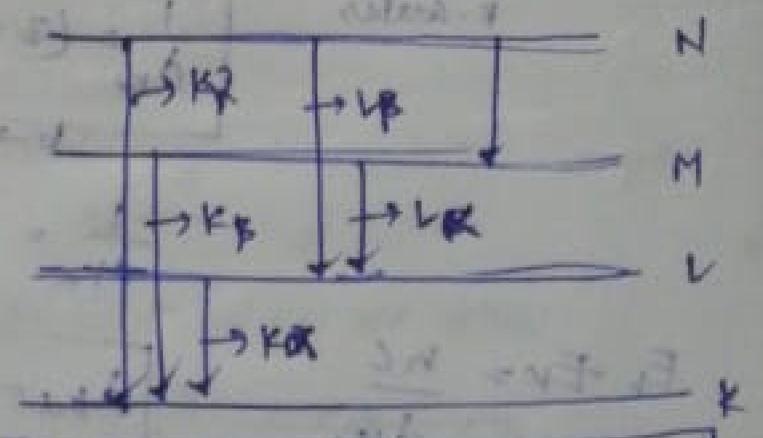
Intensity of X-Ray $\propto$ coil voltage [V_1]

→ Intensity of X-Ray even depends on operating voltage

→ If intensity of X-Rays is less → $\boxed{\text{SOFT X-RAYS}}$

If intensity of X-Rays is more → $\boxed{\text{HARD X-RAYS}}$.





$E_{L\beta} > E_{L\alpha}$

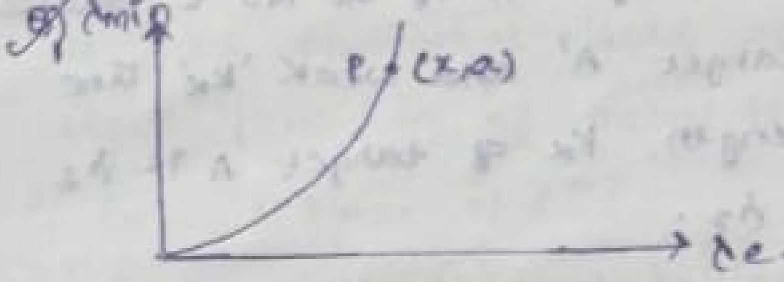
$\lambda_{L\beta} < \lambda_{L\alpha}$.

$$\boxed{\begin{array}{l} E_{K\alpha} < E_{K\beta} < E_{K\gamma} \\ \Rightarrow \cancel{\lambda_{K\alpha} <}\ \lambda_{K\gamma} > \lambda_{K\beta} > \lambda_{K\alpha}. \end{array}}$$

$$\boxed{\begin{array}{l} E_{K\alpha} > E_{L\alpha} \\ \lambda_{K\alpha} < \lambda_{L\alpha} \end{array}}$$

→ Wave length of K-series will have less 'λ' comparing with L-series.

Q)



λ_{min} → cut off wave length

λ_e → debroglie wave length of e^- just before entering into the atom.

Find the X-coordinate of point 'P' on the graph?

Soln:-

$$\left[\lambda_{min} = \frac{h \cdot c}{eV_0}\right]$$

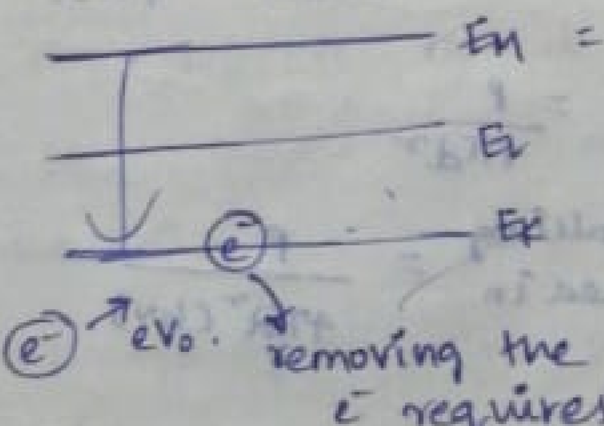
$$\lambda_e = \frac{h}{P} = \frac{h}{m \cdot v} = \frac{h}{\sqrt{2mK.E}}$$

$$\lambda_e^2 = \frac{h^2}{2meV_0} = \left(\frac{hc}{eV_0}\right)\left(\frac{h}{2mc}\right)$$

$$\Rightarrow \boxed{\lambda_e = \sqrt{\frac{h \cdot \lambda_{min}}{2m \cdot c}}} \Rightarrow \boxed{\lambda_e = \sqrt{\frac{a \cdot h}{2mc}}}$$

Q2) If wave length of K_β line in metal target is 12.42 pm and 10 keV is req. to remove e^- from 'M' shell. Find the min. accelarating voltage req. such that 'K_α' line can be obtained?

Soln:



$$-(E_K - E_M) = \frac{h(c)}{\lambda}$$

$$E_K = -\frac{hc}{\lambda} + E_M$$

$$\Rightarrow E_K = -\left(\frac{12420}{12.42 \times 10^{-2}}\right) - 10 \text{ keV} = -10^5 - 10^4 \text{ eV}$$

$E_k = \cancel{100}\ -110\,keV$

$e.V_0 = -(-110000\,eV).$

$\Rightarrow \boxed{V_0 = 110\,kV}$

Q3) X-Ray from a tube with target 'A' of At. No 'Z' shows strongs 'K_α' line for target 'A' and weak 'K_α' line for impurities. wavelength K_α of target A is λ_Z and of impurities λ_1 & λ_2:

If $\frac{\lambda_Z}{\lambda_1} = 4$ $\quad \frac{\lambda_Z}{\lambda_2} = \frac{1}{4}$

Find. at. no of impurities.

soln: $\frac{1}{\lambda_{K_\alpha}} \propto (Z-b)^2$ $\quad \left[\frac{1}{\lambda_{K\alpha}} = (Z-1)^2 \frac{3R}{4}\right]$

Imp-1: $\Rightarrow \frac{\lambda_Z}{\lambda_1} = \frac{(Z_1-1)^2}{(Z-1)^2} = 4.$ $\quad \Rightarrow Z_1 - 1 = 2Z - 2.$

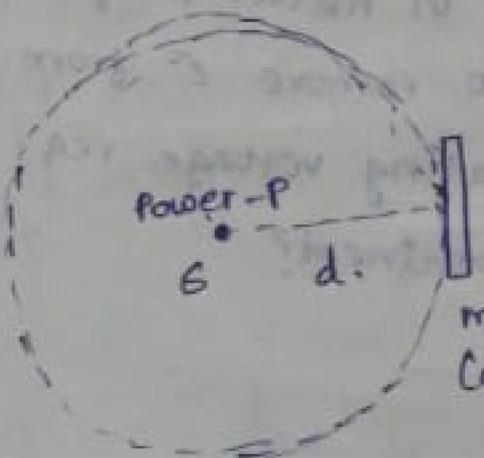
$\boxed{Z_1 = 2Z - 1}$

Imp-2: $\frac{\lambda_Z}{\lambda_2} = \frac{(Z_2-1)^2}{(Z-1)^2} = \frac{1}{4}$ $\quad \Rightarrow 2Z_2 - 2 = Z - 1.$

$\boxed{Z_2 = \frac{Z+1}{2}}$

Q4) Important Idea of photo electric effect:-

→



$I = \frac{n \cdot h\nu}{A \cdot t}$

Intensity of light at metal Plate is:

$I = \frac{\text{Power}}{\text{Area}} = \frac{P}{4\pi d^2}$

$\frac{n(h\nu)}{A \cdot t} = \frac{P}{4\pi d^2}$

$\Rightarrow \frac{n}{A \cdot t} =$ no of photons falling per unit area in unit time $= \frac{P}{4\pi d^2 (h\nu)}$

no of photons falling on metal per second $= \left(\frac{P}{4\pi d^2 h\nu}\right)$ (area of plate) $= \frac{P \cdot A}{4\pi d^2 h\nu}$

Photo current $(I) = \frac{q}{t} = \frac{(n)e}{t}$

$\left[\text{quantum efficiency} = \frac{\text{no of } e^-}{\text{no of photons}}\right]$

Q5) A source of power 40W emits light of $\lambda = 2480\text{Å}$. It falls on metal placed at 2m from the source. Work function of metal is 3.68eV

a) Find KE_{max} of e^-?

b) Find no of photons falling on metal per unit area in unit time?

Soln:- a) $KE_{max} = \frac{h \cdot c}{\lambda} - W_0$.

$$= \frac{4.41 \times 10^{-15} \times 3 \times 10^8}{2480\text{Å}} = \frac{12400}{\lambda(\text{in Å})} = 5eV$$

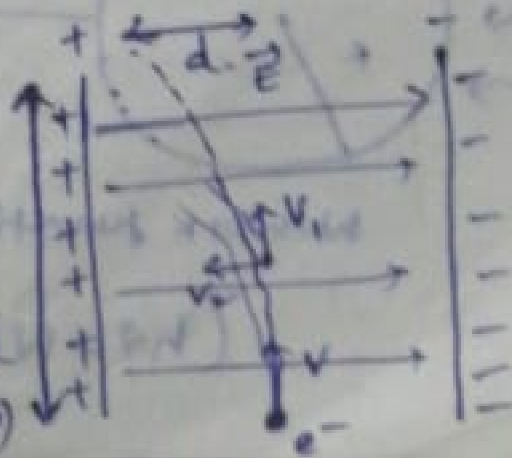
$$= 5 - 3.68 = 1.32\ eV$$

b) $\frac{n(E)}{A \cdot t} = \frac{P}{4\pi d^2}$ $A = 1\ \text{unit}^2$, $t = 1\ \text{sec}$

$$\Rightarrow n = \frac{P}{(4\pi d^2)(E)} = \frac{40}{2 \times 4 \times \pi \times 4 \times 5 \times 1.6 \times 10^{-19}}$$

$$= \frac{10^{19}}{3.2 \times \pi} = \frac{10^{20} \times 7}{32 \times 22} \approx \frac{10^{20}}{100} = 10^{18}\ \text{photons}.$$

Q6) Most energetic e^- from photo electric effect is sent into parallel plate capacitor of length 'l' having uniform electric field '$\vec{E}$'. While entering velocity vector of e^- is parallel to length of the plate and it deflects by 'd' distance while coming out of capacitor. Then find stopping potential of the e^-.



Soln:- Energy of $e^- = h\nu - W_0 = eV_0$.

$\frac{1}{2}mv_1^2 = KE$ of e^-

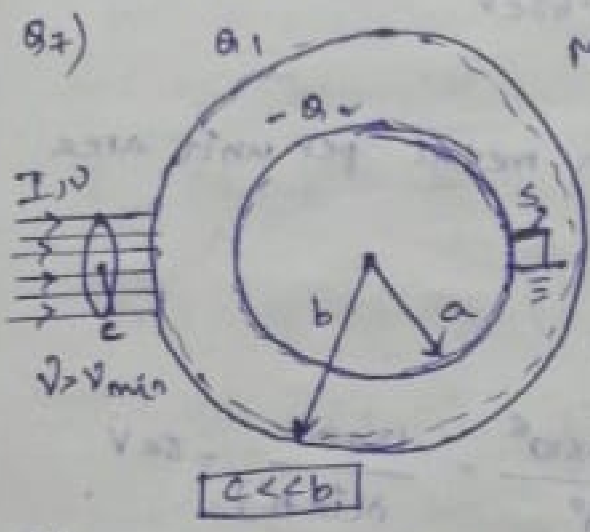
$t = \frac{l}{v} \Rightarrow \boxed{d = \frac{1}{2}a_t t^2}$ $(u_x = 0)$

$$\frac{2d(m)}{qE} = \frac{l^2}{v^2} \Rightarrow v^2 = \frac{qEl^2}{2dm}$$

$$\frac{1}{2}mv^2 = \frac{qEl^2}{2dm}\left(\frac{m}{2}\right) = q(V_0)$$

$$\Rightarrow \boxed{V_0 = \frac{El^2}{4d}}$$

Q7)



Metal sphere

Find the current through switch.

(Charge stays on the inner surface of outer sphere)

[quant-efficiency = 1]

Soln:

$I = \frac{nh\nu}{A \cdot t}$ (per second) $\Rightarrow I\pi c^2 = \frac{n}{t} h\nu$

$$\Rightarrow \left[\left(\frac{n}{t}\right) = \frac{I(\pi c^2)}{h\nu}\right] \longrightarrow \text{No. of photons fallen per second.}$$

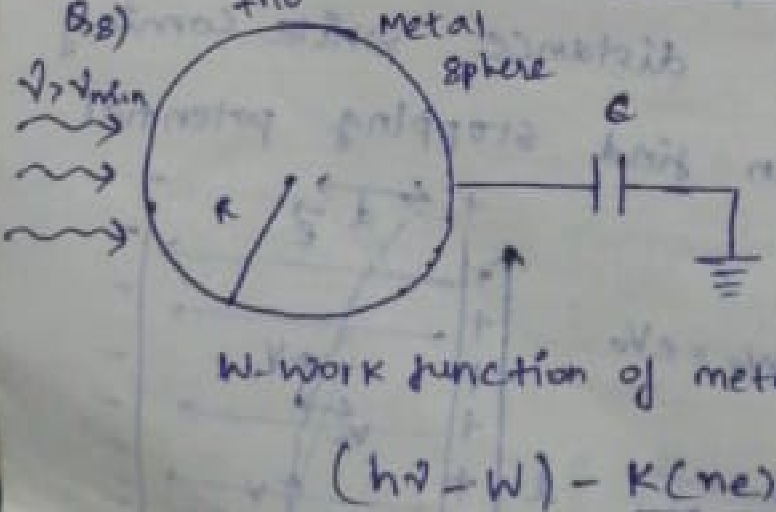
$\Rightarrow$ no. of e^- ejected per from outer surface per second $= \left(\frac{I\pi c^2}{h\nu}\right)e$.

$\rightarrow$ on inner sphere pot. $= 0$.

$$\Rightarrow \frac{KQ_1}{b} - \frac{KQ_2}{a} = 0 \Rightarrow Q_2 = \frac{a}{b}(Q_1)$$

$$i = \frac{dQ_2}{dt} = \frac{a}{b}\left(\frac{Q_1}{t}\right) = \boxed{\frac{a}{b}\left[\frac{I\pi c^2 e}{h\nu}\right]}$$

Q8)



Find the final charge on the capacitor.

W - work function of metal sphere

$$(h\nu - W) - \frac{K(ne)(e)}{r} < 0 \Rightarrow \frac{r(h\nu - W)}{Ke^2} < n.$$

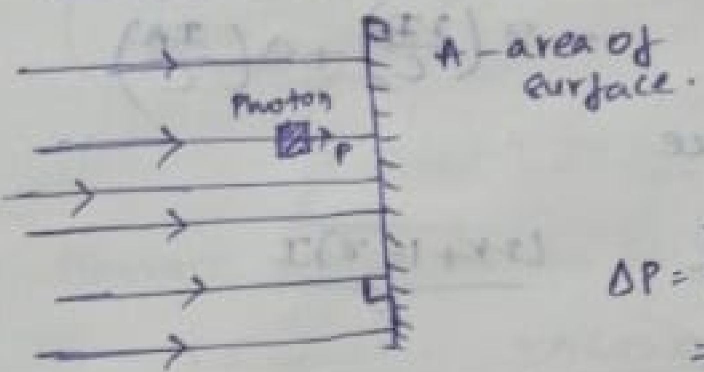
$h_{max} = \dfrac{r(h\nu - w)}{Ke^2}$

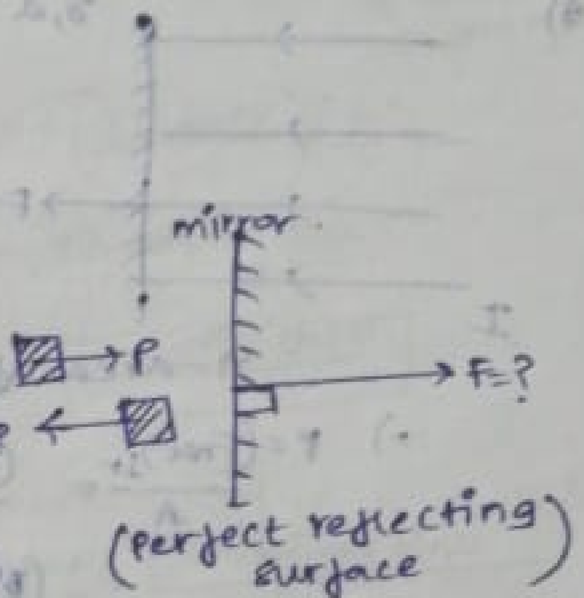
Pot. of sphere $= \dfrac{K(ne)}{r} = \dfrac{\cancel{K}(e)}{\cancel{r}}\left[\dfrac{\cancel{r}(h\nu-w)}{\cancel{K}e^{\cancel{2}}}\right] = \dfrac{h\nu - w}{e}$

$\Delta v = \dfrac{q}{c}$

$\Rightarrow \boxed{q = c\left[\dfrac{h\nu - w}{e}\right]}$

RADIATION PRESSURE:





$\Delta P = P_f - P_i$

$= P - (-P)$

$\Delta P = 2P$

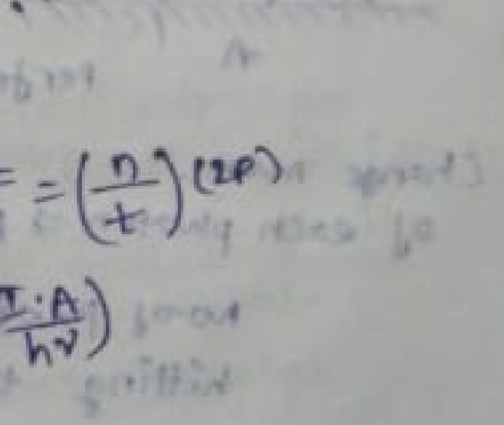
I(intensity of light)

for photon: $E = h\nu = \dfrac{hc}{\lambda}$

$\Rightarrow \dfrac{h}{\lambda} = \dfrac{E}{c} = P$.

change in momentum of each photon $= (P)(2)$

intensity $(I) = \dfrac{nh\nu}{A \cdot t}$



no. of photons hitting per second $= \dfrac{n}{t} = \dfrac{I \cdot A}{h\nu}$

total change in momentum in one sec $\Rightarrow \Delta P = F = \left(\dfrac{n}{t}\right)(2P)$

$= (2P)\left(\dfrac{I \cdot A}{h\nu}\right)$

$F = \dfrac{I \cdot A}{\cancel{h}c} \times \cancel{h} \times \dfrac{2 \times \cancel{\nu}}{\cancel{\nu}} = \dfrac{2I \cdot A}{c}$

$\boxed{\text{Pressure} = \dfrac{F_{\perp r}}{A} = \dfrac{2I}{c}}$

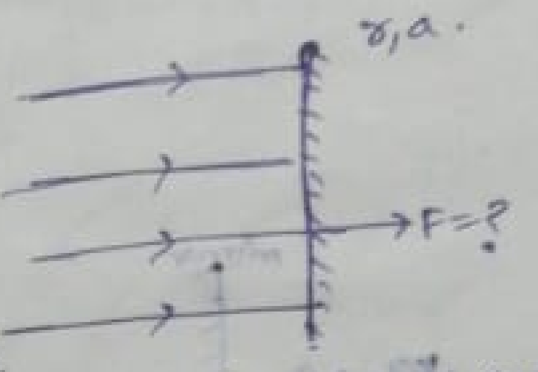
→ If surface is perfectly absorbing

$F = \dfrac{I \cdot A}{c} \Rightarrow \boxed{\text{Pressure }(P) = \dfrac{I}{c}}$

Reflection coefficient $(r) = \dfrac{\text{no. of photons reflected}}{\text{no. of photons } \cancel{\text{absorbed}} \text{ incident}}$ (28)

absorption coefficient $(a) = \dfrac{\text{no. of photons absorbed}}{\text{no. of photons incident}}$

Q)



A – area of surface

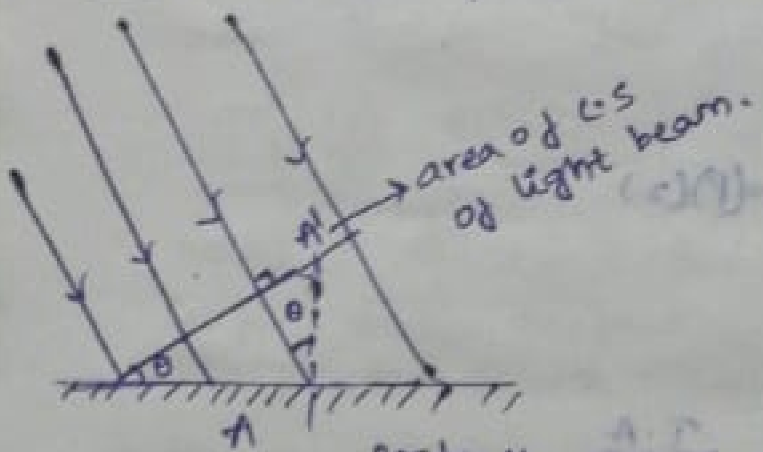
$F_{net} = F_r + F_a$

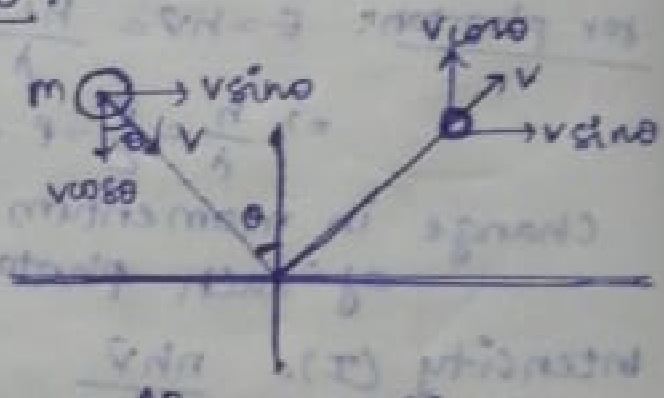
$= r\left(\frac{2IA}{c}\right) + a\left(\frac{IA}{c}\right)$

$\Rightarrow P = \frac{(F_{net})_{\perp r}}{A} = \frac{(2r+a)I}{c} = \frac{(2r+1-r)I}{c}$

$= \frac{(r+1)I}{c}$

If light falls at an angle 'θ':–





$\Delta P = 2mv\cos\theta$

perfectly reflecting surface

Change mom. of each photon $\Rightarrow \Delta P = \frac{2h}{\lambda}(\cos\theta)$

no. of photons hitting the surface per sec. $= \frac{n}{t} = \frac{I \cdot (A')}{h\nu}$ may / may not be area of surface

$\frac{n}{t} = \frac{I(A\cos\theta)}{h\nu}$

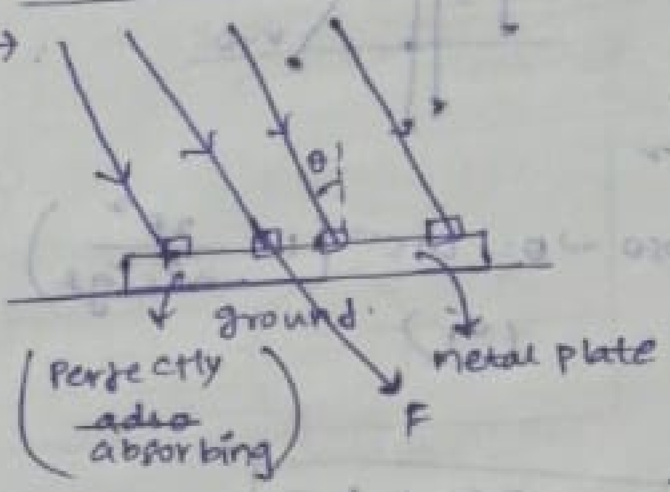
F = total change in mom. per second $= \left(\frac{IA\cos\theta}{h\nu}\right)\left(\frac{2h}{\lambda}\cos\theta\right)$

$= \left(\frac{IA\cos\theta}{\frac{hc}{\lambda}}\right)\left(\frac{2h}{\lambda}\cos\theta\right)$

$\therefore F = \frac{2IA\cos^2\theta}{c}$

$\boxed{\text{Pressure } P = \frac{F}{A} = \frac{2I\cos^2\theta}{c}}$

If surface is perfectly absorbing & light falls at an angle θ:

→ 

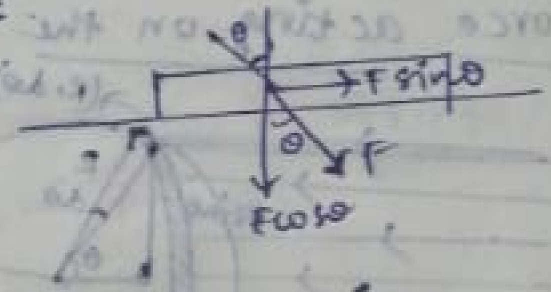
$$F = \begin{pmatrix}\text{no. of photons} \\ \text{hitting per sec}\end{pmatrix} \cdot \begin{pmatrix}\text{change in mom.} \\ \text{of each photon}\end{pmatrix}$$

$$F = \left(\frac{IA\cos\theta}{h\nu}\right)\left(\frac{h}{\lambda}\right)$$

$$F = \frac{IA\cos\theta}{hc}\left(\frac{\lambda h}{\lambda}\right)$$

$$\Rightarrow \boxed{F = \frac{IA\cos\theta}{c}}$$

Pressure acting on the surface is



$$P = \frac{F\cos\theta}{A} = \frac{IA\cos^2\theta}{c\cancel{A}}$$

$$\Rightarrow \boxed{P = \frac{I\cos^2\theta}{c}}$$

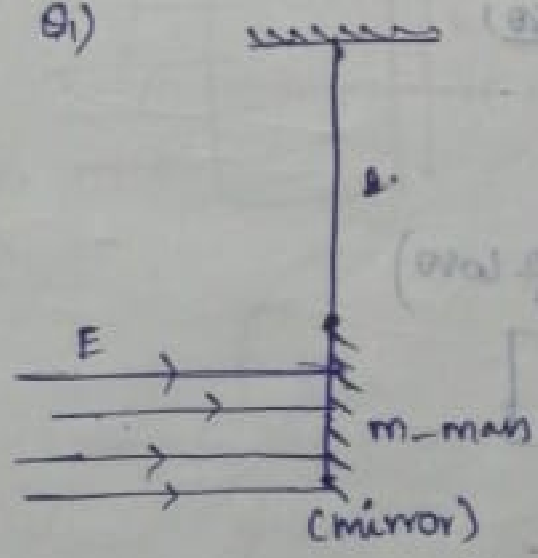
→ If ground is smooth, metal plate acceleration

$$a = \frac{F\sin\theta}{m}$$

→ If ground is rough, metal plate moves when

$$F\sin\theta > \mu N$$

$$\boxed{F\sin\theta > \mu(mg + F\cos\theta)}$$

Q1) 

If light of energy E is incident on the mirror and ⊥r to it for small time interval. Find the max. angular deflection of the mirror?

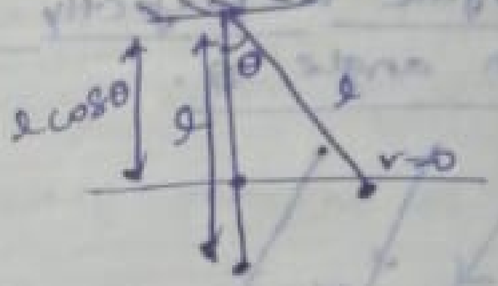
Soln: Force acting on the mirror due to radiation $\Rightarrow F = P(\text{area})$

$$F = \left(\frac{2I}{c}\right)(A) = \left(\frac{2E}{\Delta t\,\cancel{A}}\right)\left(\frac{\cancel{A}}{c}\right)$$

$$\Rightarrow F\cdot\Delta t = \frac{2E}{c} \Rightarrow \Delta P = \frac{2E}{c}$$

$mv - 0 = \frac{2E}{c}$

$\Rightarrow \boxed{v_f = \frac{2E}{mc}}$



$mg\ell(1-\cos\theta) = \frac{1}{2} m \cdot \frac{4E^2}{m^2c^2}$

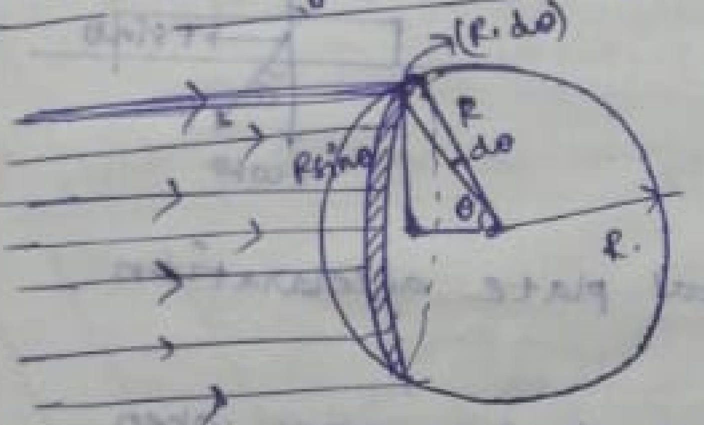
$\frac{2E^2}{m^2c^2g\ell} = 1-\cos\theta \Rightarrow \theta = \cos^{-1}\left(1 - \frac{2E^2}{m^2c^2g\ell}\right)$

(or)

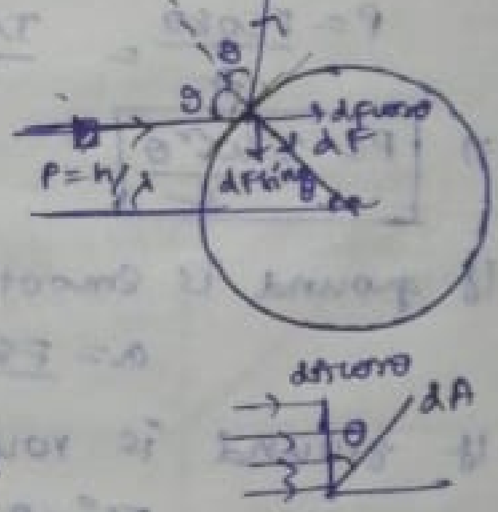
$2\sin^2\left(\frac{\theta}{2}\right) = \frac{2E^2}{m^2c^2g\ell}$

$\theta^2 = \frac{4E^2}{m^2c^2g\ell} \Rightarrow \boxed{\theta_{max} = \frac{2E}{mc}\left(\frac{1}{\sqrt{g\ell}}\right)}$

Force acting on the sphere:



Perfectly reflecting



change in momentum of each photon $= 2P\cos\theta = \frac{2h}{\lambda}\cos\theta$

no of photons hitting per sec. $= \left(\frac{n}{t}\right) = \frac{I(dA\cos\theta)}{h\nu}$

Force acting on strip is $\rightarrow$

$dF = \frac{I(dA\cos\theta)}{h\nu}\left(\frac{2h}{\lambda}\cos\theta\right)$

$\boxed{dF = \frac{2I(dA\cos^2\theta)}{c}}$

Net force acting on sphere $F = \int_0^{\pi/2} dF\cos\theta$.

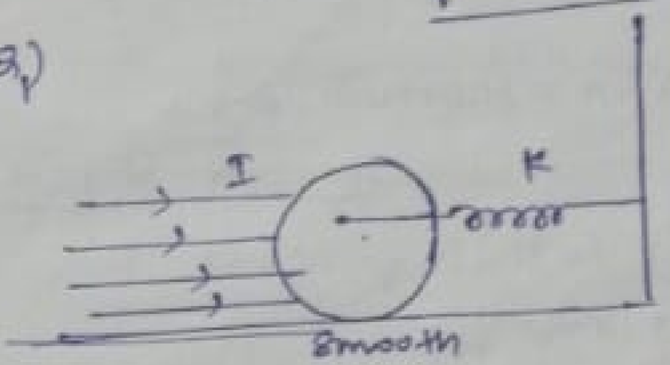
$= \int_0^{\pi/2} \frac{2I(2\pi R^2\sin\theta \cdot d\theta)\cdot\cos^2\theta}{c}\cdot\cos\theta$

$= \frac{4I\pi R^2}{c}\int_0^{\pi/2}\sin\theta\cdot\cos^3\theta\, d\theta$

$$= \frac{4I\pi R^2}{c}\left[\frac{-\cos^4\theta}{4}\right]_0^{\pi/2}$$

$$= \frac{I\pi R^2}{c} \Rightarrow \boxed{F_{net} = \frac{I}{c}(\text{Proj. area})}$$

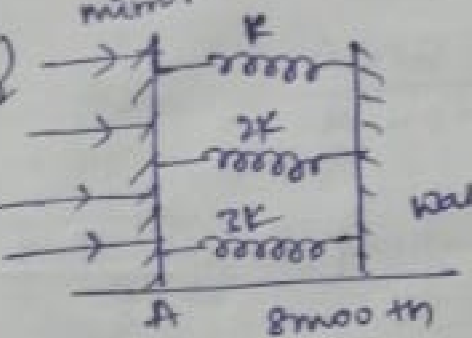
Q.) Find the comp. in spring at equilibrium?



Soln.: $F = \frac{I}{c}(\pi R^2) = kx_0$

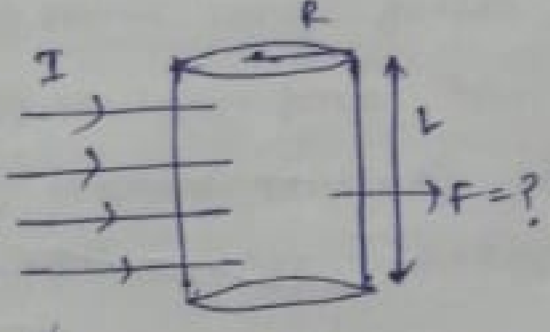
$$\Rightarrow x_0 = \frac{I(\pi R^2)}{cK}$$

Q.) Find the comp. in springs at equilibrium?



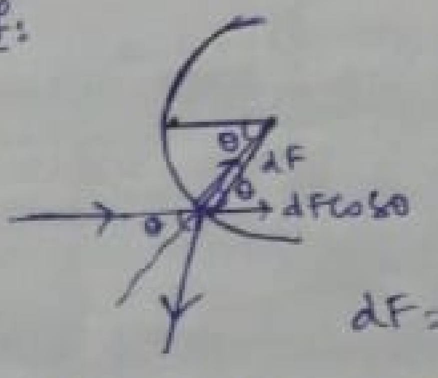
Soln.: $k_{eff} = K + 2K + 3K = 6K$

$$(6K)(x_0) = \frac{2I}{c}(A) \Rightarrow \boxed{x_0 = \frac{2I \cdot A}{6CK_0}} \Rightarrow \boxed{x_0 = \frac{IA}{3CK}}$$ *



$$\boxed{F = \frac{8IRl}{3C}}$$

Proof:



$dA = R \cdot d\theta \sin\theta (l)\cos$

$dA\cos\theta$ is ⊥r to direction of ray.

$$\frac{n}{t} = \frac{I(dA\cos\theta)}{h\nu}$$

$$dF = \frac{I(dA\cos\theta)}{hc}\left[\frac{2h}{\lambda}\cos\theta\right]$$

$$dF = \frac{2I(R \cdot d\theta\cos\theta)(l)\cos\theta}{c}$$

$$\int_0^{\pi/2} 2\,dF\cos\theta \cdot d\theta = \int_0^{\pi/2}\frac{4IRl}{c} \cdot \cos^3\theta \cdot d\theta$$