Orbital

Space where electrons are found

Orbitals are characterized by set of quantum numbers (n,l,m)

solution of Schrodinger wave functⁿ

Principal Quantum no. → $n \rightarrow$ shell no.

Azimuthal " → $l \rightarrow$ subshell

Magnetic " → $m \rightarrow$ orbital

Quantum Number

Set of numbers which represent the position of electron in an atom

Concept came from **Quantum Mechanics**

Schrodinger Eqn

$\hat{H}(\psi) = E(\psi$

Solution of this Equation gave three set of quantum numbers

(n)

(l)

(m)

$$\frac{\partial^2\psi}{\partial^2 x} + \frac{\partial^2\psi}{\partial^2 y} + \frac{\partial^2\psi}{\partial^2 z} + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0$$

Schrodinger Eqn

$\widehat{H}(\psi) = E(\psi$

Solution of this Equation gave **three set of quantum numbers**

schordinger

Principal quantum numbers(n)

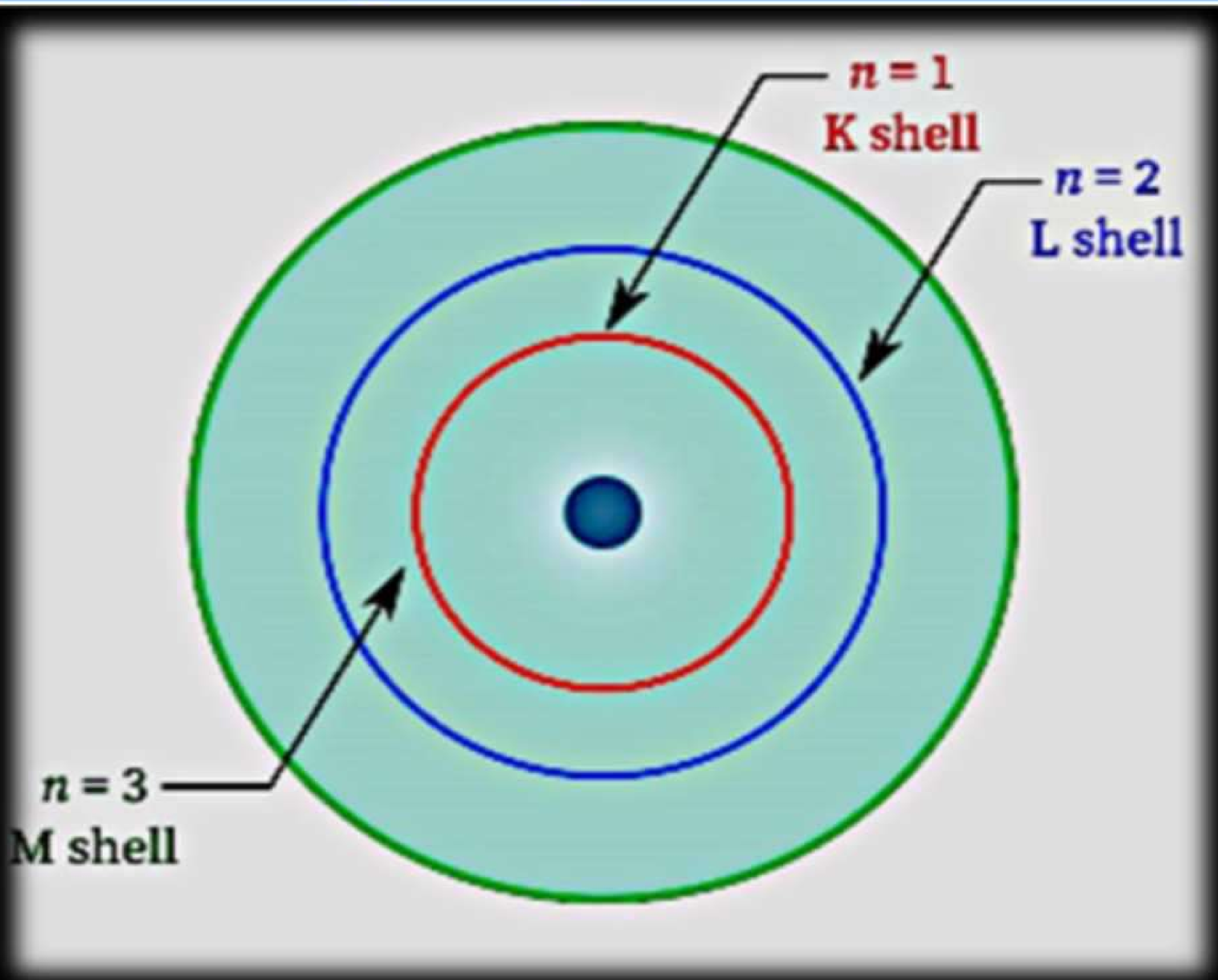
Magnetic quantum numbers(m)

Azimuthal quantum numbers(l)

* But 4^{th} Quantum no.
Came from
experiment

Spin quantum numbers(s)

Principal quantum numbers(n)



* It represents the shell no.
* Also tell about size & energy of shell as $(n)\uparrow \Rightarrow$ size $\uparrow$ energy $\uparrow$

* (n) shell no.
  - subshell = (n)
  - orbitals = (n^2)
  - e^- = $(2n^2)$

shell no.	(2)	(3)
subshells	(2)	(3)
orbitals	(4)	(9)
e^-	(8)	(18)

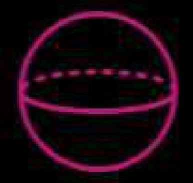
* size $(2 < 3)$
* energy $(2 < 3)$

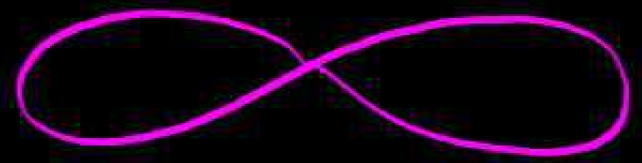
Azimuthal (Angular momentum) quantum numbers(l)

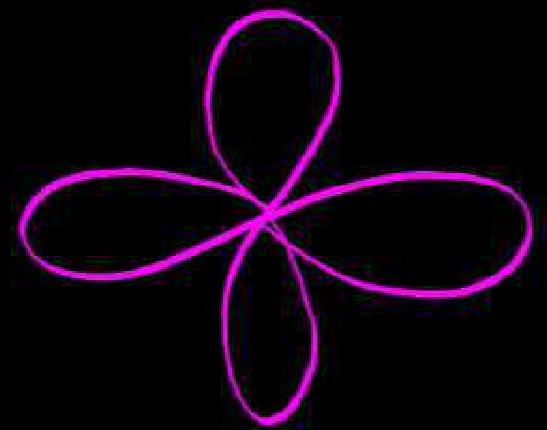
(*) shape of orbital in given subshell

(*) Name of subshell

(*) Its value $(0 \text{ to } (n-1))$

(*) $l = 0 \Rightarrow$ s - subshell $\Rightarrow$ spherical shape 

$l = 1 \Rightarrow$ p - subshell $\Rightarrow$ dumbell shape 

$l = 2 \Rightarrow$ d - subshell $\Rightarrow$ double dumbell shape 

$l = 3 \Rightarrow$ f - subshell $\Rightarrow$ not defined

(*) orbital angular momentum $= \sqrt{l(l+1)}\,\frac{h}{2\pi}$

(*) No. of orbitals $= (2l+1)$ (*) no. of e⁻ $2(2l+1) \Rightarrow 4l+2$

Ex: $n = 1 \Rightarrow l = 0 \Rightarrow 1s$

$n = 2 \Rightarrow l = 0, 1 \Rightarrow 2s, 2p$

$n = 3 \Rightarrow l = 0, 1, 2$

$3s, 3p, 3d$

NOTE:

1) Bigger (n) $\Rightarrow$ Far, more energy

2) Same (n)

$s > p > d > f$

Penetration power

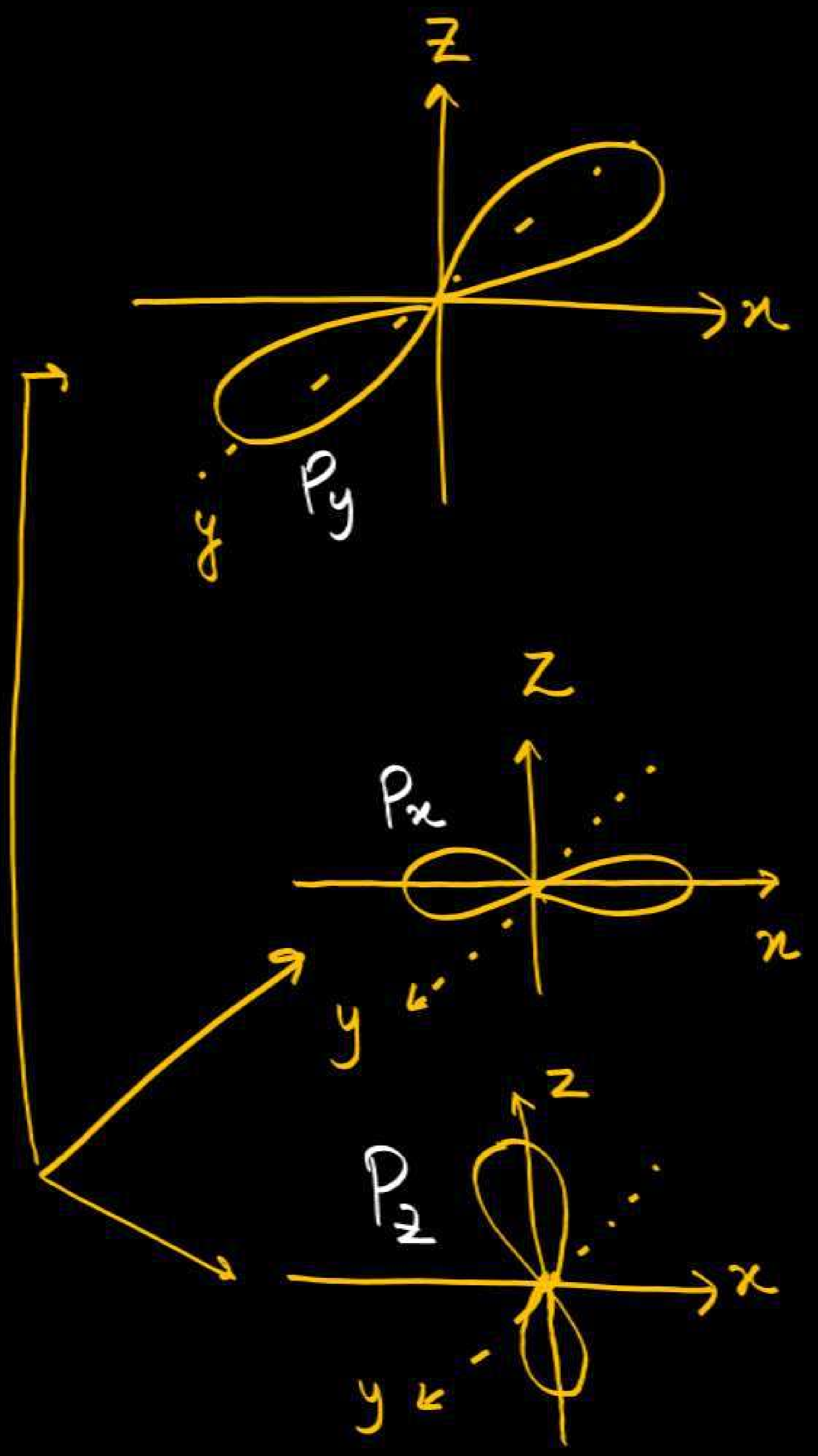
3) Energy $\Rightarrow s < p < d < f$

Magnetic quantum numbers(m_l)

* (3-d) Spatial arrangement of orbitals
* Its value from $(-l)$ to $(+l)$ $\longrightarrow$ Total values $(2l+1)$
* Each orbital have diff orientation
* Total orbitals (orientation) $= (2l+1)$
* $l = 0 \Rightarrow (s) \Rightarrow m = 0 \Rightarrow$ one orientation $\boxed{}$
* $l = 1 \Rightarrow (p) \Rightarrow m = -1, 0, 1 \Rightarrow$ Three orientation

-1	0	1
P_x	P_y	P_z

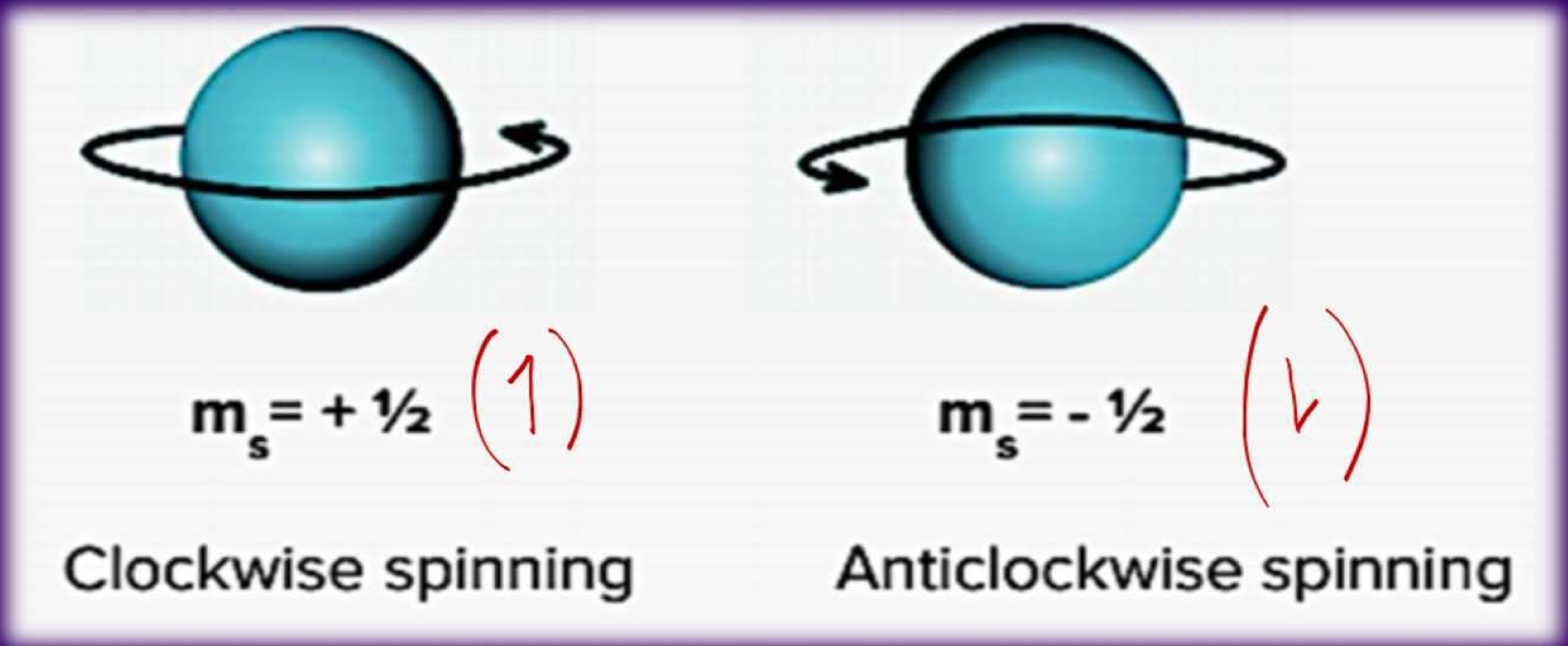
(Degenerate orbital) $\Rightarrow$ same energy



Spin quantum numbers(n or m_s) → From experiment

1. Represents the spin(rotation) of electron around nucleus. It can be CW or ACW

2. It takes value $\pm\frac{1}{2}$,



(s) $\boxed{\uparrow\downarrow}$ = 2e

(p) $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$ = 6e

(d) $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$ = 10e

(f) $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$ = 14e

Principal quantum numbers(n)

1. It represents the shell number
2. It determines the size and energy of orbital
3. It tells number of subshells(n) present in it
4. It tells number of orbitals(n^2) present in it.
5. It tells number of electron $2(n^2)$ present

Magnetic quantum numbers(n)

1. Defines the orientation of orbitals in space
2. Its value is from { -l to +l}
3. It tells number of orbitals present in a subshells = (2l+1)
1. Orbitals having same (n,l) value have same energy called **degenerate orbitals**

Spin quantum numbers(n)

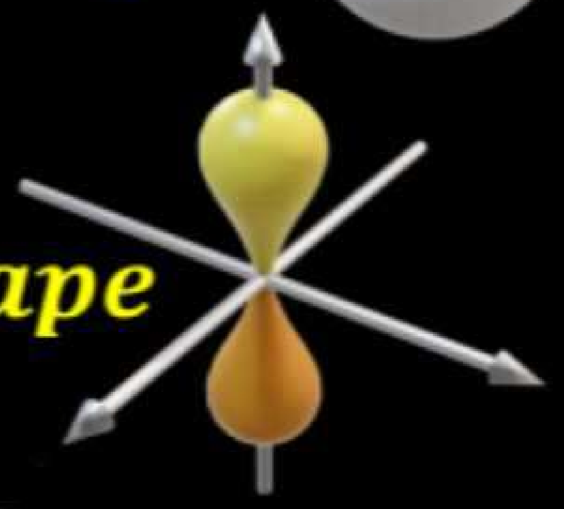
1. Represents the spin(rotation) of electron around nucleus. It can be CW or ACW
2. It takes value $\pm\frac{1}{2}$,

Azimuthal quantum numbers(l)

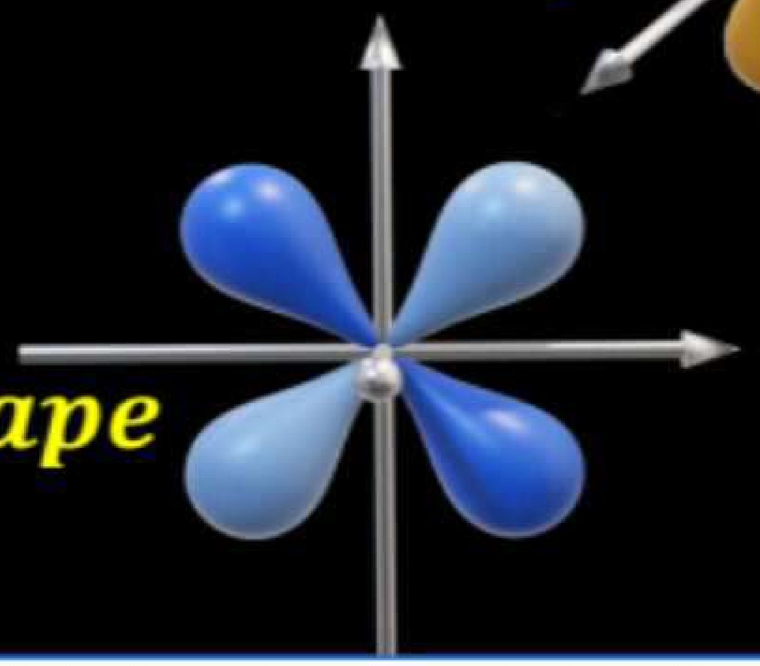
1. Tells the name, shape and no. of subshell present in given shell
2. Its value is from { l=0 to l=(n-1)}
   - l = 0 → [S] subshell
   - l = 1 → [p] subshell
   - l = 2 → [d] subshell
   - l = 3 → [f] subshell

   Name of subshells
3. No. of subshell in a shell = **(n)**
4. **Shape of subshell**
   - ❖ [S] subshell → ***Spherical shape***

   - ❖ [p] subshell → ***dumbell shape***



   - ❖ [d] subshell → double ***dumbell shape***



❖ **[f] subshell →** ***Not in syllabus***

Graph predict nodes and antinodes

JEE

- ✓ Nucleus is considered as origin
- ✓ For S-orbital graph starts from max.
- ✓ For p, d, f graph start from origin
- ✓ Point where graph cuts x - axis is called radial node
- ✓ As (r) increases height of peak decreases

Graph based Schordinger's Eqn

① R v/s r or ψ v/s r

② R^2 v/s r or ψ^2 v/s r

③ Probability (P) v/s (r)

$(4\pi r^2)R^2$ v/s (r)

Nodes

where (e^-) finding Prob. is zero

1. The region of zero probability density (excluding nucleus and infinity)
2. Total number of angular nodes(nodal planes) = l
3. Total number of radial nodes = n – l – 1
4. Thus, total number of nodes = n – 1

Nodes

- Radial nodes = $[(n-1) - l]$
- Angular nodes = (l)
- Total nodes $(n-1)$

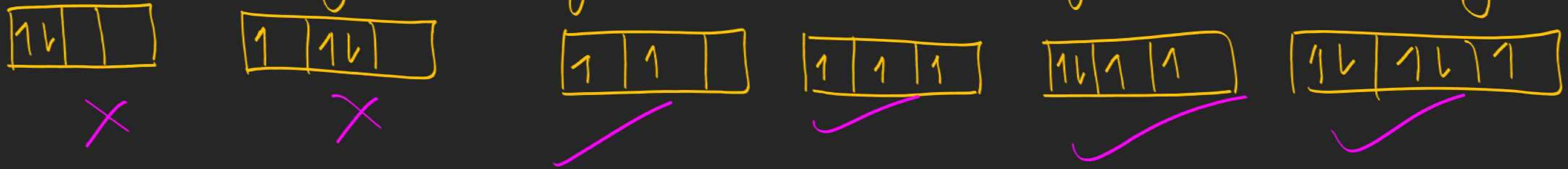
r = distance from nucleus

Rule (1) AFbau's $(n+l)$ rule $\Longrightarrow$ i) smaller $(n+l)$ $\Rightarrow$ $\boxed{\text{smaller energy}}$ filled first

ii) If $(n+l)$ same then (n) small

$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d$

Hund's Rule : Pairing occurs only after each orbital of same subshell gets on e-



3) Pauli's exclusion Principle

No two e-s can have same set of Quantum no.

b/c they have diff. spin

3s → $\boxed{\uparrow\uparrow}$ wrong

→ $\boxed{\uparrow\downarrow}$ correct

Quantum Numer $(3, 0, 0, \frac{1}{2})$ $(3, 0, 0, -\frac{1}{2})$

Paired e- # unpaired e-

$\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ ⟹ unpaired e- = 3

Paired e- = 4

unpaired = (3)

(i) Total spin $= n\left(\pm\frac{1}{2}\right)$ ⟹ Total spin $= \pm 3/2$

(ii) Magnetic Moment $= \sqrt{n(n+2)}$ ⟹ $B.M. = \sqrt{3 \times 5}$
(Bohr Mangueton)

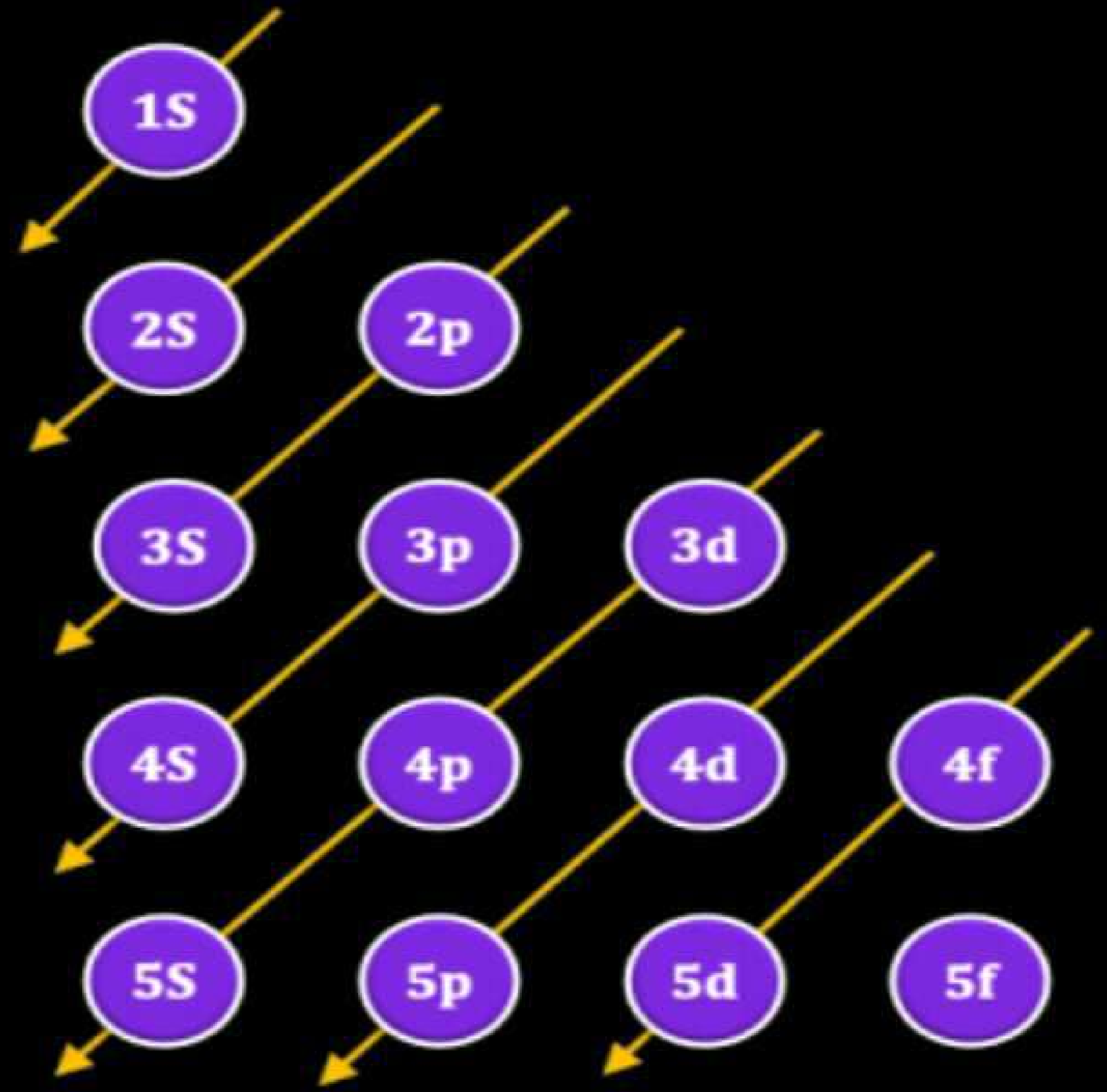
$= \sqrt{15}$

$= (3.87)$

$n \rightarrow$ no. of unpaired e-

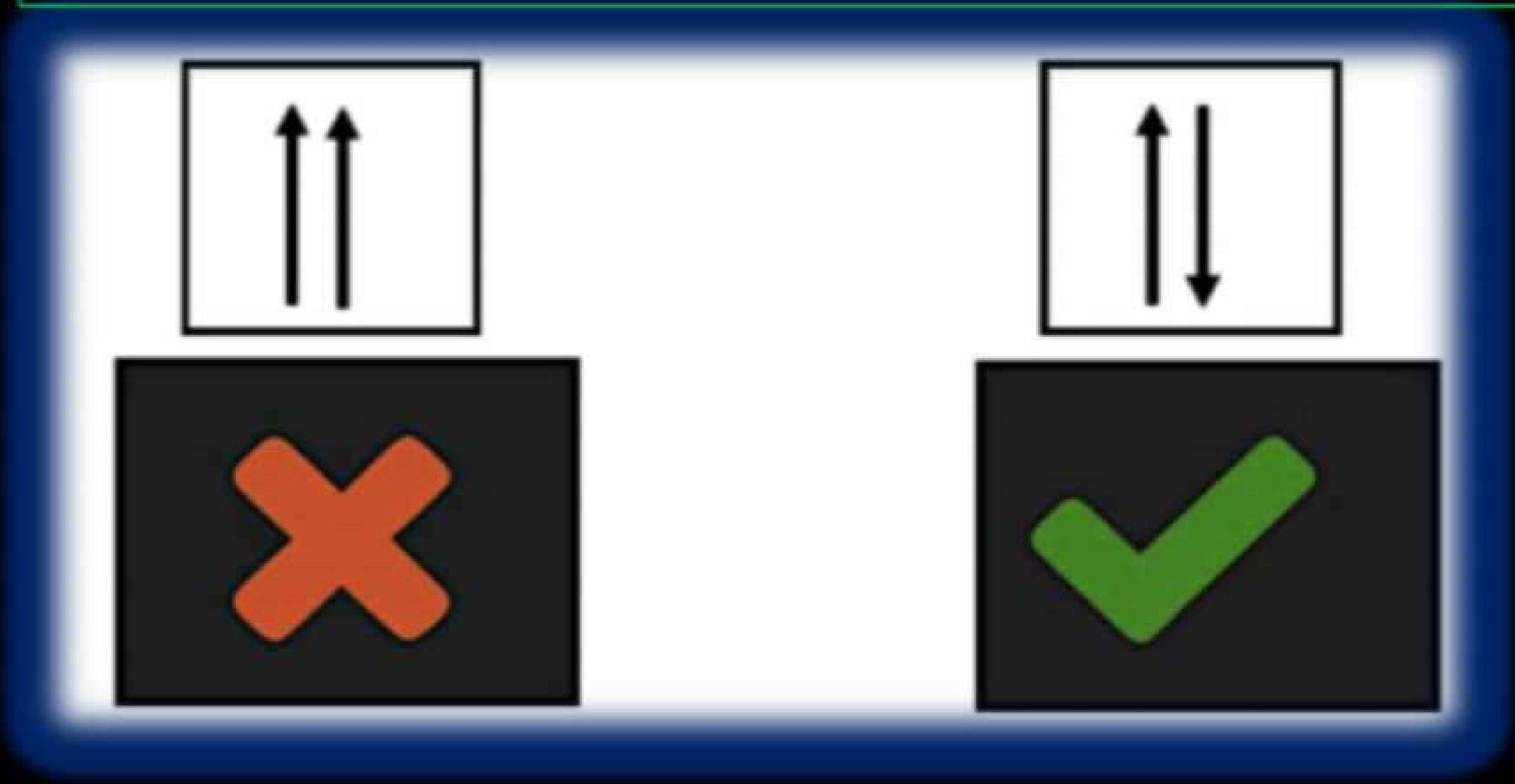
Aufbau principle

- Orbitals are filled in order of their increasing energies
- Orbital with lower value of (n+l) is filled first
- If (n+l) value is same the one having smaller (n) is filled first.



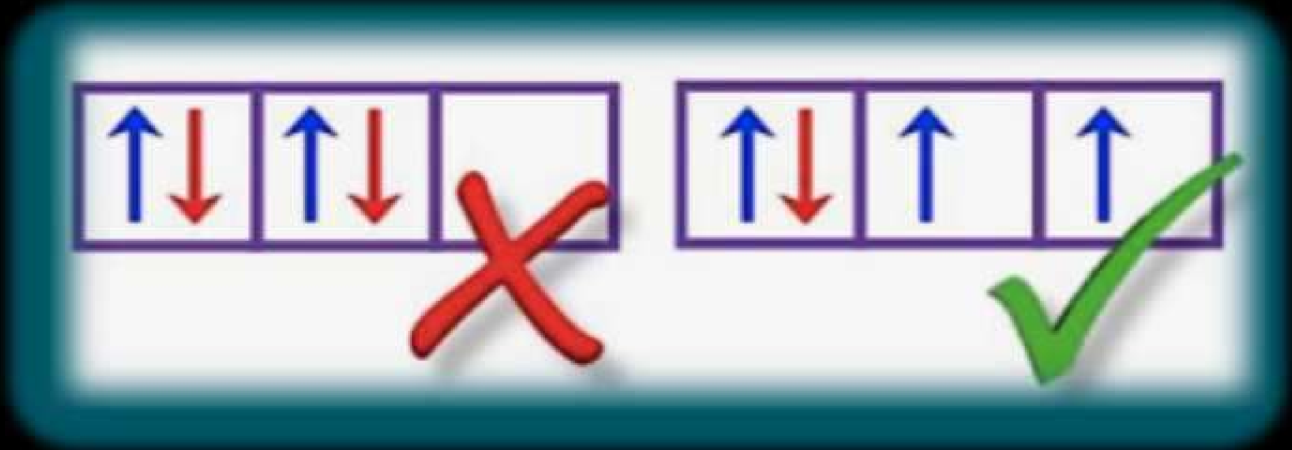
Pauli exclusion principle

- No two electrons in an atom can have the same set of four quantum numbers.
- "Only two electrons may exist in the same orbital and these electrons must have opposite spin."



Hund's Rule

- It states : "pairing of electrons in the orbitals belonging to the same subshell (p, d or f) does not take place until each orbital belonging to that subshell has got one electron each i.e., it is singly occupied".



Application of Quantum no.

~~(i)~~ Comparing energy of orbital

(ii) Electronic configuration

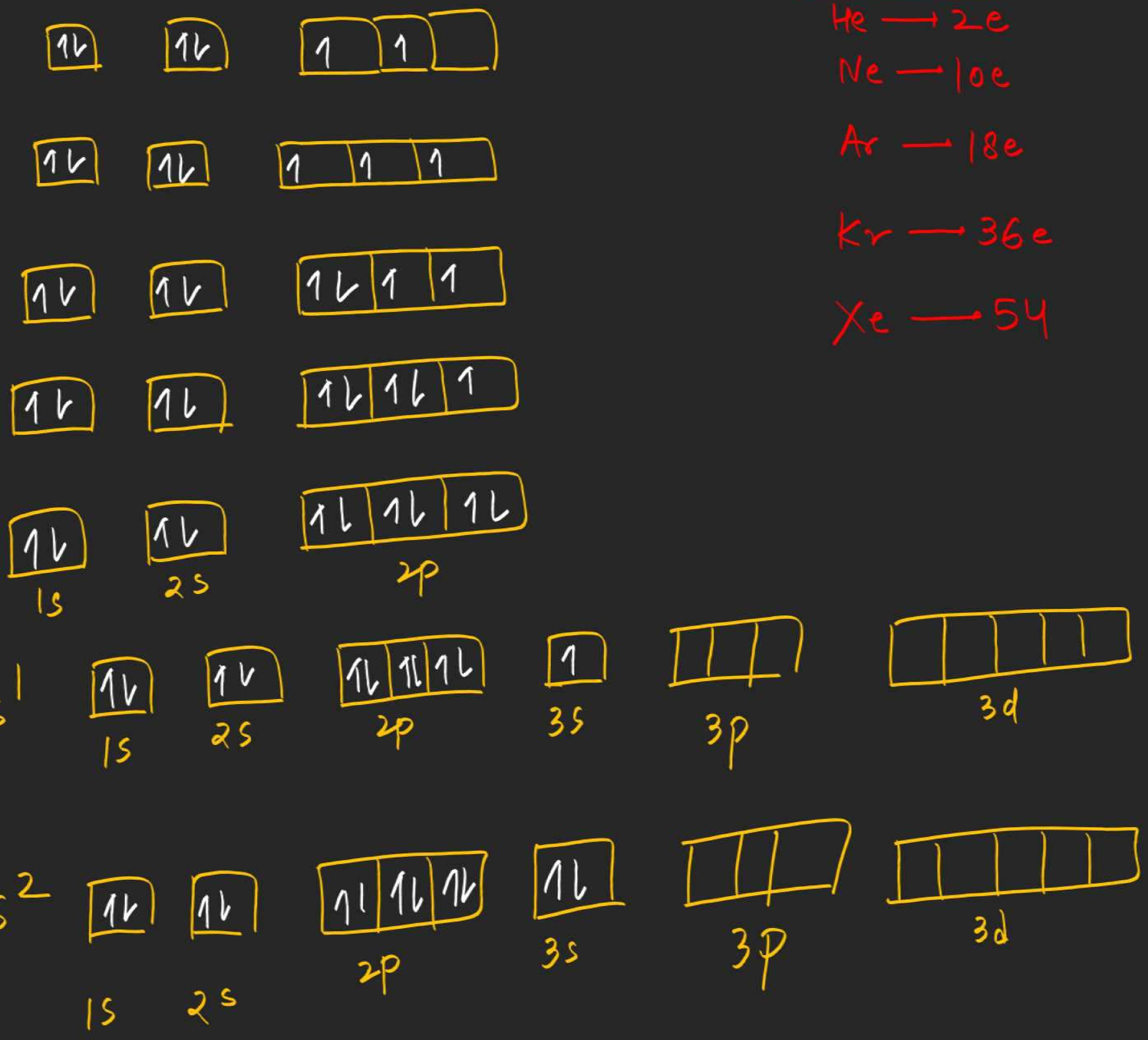
- ⟹ Para / diamagnetic
- ⟹ Unpaired e^- and Magnetic moment $= \sqrt{n(n+2)}$
- ⟹ stability of Half / fully filled
- ⟹ excitation of e^-

<u>Electronic configuration</u> : sequential distribution of e-s in orbitals using all three rules.

<u>Element</u> / No. of e-	<u>Configuration</u>	
H (1e)	$1s^1$	$\boxed{\uparrow}$
He (2e)	$1s^2$	$\boxed{\uparrow\downarrow}$
Li (3e)	$1s^2 2s^1$	$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow}$
Be (4e)	$1s^2 2s^2$	$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$
B (5e)	$1s^2 2s^2 2p^1$	$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow}\boxed{}\boxed{}$

1s
2s
2p
3s
3p
4s
3d
4p
5s
4d
:
:

Element / No. of e-	configuration
C (6e)	$\longrightarrow 1s^2 2s^2 2p^2$
N (7e)	$\longrightarrow 1s^2 2s^2 2p^3$
O (8e)	$\longrightarrow 1s^2 2s^2 2p^4$
F (9e)	$\longrightarrow 1s^2 2s^2 2p^5$
Ne (10e)	$\longrightarrow 1s^2 2s^2 2p^6$
Na (11e)	$\longrightarrow \boxed{1s^2 2s^2 2p^6} 3s^1$
$\downarrow$ [Ne] $3s^1$	
Mg (12e)	$\longrightarrow \boxed{1s^2 2s^2 2p^6} 3s^2$
$\downarrow$ [Ne] $3s^2$	



Noble Gas

He → 2e
Ne → 10e
Ar → 18e
Kr → 36e
Xe → 54

1s
2s
2p
3s
3p
4s
3d
4p
5s
4d
⋮

Al $(13e) \longrightarrow \boxed{1s^2 2s^2 2p^6} 3s^2 3p^1 = [Ne]3s^2 3p^1 \longrightarrow$ Valence $e^- = 2+1 = 3e$

Si $(14e) \longrightarrow$ —〃— $3s^2 3p^2 = [Ne]3s^2 3p^2 \longrightarrow$ —〃— $= 2+2 = 4e$

P $(15e) \longrightarrow$ —〃— $3s^2 3p^3 = [Ne]3s^2 3p^3 \longrightarrow 5e$

[Ne] [1↓] [1|1|1] [| | | |]
3s 3p 3d

S $(16e) \longrightarrow$ —〃— $3s^2 3p^4 = [Ne] 3s^2 3p^4 \longrightarrow 6e$

Cl $(17e) \longrightarrow$ —〃— $3s^2 3p^5 = [Ne] 3s^2 3p^5 \longrightarrow 7e$

Ar $(18e) \longrightarrow$ —〃— $3s^2 3p^6 = (Ar) \longrightarrow 8e$

K $(19e) \longrightarrow \boxed{1s^2 2s^2 2p^6 3s^2 3p^6} 4s^1 = (Ar) 4s^1 \longrightarrow 1e$

Ca $(20e) \longrightarrow$ —〃— $4s^2 = (Ar) 4s^2 \longrightarrow 2e$

Scandium $\Rightarrow$ Sc (21) $\Rightarrow$ [Ar] $4s^2 3d^1$

Titanium $\Rightarrow$ Ti (22) $\Rightarrow$ [Ar] $4s^2 3d^2$

Vanadium $\Rightarrow$ V (23) $\Rightarrow$ [Ar] $4s^2 3d^3$

$\boxed{\text{Chromium} \Rightarrow Cr(24) = [Ar]\,4s^1 3d^5}$

Manganese $\Rightarrow$ Mn (25) = [Ar] $4s^2 3d^5$

Iron $\Rightarrow$ Fe (26) = [Ar] $4s^2 3d^6$

Cobalt $\Rightarrow$ Co (27) = [Ar] $4s^2 3d^7$

Nickel $\Rightarrow$ Ni (28) = [Ar] $4s^2 3d^8$

$\boxed{\text{Copper} \Rightarrow Cu(29) = [Ar]\,4s^1 3d^{10}}$

Zinc $\Rightarrow$ Zn (30) = [Ar] $4s^2 3d^{10}$

Half / fully filled are more stable orbitals

d^5, d^{10}

p^6, p^3

are stable configuration

Sc (21)	Ti	V (23)	Cr* (24)	Mn
$4s^2 3d^1$		$4s^2 3d^3$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow \mid \uparrow \mid \uparrow \mid \quad \mid \quad}$ 4s $(n = 3)$ ↳ unpaired e−	$4s^1 3d^5$ $\boxed{\uparrow}$ $\boxed{\uparrow \mid \uparrow \mid \uparrow \mid \uparrow \mid \uparrow}$ 4s 3d $(n = 6)$ max unpaired e−	

Fe (26)	Co	Ni (28)	Cu	Zn
$4s^2 3d^6$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow \mid \uparrow \mid \uparrow \mid \uparrow \mid \uparrow}$ $n = 4$	$n = 3$	$4s^2 3d^8$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow \mid \uparrow\downarrow \mid \uparrow\downarrow \mid \uparrow \mid \uparrow}$ $n = 2$	$n = 1$	$n = 0$

Sc	Sc^{+}	Sc^{+2}	V (23)	V^{+}	V^{+3}
$4s^2 3d^1$	$4s^1 3d^1$	$4s^0 3d^1$	$4s^2 3d^3$	$4s^1 3d^3$	$4s^0 3d^2$

configuration of ions : e- are removed / added in outer shell

$[O] = 1s^2 2s^2 2p^4$

O^{2-} $1s^2 2s^2 2p^6$

O^{+} $1s^2 2s^2 2p^3$

$Fe = [Ar] 4s^2 3d^6$

Fe^{+2} : $[Ar] 4s^0 3d^6$

Fe^{+3} : $[Ar] 4s^0 3d^5$

$Cu : 4s^1 3d^{10}$

$Cu^{+1} : 4s^0 3d^{10}$

$Cu^{+2} : 4s^0 3d^9$

$Zn^{+2} : 4s^0 3d^{10}$

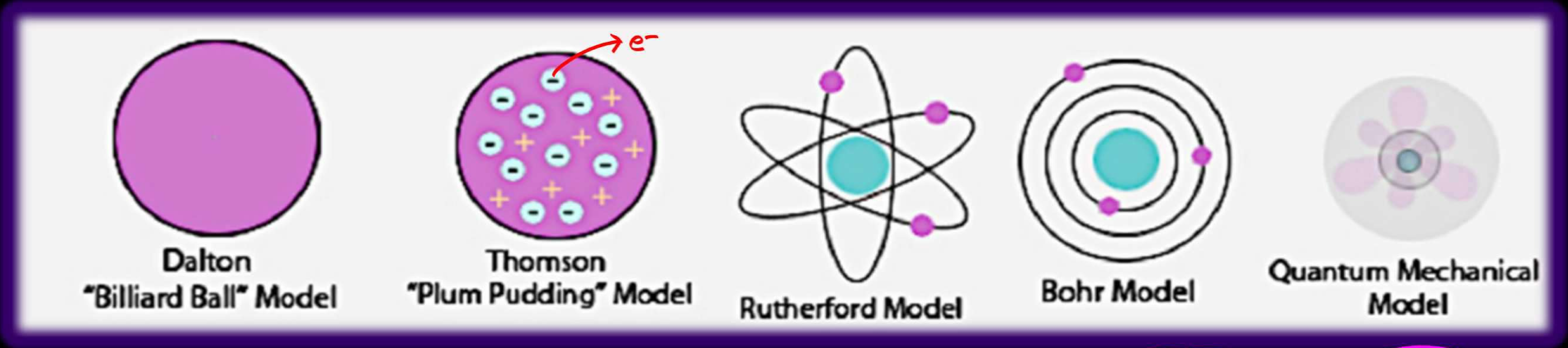
$Mn : 4s^2 3d^5$

$Mn^{+2} : 4s^0 3d^5$

$Mn^{+3} : 4s^0 3d^4$

LIVE

Atomic Models We know



Dalton

- # Smallest particle (Atom)
- # No subatomic particle

Thomson

- # e^- at rest
- * $\vec{F}_{net} = 0$
- * Equilibrium

Rutherford

- # Discovered nucleus
- # α- gold foil exp.
- # e^- revolves around nucleus
- # (n, p) inside nucleus

Classical mechanics

$\Downarrow$

NLM applicable

(Macroscopic object)

Quantum mechanics

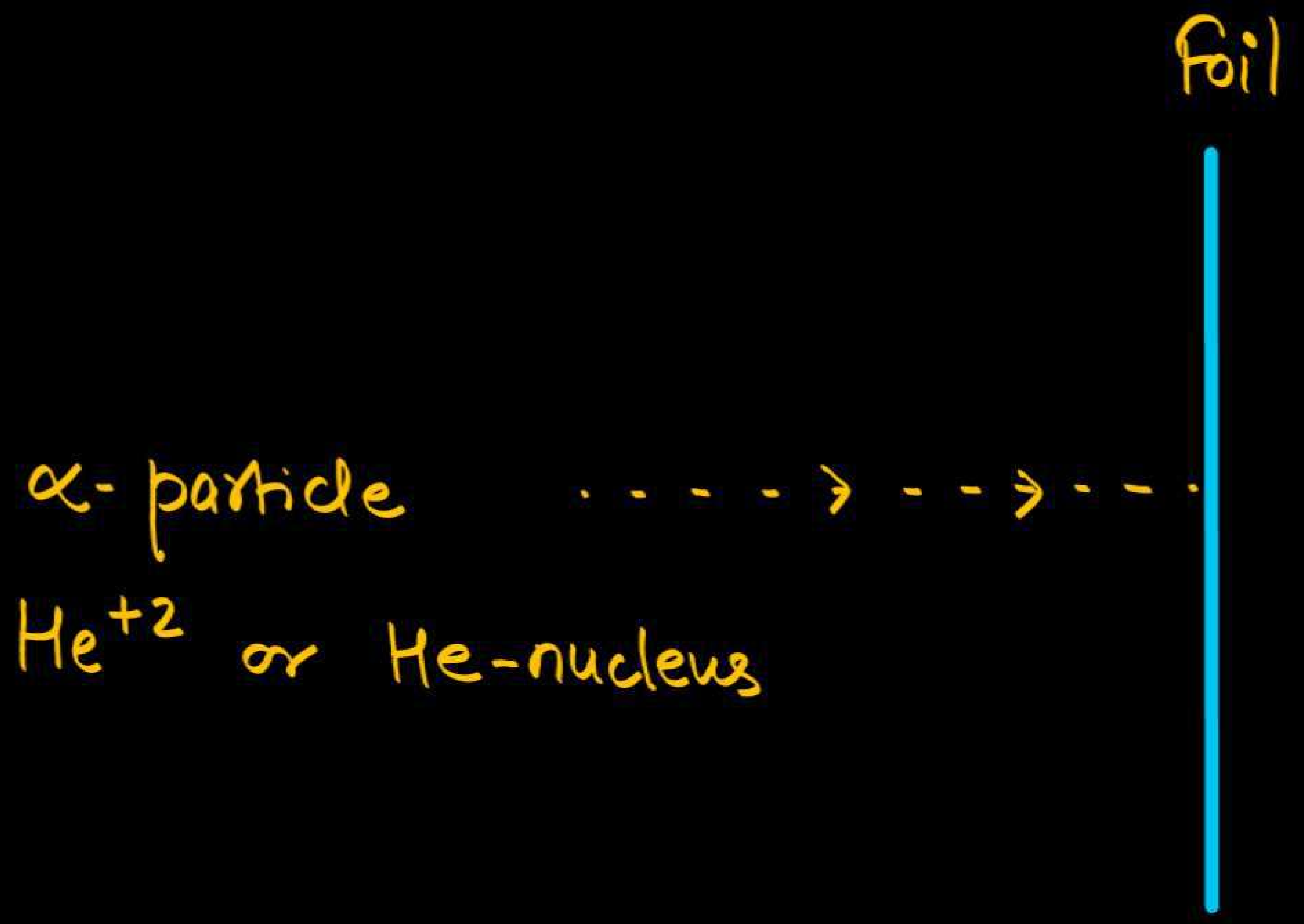
$\Downarrow$

NLM not applicable

(microscopic object)

Rutherford Model

❖ No. of $\alpha - particle$ deflected $\propto$ thickness of foil $\propto$ (atomic number)^2 $\propto \frac{1}{(K.E. of\ \alpha-particle)^2} \propto \frac{1}{\left[\sin\frac{\theta}{2}\right]^4}$



where

$\left(t \equiv \text{thickness} \right)$

(i) $\frac{N_1}{N_2} = \frac{t_1}{t_2}$

(ii) $\frac{N_1}{N_2} = \left(\frac{Z_1}{Z_2}\right)^2$

(iii) $\frac{N_1}{N_2} = \left(\frac{KE_2}{KE_1}\right)^2$

(iv) $\frac{N_1}{N_2} = \left(\frac{\sin\theta_2/2}{\sin\theta_1/2}\right)^4$

Ex: If 50 α-particle were deflected using mg-foil of thickness 4mm. then no. of Particles deflected

a) thickness is doubled

b) Same thickness of 'Cr'

c) Double (KE)

a) $\frac{N_1}{N_2} = \frac{t_1}{t_2} \Rightarrow \frac{50}{N_2} = \frac{4}{8}$

$$\boxed{N_2 = 100}$$

b) $\frac{N_1}{N_2} = \left(\frac{Z_1}{Z_2}\right)^2 \Rightarrow \frac{50}{N_2} = \left(\frac{12}{24}\right)^2$

$$200 = N_2$$

$$\frac{N_1}{N_2} = \left(\frac{KE_2}{KE_1}\right)^2$$

$$\frac{50}{N_2} = \left(\frac{2}{1}\right)^2$$

$$N_2 = 50/4$$

Wave : Transfer of energy / momentum / Pressure difference

G.K.

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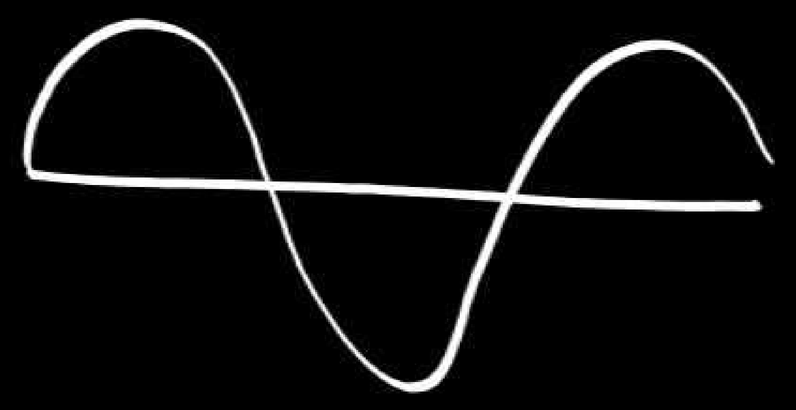
Type of waves

Mechanical Waves

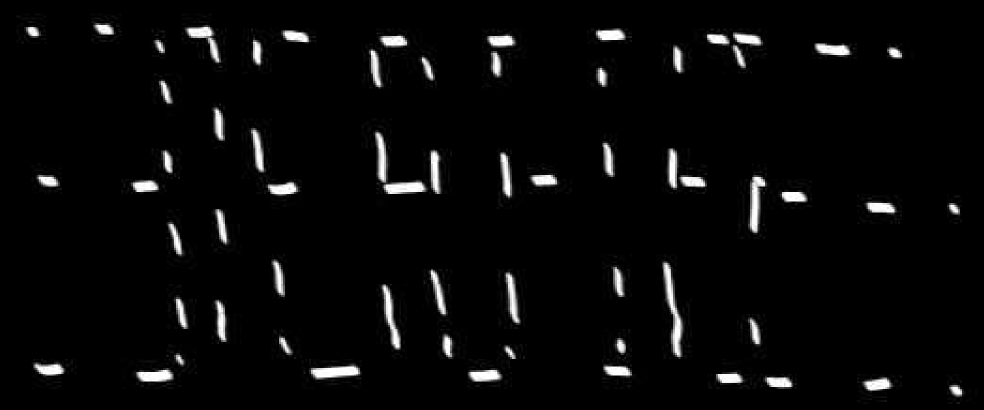
* Require medium to travel

Transverse

Longitudinal



ex string wave



sound wave

Electromagnetic Waves (EMW) (Non-mechanical wave)

* Doesn't req. medium to travel
* Transverse wave
* Produced by accelerating charge particle
* EMW is an oscillation of electric ($\vec{E}$) and magnetic ($\vec{B}$) field vectors ⊥r to its propagation

Wave Parameter

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Speed of All EMW is speed of light $(c) = 3 \times 10^{8}\, m/s$

(i) wavelength (λ)

(ii) wave no. $\left(\frac{1}{\lambda}\right)$

(iii) Time period $\left(T = \frac{\lambda}{c}\right)$

(iv) frequency $(\nu) = \frac{1}{T}$

$\hookrightarrow$ Unit : Hz

$$\boxed{\text{** } \nu \qquad \nu = \frac{c}{\lambda}}$$

* $nm = 10^{-9}\, m$
* $A^{\circ} = 10^{-10}\, m$
* $Pm = 10^{-12}\, m$

Wave Number$(\bar{\nu})$: It is defined as the number of wavelengths per unit length.

γ-rays X-rays UV IR Microwave Radio wave

white light

Visible light

400nm 750nm

λ_{min}

ν_{max}

more penetrat^{n}

more energy

λ_{max}

ν_{min}

low energy

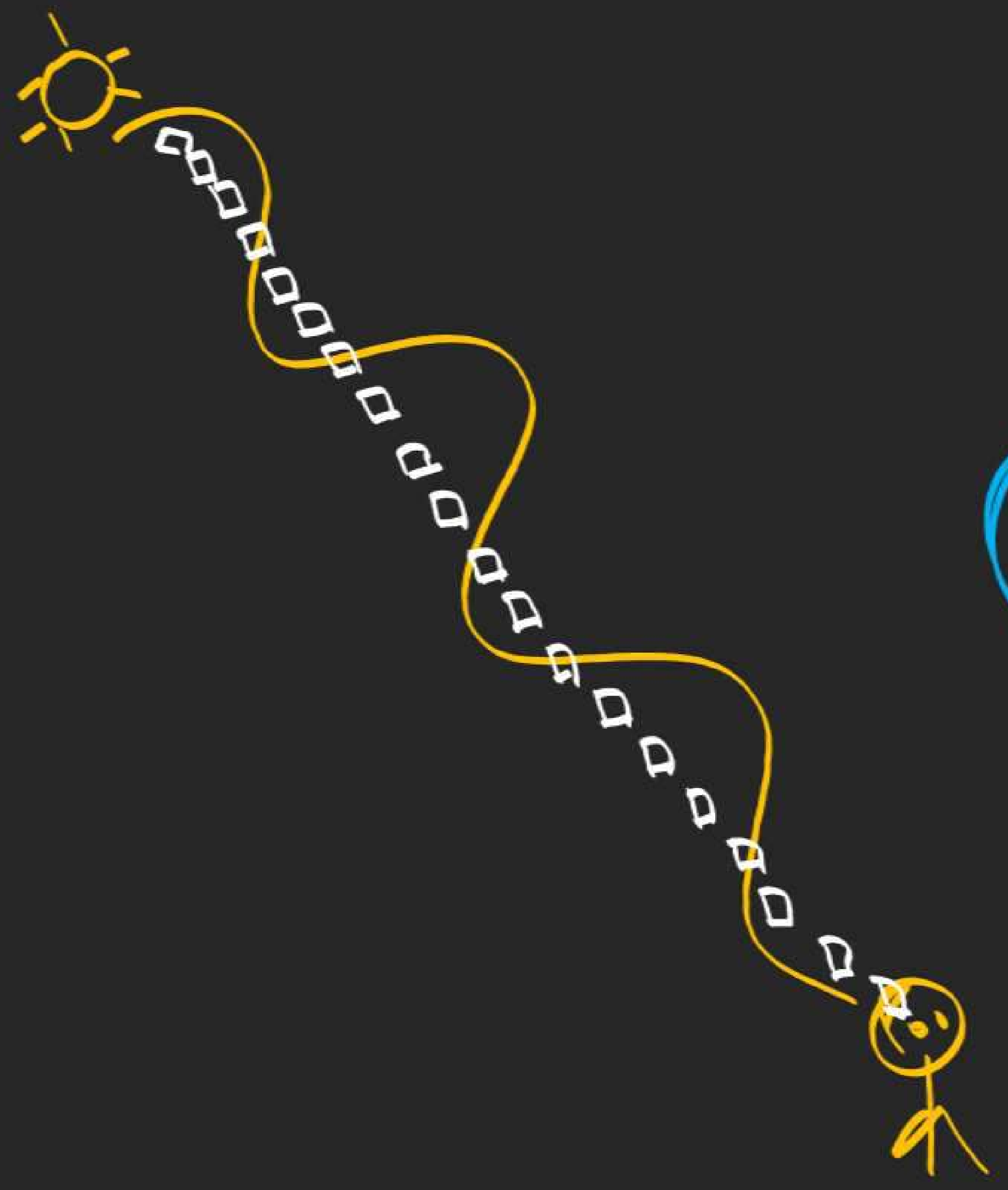
V I B G Y O R

ν_{more} $\longleftrightarrow$ λ_{more}

energy more $\longleftrightarrow$ energy less

Plank's Quantum Theory : energy transfer through radn is not continuous but in $\boxed{\text{discreate manner}}$

- In the form of small packets of energy called photon (Quanta of light)
- Quantisation of energy (energy is integral multiple of one photon energy)



Imp

Energy of photon $\propto$ freq $\propto \frac{1}{\text{wavelegth}}$

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

where

h = Plank's const.

$= 6.62 \times 10^{-34}$ J.s.

$\Rightarrow$ Total energy $\Rightarrow E_T = n(h\nu) = \frac{nhc}{\lambda}$

($n \rightarrow$ no. of photon)

Equating energy of photons and wave

LIVE

(i) one photon : $\varepsilon = h\nu = \frac{hc}{\lambda}$

(ii) n - photon : $\varepsilon_T = n(h\nu) = n\left(\frac{hc}{\lambda}\right)$

(iii) Power in 1 sec = Energy $= n(h\nu) = n\left(\frac{hc}{\lambda}\right)$

(iv) (Power × time) = energy total = —, —

i) 1 mole photon $= 6.02 \times 10^{23}$ photon
$= (N_A)$ photon

⇒ energy $= (N_A) h\nu$

$= (N_A) \frac{hc}{\lambda}$

(ii) Energy — Joule, (eV)

(eV) $\xrightarrow{\times 1.6 \times 10^{-19}}$ Joule

Joule $\xrightarrow{\div 1.6 \times 10^{-19}}$ (eV)

Bohr model (Valid for single e^- system) → H, He^+, Li^{+2}, Be^{+3} ...

(i) e^- will revolve only in those orbit which has angular momentum $= n\left(\frac{h}{2\pi}\right)$

$$\Rightarrow \boxed{mvr = \frac{nh}{2\pi}}$$

where $n = 1, 2, 3, 4 \ldots$

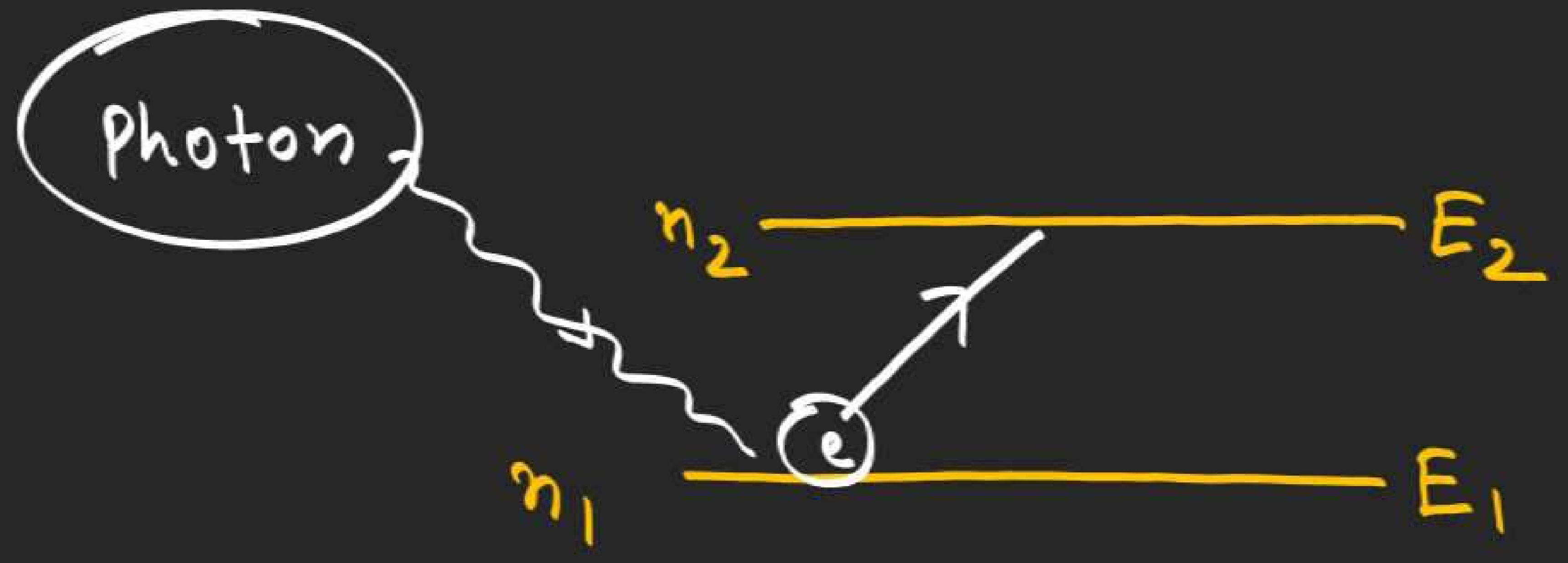
⇒ Quantisation of ang. mom.

(ii) stationary orbits have fixed energy of e^- → P.E., K.E., T.E.

fixed velocity of e^-

fixed radius of orbit

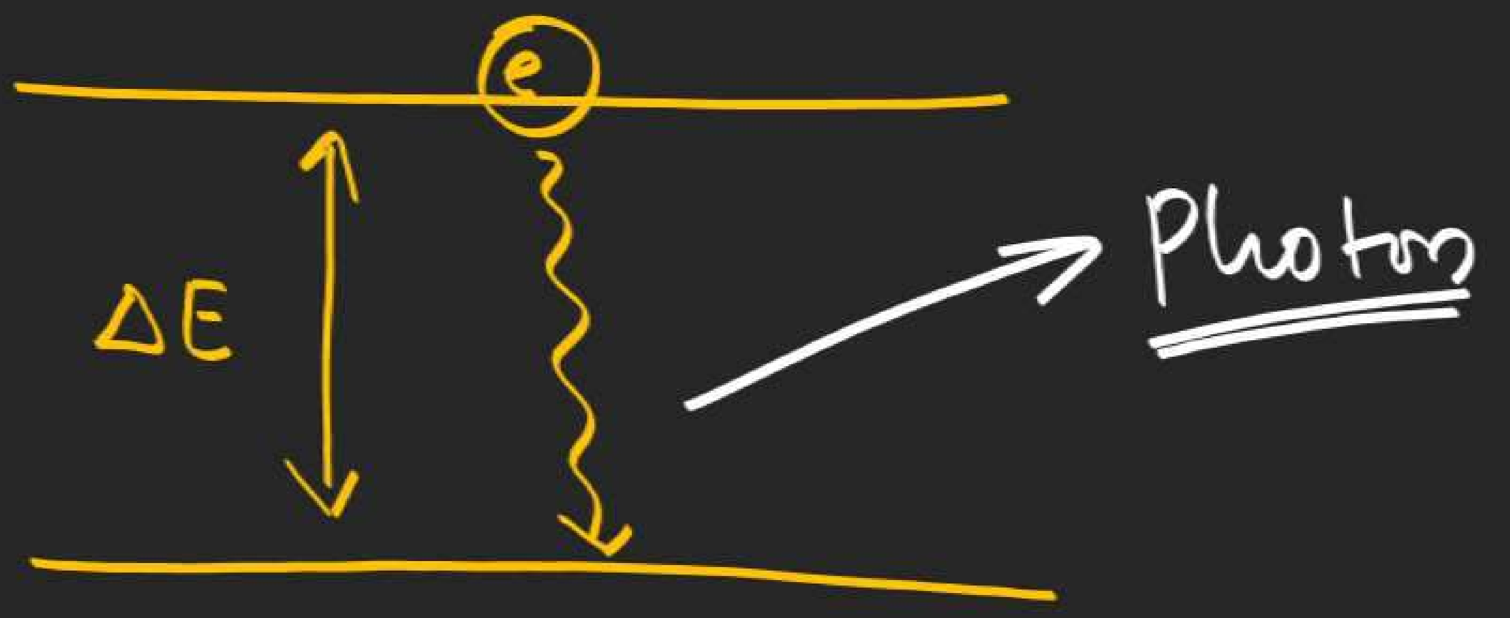
(*)



(e-) upon absorbing energy Jumps into higher energy level.

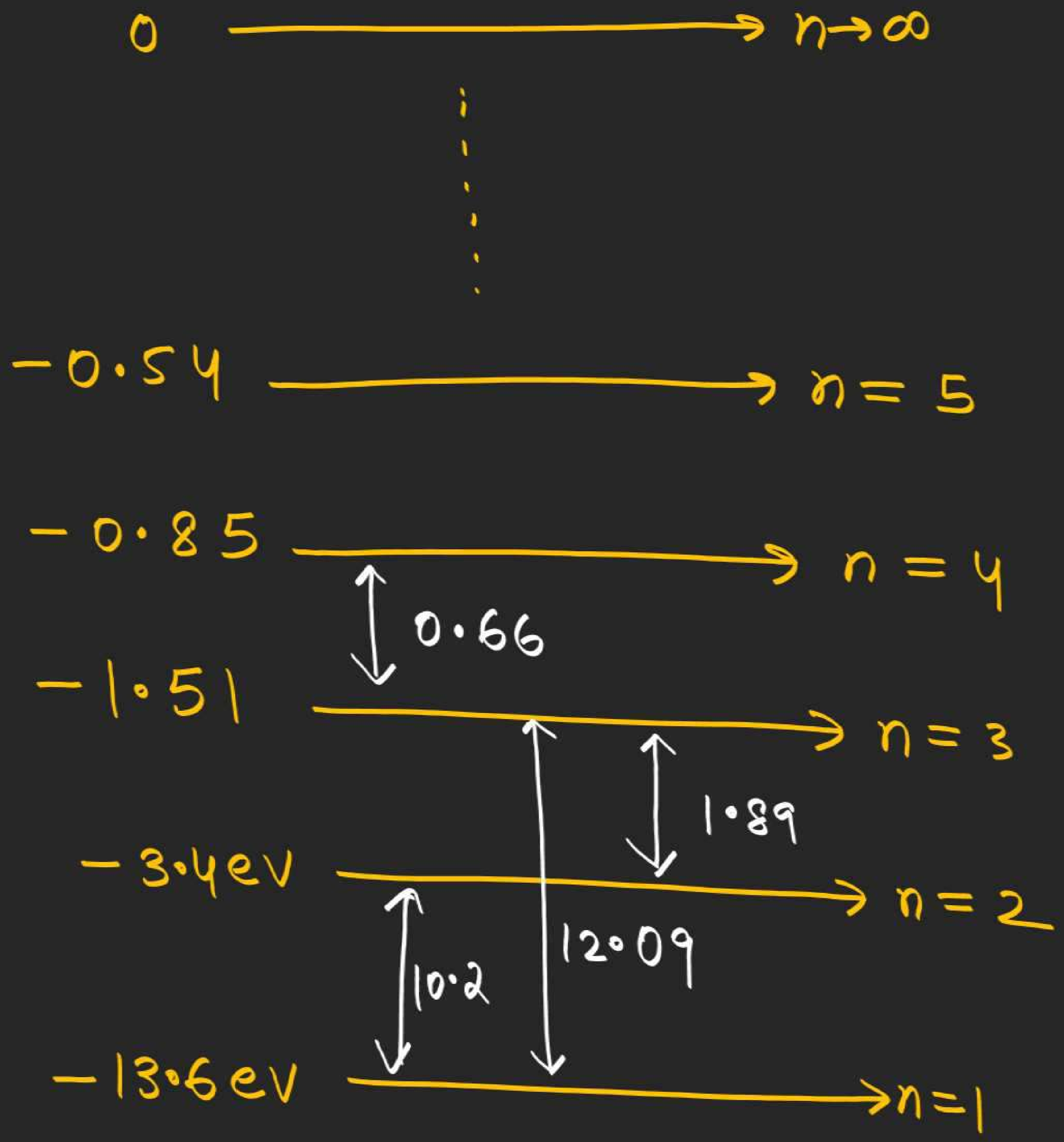
(*) e- from higher energy level jump to lower energy level emit rad^n (Photon)

Photon/rad^n emitted energy = energy Gap



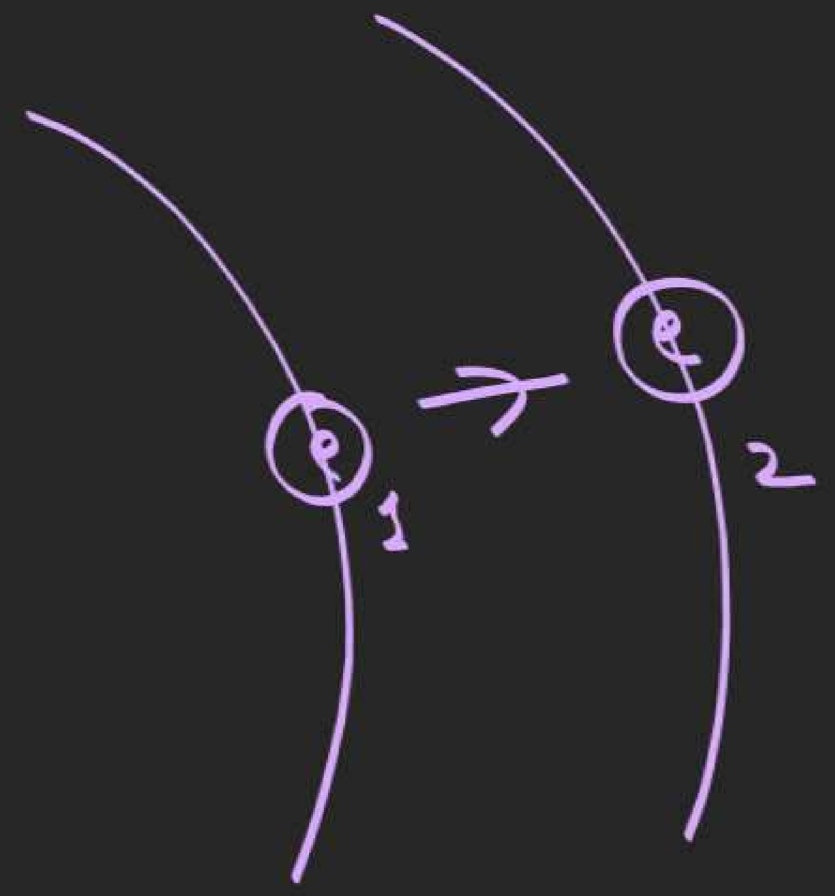
$$\Delta E = h\nu = \frac{hc}{\lambda} = \frac{1240}{\lambda(nm)}\,eV$$

$$\text{Energy} = -13.6\left(\frac{Z}{n}\right)^2$$



As $(n) \uparrow$ $\Rightarrow$ (Energy, P.E.) $\uparrow$

$\Rightarrow$ (KE) $\downarrow$



$E_2 > E_1$

$(PE)_2 > (PE)_1$

$(KE_1) > (KE_2)$

Note :

$n = 6$
5th excited state

$n = 3$
2nd excited state

$n = 2$
1st excited state

$n = 1$
Ground state

Note Ionisation energy

Energy required to remove e⁻ from $n = 1$ to $n \to \infty$

$$I.E. = E_\infty - E_1$$

+ve

$$= 0 + \frac{13.6\, Z^2}{(1)^2}$$

$$\boxed{I.E. = 13.6\, Z^2}$$

Ionisation Potential : Potential diff to remove e- from $n=1$ to $n \to \infty$

+ve

$$I.P. = 13.6 Z^2 \text{ Volt}$$

Excitation potential

Excitation energy

+ve Values

From $n_1 \longrightarrow n_2$

$$13.6 Z^2 \left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$$

Separation energy from given (n) to ∞ $\Rightarrow \left(\frac{13.6 Z^2}{n^2}\right)$

(i) $E_n = -13.6 \frac{Z^2}{n^2}$

(ii) $KE = 13.6 \frac{Z^2}{n^2}$

(iii) $PE = -27.2 \frac{Z^2}{n^2}$

(iv) $\underset{(1\to\infty)}{I.E.} = 13.6 Z^2$ & (I.P.)

(v) $\underset{(n\to\infty)}{\text{sep}^n \text{ energy}} = 13.6 \frac{Z^2}{n^2}$ & (separation potential)

(vi) Excitation energy (excit^n potential) $= 13.6 Z^2 \left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$

(vii) $\Delta E =$ ______ , ______

(viii) $\frac{E_1}{E_2} = \left(\frac{Z_1}{Z_2}\right)^2 \left(\frac{n_2}{n_1}\right)^2$

(ix) $n \uparrow$ $KE \downarrow$

(Energy, PE) $\uparrow$

Radius of orbit : $r_n = 0.529\left(\frac{n^2}{Z}\right)$ A°

(i) compare : $\frac{r_1}{r_2} = \left(\frac{n_1}{n_2}\right)^2 \left(\frac{Z_2}{Z_1}\right)$

(ii) Bohr radius $(n=1)$ $\xrightarrow{\text{H- atom}}$ $0.529 \times \frac{1^2}{1} = 0.529$

(iii) If Bohr radius is (x)
then radius of $n=3$ } Ans $(9x)$

Find ratio of radius of $n = 3$ for He^+ and 4th excitate state of Be^{+3}

Ans $$\frac{r_1}{r_2} = \left(\frac{n_1}{n_2}\right)^2 \left(\frac{Z_2}{Z_1}\right)$$

$$= \left(\frac{3}{5}\right)^2 \left(\frac{4}{2}\right)$$

$$= \frac{9}{25} \times 2 = \frac{18}{25}$$

Velocity of e^- in an orbit

$$\boxed{V_n = 2.18 \times 10^6 \left(\frac{Z}{n}\right)} \quad m/s$$

$\frac{V_1}{V_2} = \left(\frac{Z_1}{Z_2} \times \frac{n_2}{n_1}\right)$

Time period of e^-

* $T = \frac{2\pi r}{v}$

$$T = \frac{2\pi\left(0.529 \times \frac{n^2}{Z}\right) \times 10^{-10}}{2.18 \times 10^6 \left(\frac{Z}{n}\right)}$$

Imp

$$T \propto \frac{n^3}{Z^2} \Rightarrow \frac{T_1}{T_2} = \left(\frac{n_1}{n_2}\right)^3 \left(\frac{Z_2}{Z_1}\right)^2$$

Angular mom: $\boxed{\vec{L} = mvr = n\left(\frac{h}{2\pi}\right)}$

$$\frac{L_1}{L_2} = \frac{n_1}{n_2}$$

$\xrightarrow{\text{Check}}$ $m\left(2.18 \times 10^6 \frac{Z}{n}\right)\left(0.529 \times \frac{n^2}{Z} \times 10^{-10}\right)$

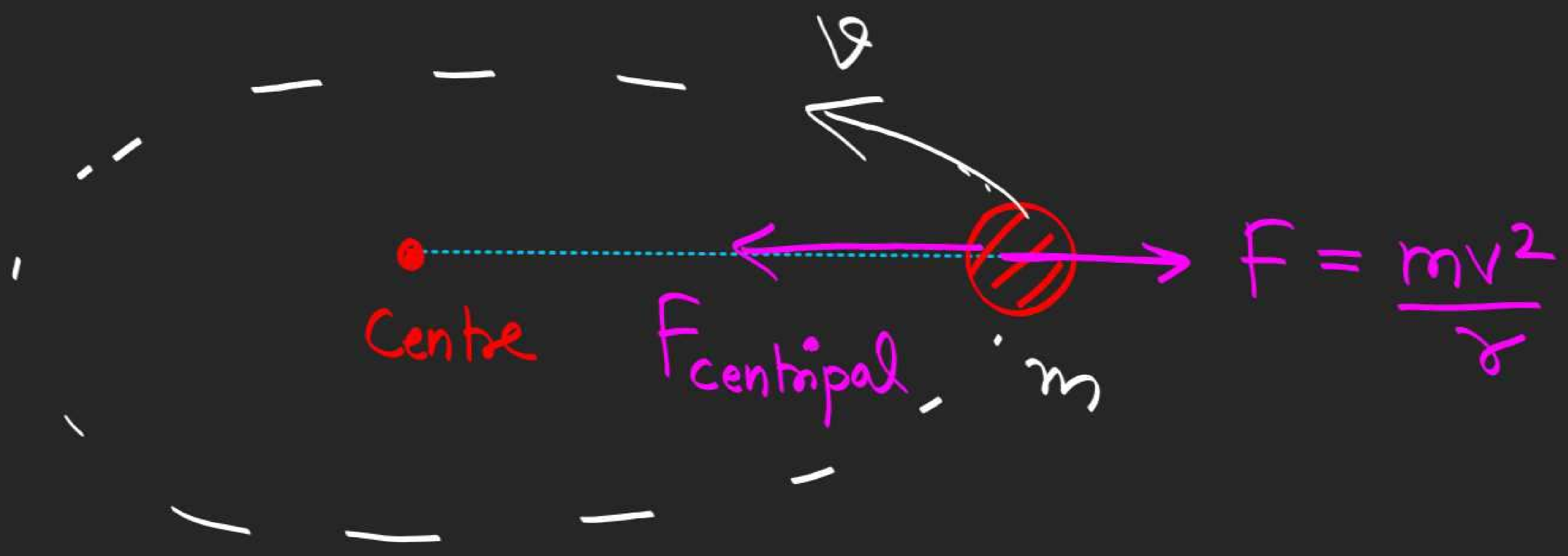
Independent of (Z)

linear momentum $(P = mv) \Rightarrow P = m\left(2.18 \times 10^6 \frac{Z}{n}\right)$

$$\left(P \propto \frac{Z}{n}\right)$$

Centrifugal force

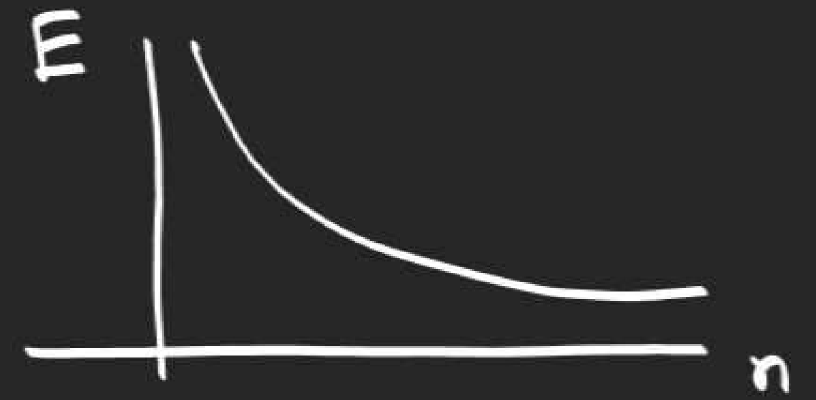
$F = \frac{mv^2}{r} \implies F \propto \frac{v^2}{r}$

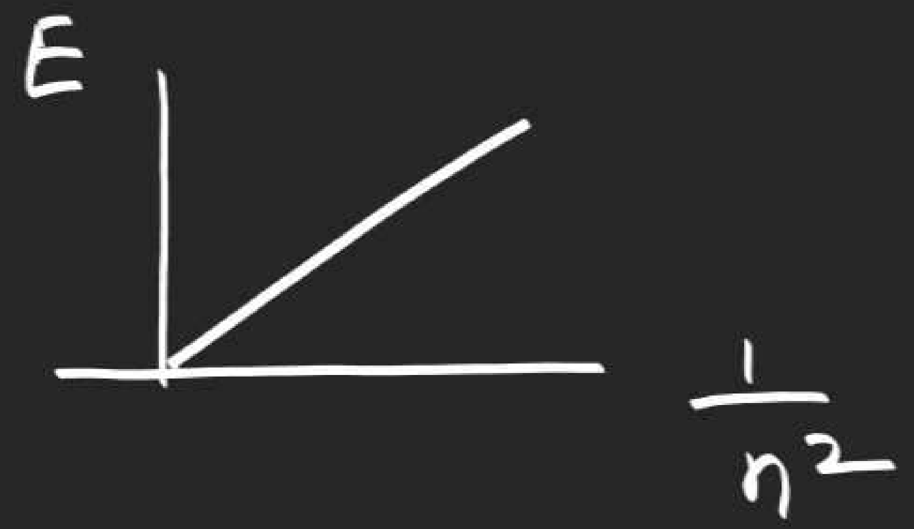


$$F \propto \frac{\left(Z/n\right)^2}{\left(\frac{n^2}{Z}\right)}$$

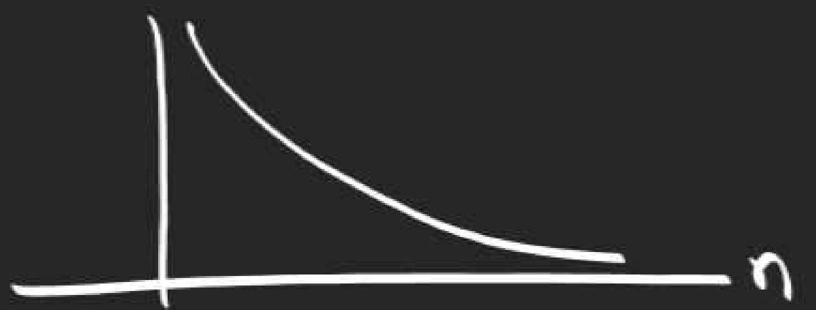
$$\boxed{F \propto \frac{Z^3}{n^4}}$$

(i) $E_n \propto \frac{Z^2}{n^2}$





(ii) $v \propto \frac{Z}{n}$

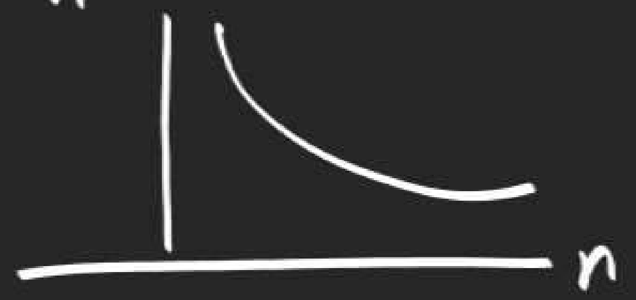


(iii) $r \propto \frac{n^2}{Z}$

(iv) $T \propto \frac{n^3}{Z^2}$

(v) $\vec{L} \propto (n)$

(vi) $\vec{P} \propto Z/n$



(vii) $\vec{F}_{centrifugal} \propto \left(\frac{Z^3}{n^4}\right)$

Spectral emission : When e- from higher level to lower level transition then radn are emitted.

⇒ studied by Rydberg

⇒ wave no. ⇒ $\boxed{\frac{1}{\lambda_{(cm)}} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$

(for H-atom)

other atom → $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

where $n_2 \rightarrow$ Higher level

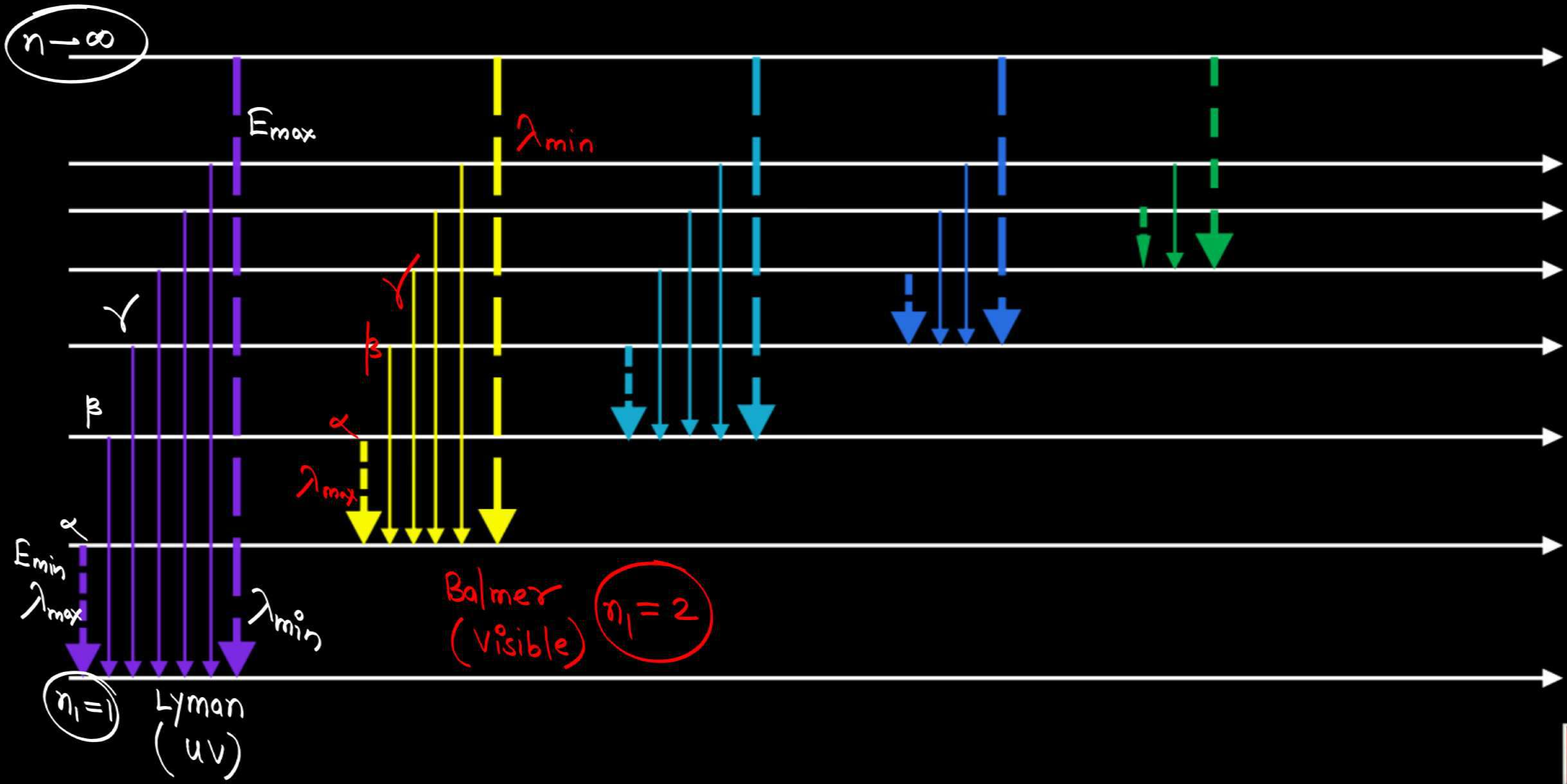
$n_1 \rightarrow$ lower level

⇒ Various series were discovered

- $n_1 = 1$ ⇒ Lyman series (UV rays)
- $n_1 = 2$ ⇒ Balmer series (visible)
- $n_1 = 3$ ⇒ Paschen series
- $n_1 = 4$ ⇒ Brackket series
- $n_1 = 5$ ⇒ Pfund series

Paschen, Brackket, Pfund: infrared

The Spectral Lines for Atomic Hydrogen



Lyman series (Analysis)

(I) From $n_2 = 2, 3, 4 \ldots \infty$ to $n_1 = 1$

(II) fall under (UV) range

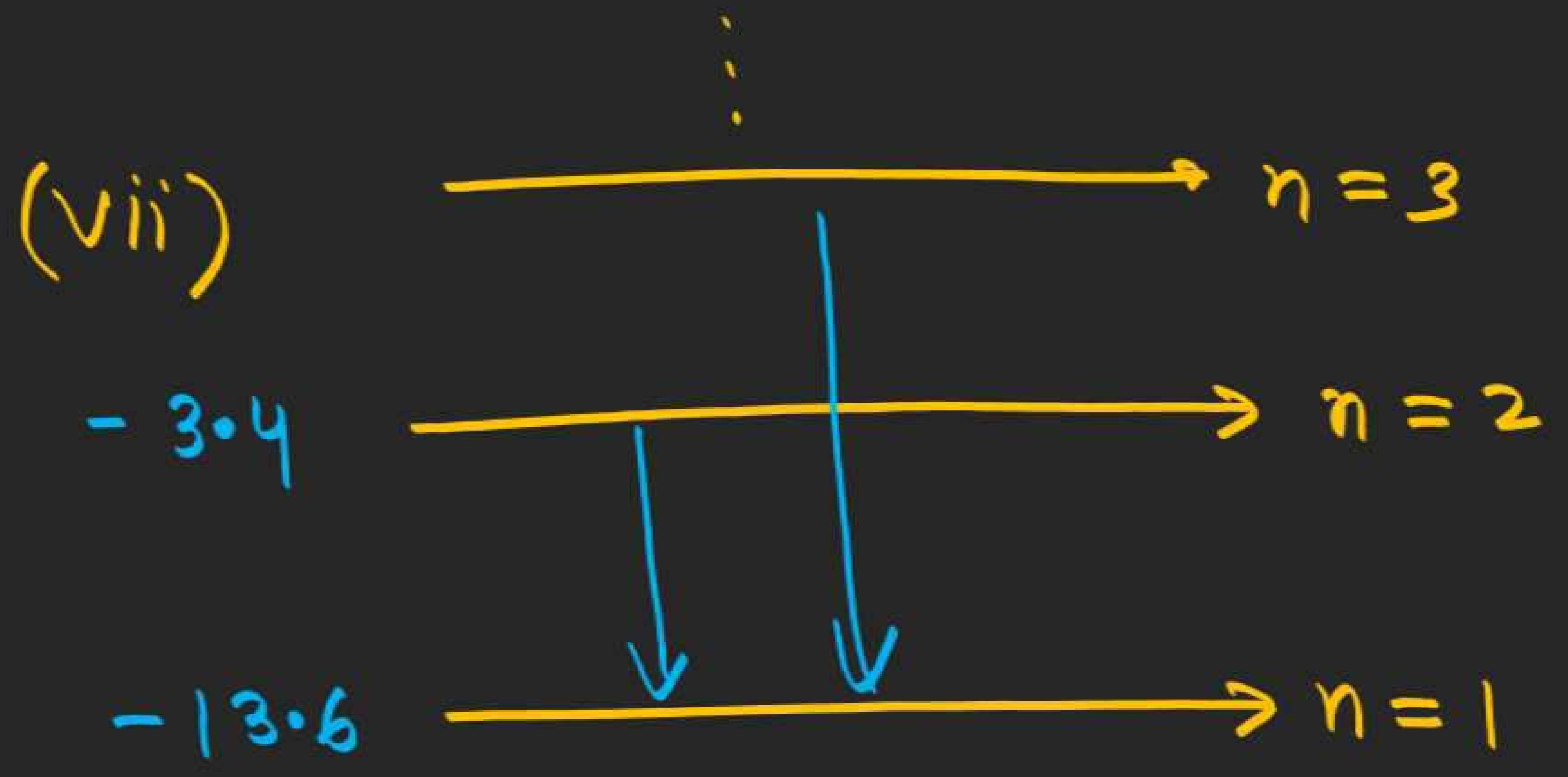
(III) $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$ — λ_{max} neighbour; λ_{min} (∞)

(iv) $\frac{1}{\lambda_{max}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \Rightarrow \boxed{\lambda_{max} = \frac{4}{3R}}$

(v) $\frac{1}{\lambda_{min}} = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] \Rightarrow \boxed{\lambda_{min} = \frac{1}{R}}$

(vi) $\frac{\lambda_{max}}{\lambda_{min}} = \frac{4}{3}$

(vii)



Photon | rad^n | e^- energy

$E \geq 10.2$ eV

$\lambda \leq 121.56$ nm

Numerical

$$\frac{\lambda_1}{\lambda_2} = \frac{\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]_2}{\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]_1}$$

Find $\longrightarrow \dfrac{(\lambda_{max})_{Paschen}}{(\lambda_{min})_{Lyman}} = \dfrac{\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)}{\left(\frac{1}{3^2} - \frac{1}{4^2}\right)} = \left(\frac{144}{7}\right)$

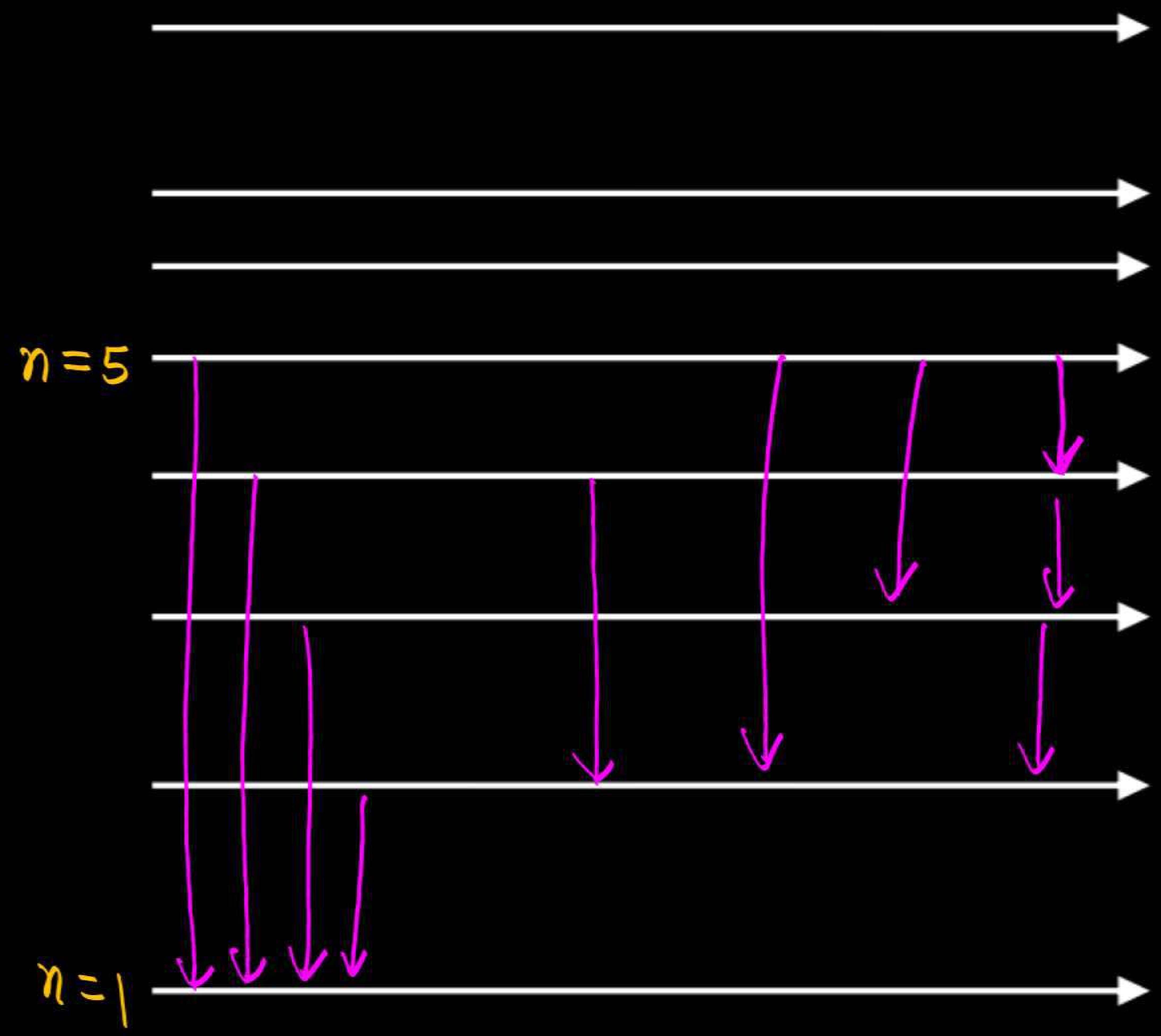
$$\frac{\lambda_{max}}{\lambda_{min}} = \frac{\left[\frac{1}{n_1^2} - \frac{1}{\infty^2}\right]_{min}}{\left[\frac{1}{n_1^2} - \frac{1}{(\text{पड़ोसी})^2}\right]_{max}}$$

$\xrightarrow{\text{Balmer}} \dfrac{\lambda_{max}}{\lambda_{min}} = \dfrac{\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)_{min}}{\left(\frac{1}{2^2} - \frac{1}{3^2}\right)_{max}}$

$= \frac{9}{5}$

No. of spectral lines

(i) Total lines $= \dfrac{(\Delta n)(\Delta n+1)}{2}$



example from $n = 5$ to 1

(i) Total lines $= \dfrac{4 \times 5}{2} = 10$ lines

Lyman (UV)
$(n_2 - 1)$
$= 4$

Balmer
(visible)
$(n_2 - 2)$
(3)

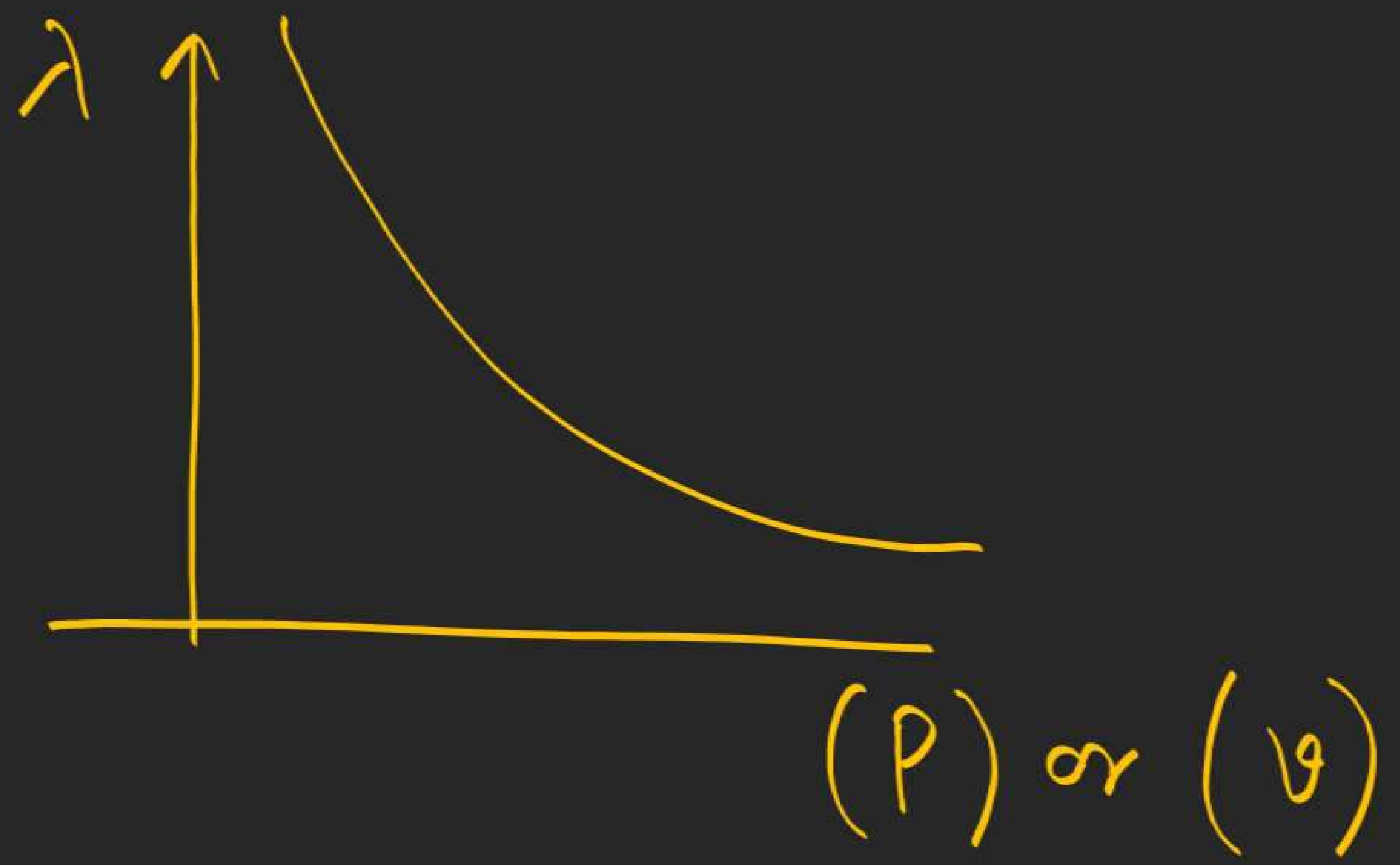
Infrared
3

Dual Behaviour of matter : De-Broglie (Hypothesis)

Every moving object posseses dual behaviour and wavelength associated is called De-Broglie wavelength.

Mathematically

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



where m = mass of particle

v = velocity —"—

$$\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}}$$

velocity

Potential diff

For e- : $\frac{h}{\sqrt{2meV}} = \sqrt{\frac{150}{V}}$ A° $= \frac{12.2}{\sqrt{V}}$

$\boxed{\text{Comparision}}$ ⟹

(i) $\frac{\lambda_1}{\lambda_2} = \frac{P_2}{P_1} = \frac{m_2 V_2}{m_1 V_1} = \sqrt{\frac{m_2 K_2}{m_1 K_1}} = \sqrt{\frac{m_2 q_2 V_2}{m_1 q_1 V_1}}$

DE BROGLIE WAVELENGTH

according to de Broglie, every object in motion has a wave character

- ✓ For different charge particle put value of (q)
- ✓ For electron $e = 1.6 \times 10^{-19}$
- ✓ For α particle put 2e
- ✓ For proton put (e)

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

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

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

$$= \frac{h}{\sqrt{2m(qV)}}$$

$$= \sqrt{\frac{150}{V}} A^\circ$$

$$= \frac{12.2}{\sqrt{V}} A^\circ$$

LIVE

De-Broglie's comparision with Bohr model

$\lambda = \frac{h}{mv}$ and $mvr = n\frac{h}{2\pi}$

$$2\pi r = n\left(\frac{h}{mv}\right)$$

$\boxed{\text{nth orbit} : (n)\lambda \text{ produced}}$

$$\boxed{2\pi r = n\lambda}$$ ---> Circumference is Quantised

⟹ means integral multiple of (λ)

$2\pi\left(0.529\frac{n^2}{Z}\right) = n\lambda$

⟹ $\boxed{\left(\frac{10}{3}\right)\frac{n}{Z} = \lambda}$ ⟹ De-Broglie wavelength in nth orbit

1. $E_n = -13.6\dfrac{Z^2}{n^2}$

2. $KE = |E_n| = -\dfrac{P.E.}{2}$

3. $(n)\uparrow$ $KE\downarrow$ $(E, PE)\uparrow$

4. $\Delta E = -13.6\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

5. Same energy / Same (λ) or photon

H	He^+	Li^{+2}
n	$2n$	$3n$

6. Energy / energy Gap / Same (n)

H	He^+	Li^{+2}
x	$4x$	$9x$

7. $\Delta E = \dfrac{hc}{\lambda} = \dfrac{1240}{\lambda(nm)}$

8. $\dfrac{1}{\lambda} = RZ^2\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$

9. $\dfrac{\lambda_1}{\lambda_2} = \dfrac{(\quad)_2}{(\quad)_1}$

10. $mvr = n\dfrac{h}{2\pi}$

11. $r_n = 0.529\dfrac{n^2}{Z}$

12. $V_n = 2.18\times10^6\left(\dfrac{Z}{n}\right)$

13) $\lambda = \dfrac{h}{mv}$

$\Rightarrow 2\pi r = n\lambda$

14) $\lambda = \left(\dfrac{10}{3}\right)\dfrac{n}{Z}$

15) $F \propto \dfrac{Z^3}{n^4}$

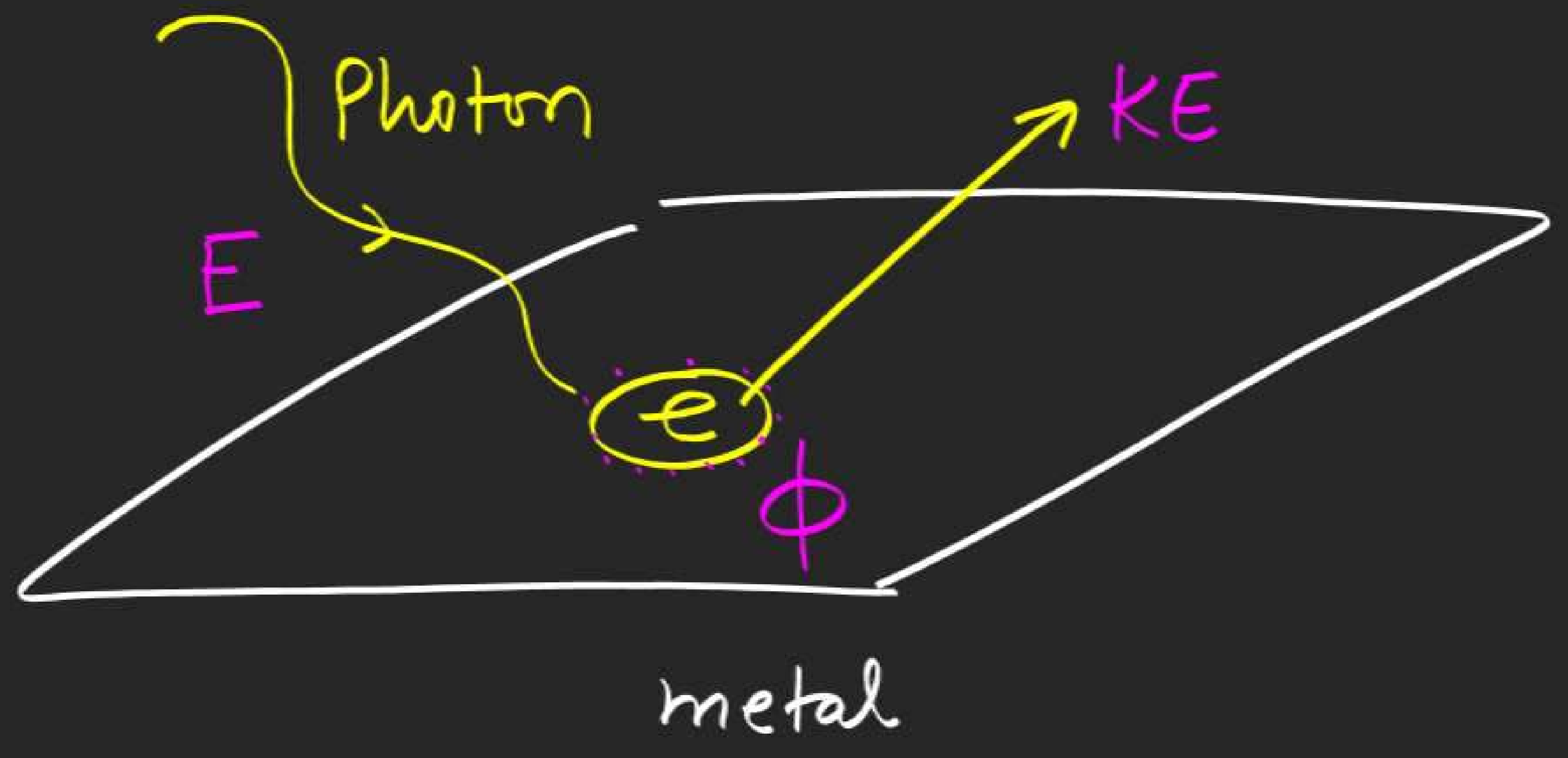
16) $T \propto n^3/Z^2$

17) $f \propto Z^2/n^3$

18) $P \propto Z/n$

19) $F \propto -\dfrac{dU}{dr}$

Photoelectric effect : Ejection of e- from metal surface when photon | rad^n of sufficient energy / freq / wavelength falls on it



Min energy required is work function (ϕ)

Energy $\geq \phi$ ..... (ϕ) is diff. for diff. metal

$\phi = h\nu_0$ when ν_0 = threshold / min freq above which Photoelectric effect occurs

$\phi = \frac{hc}{\lambda_0}$

where λ_0 = threshold / max wavelength Below which photo-electric effect occur

Einstein Eqn

$E = KE + \phi$

Cond^n for photoelectric effect

a) $E \geq \phi$ b) $\nu > \nu_0$ c) $\lambda \leq \lambda_0$

Important points

1.) one photon interact with one e-

2.) Instantaneous process (no time lag)

3.) Elastic collission (no energy loss)

4) $E = KE + \phi$

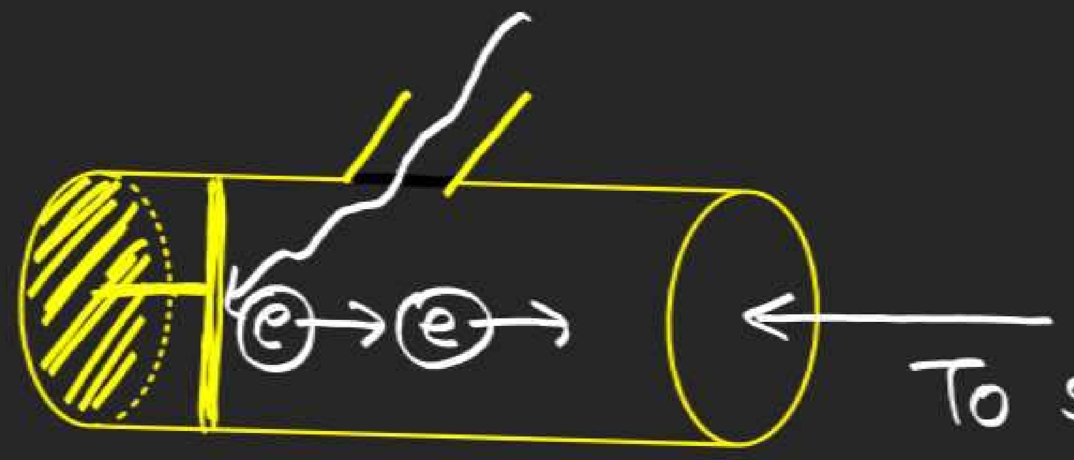
5) (K.E.) of e- depends only on freq / wavelength of rad^n / photon

6) KE is independent of Intensity

7) Current produced is called photo current

Intensity = no. of photon/sec.

8) Current $\propto$ Intensity

9) 

To stop these e- opp. potential diff is req. is called stopping Potential

$\Rightarrow KE = qV_s$

$\Rightarrow \boxed{KE = eV_s}$

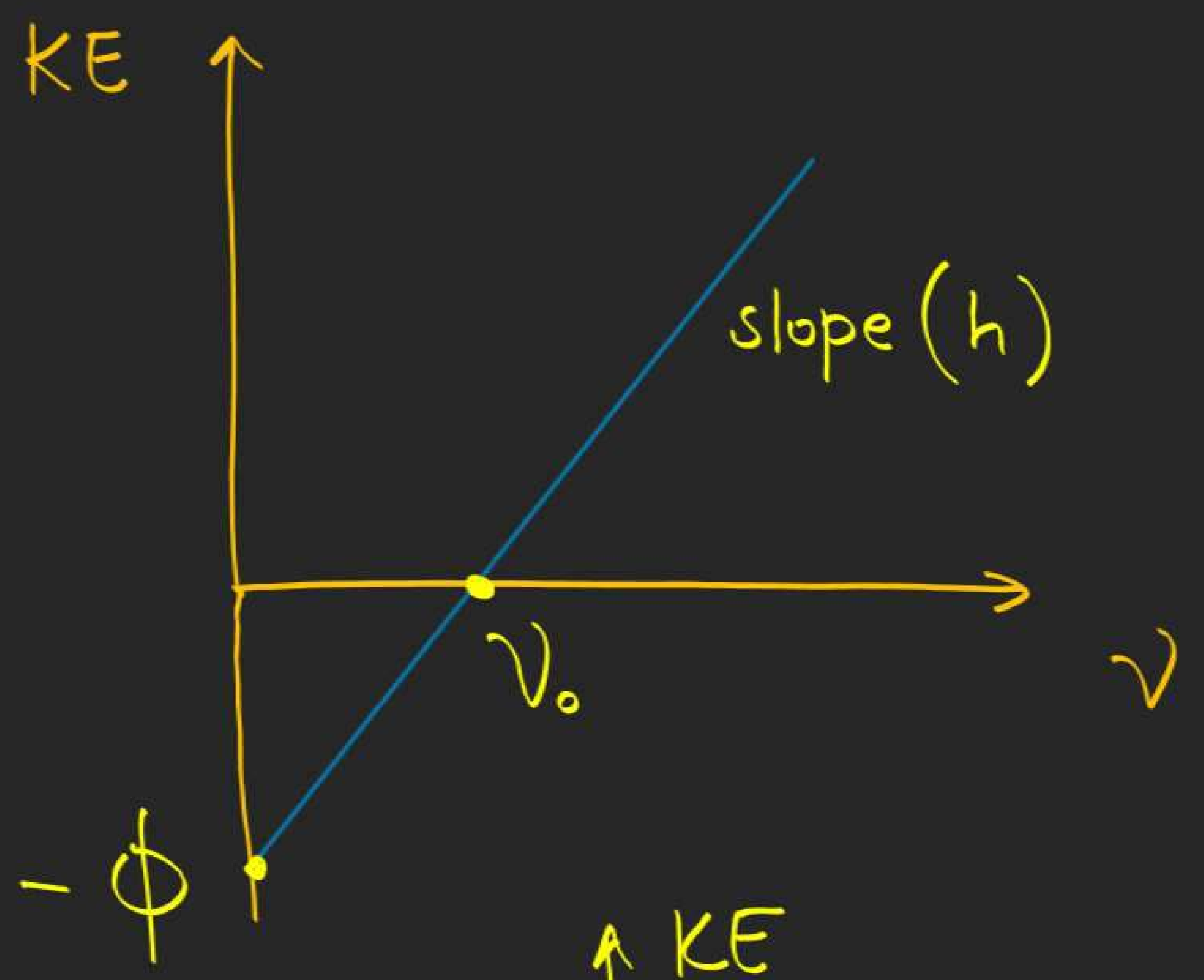
Numericals

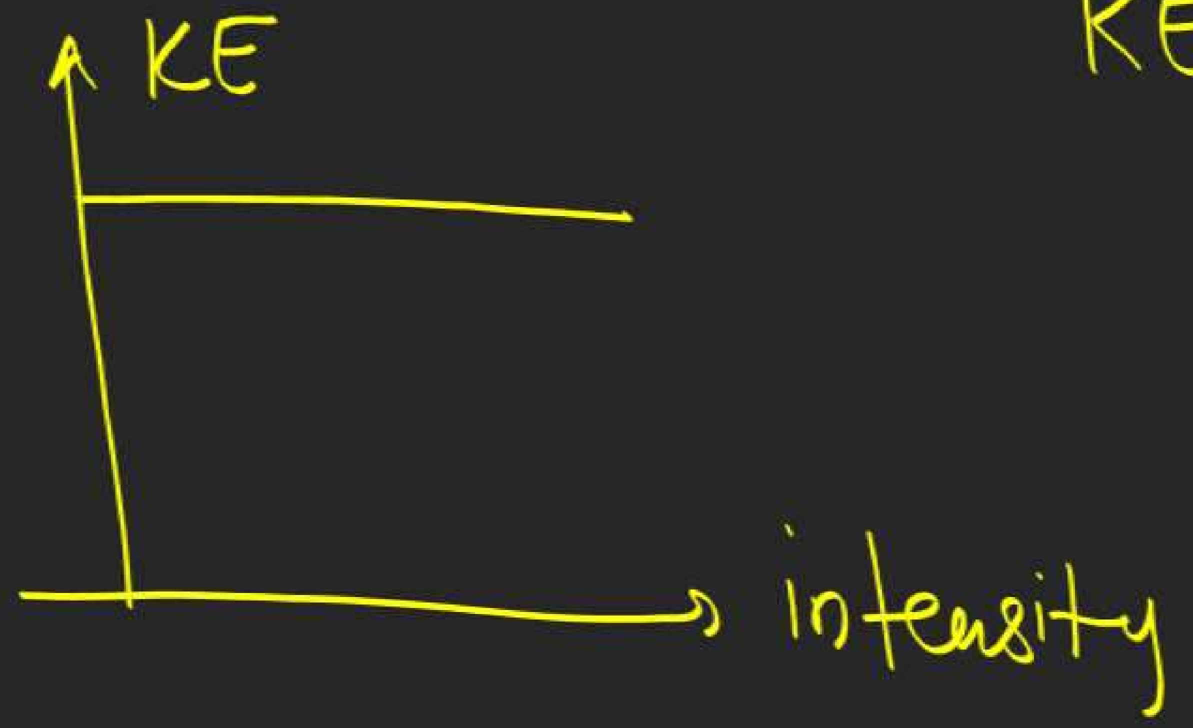
$$\boxed{\begin{array}{l} 1.\quad E = KE + \phi \\ 2.\quad KE = E - \phi \end{array}}$$

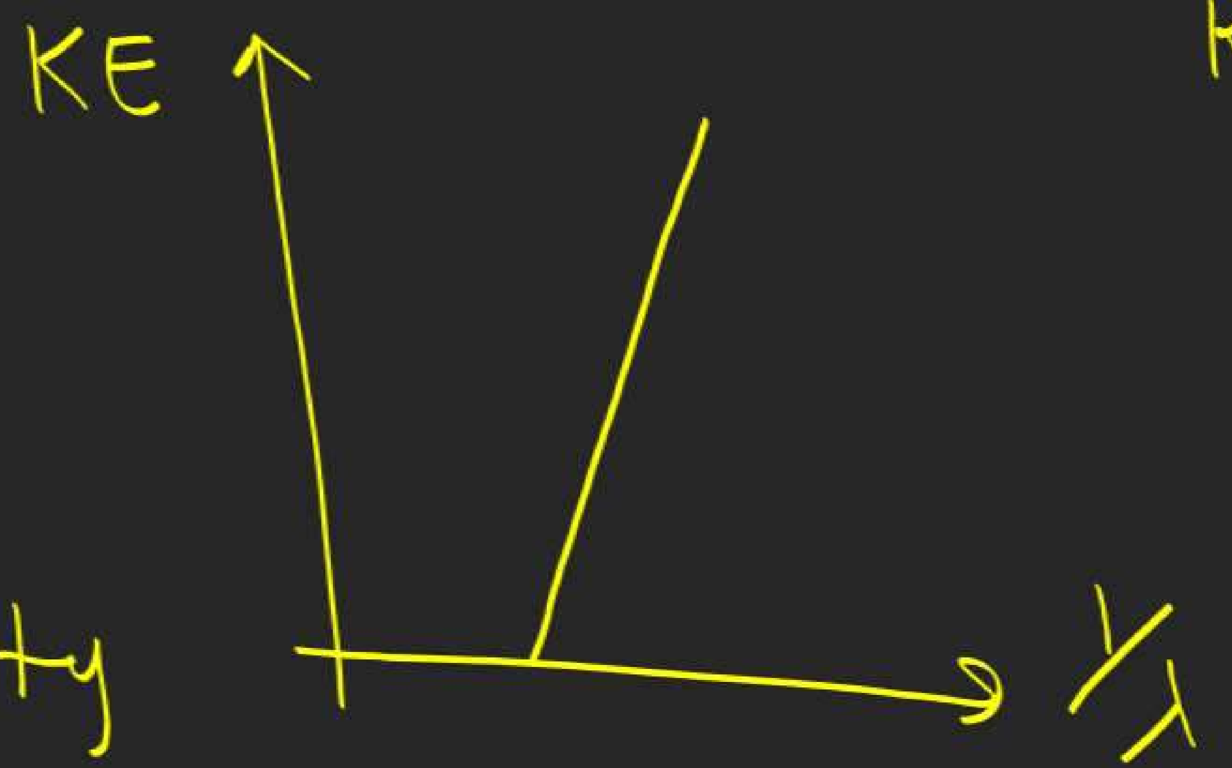
$$\Rightarrow \boxed{KE = h\nu - h\nu_0} \quad \Rightarrow \boxed{KE = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}}$$

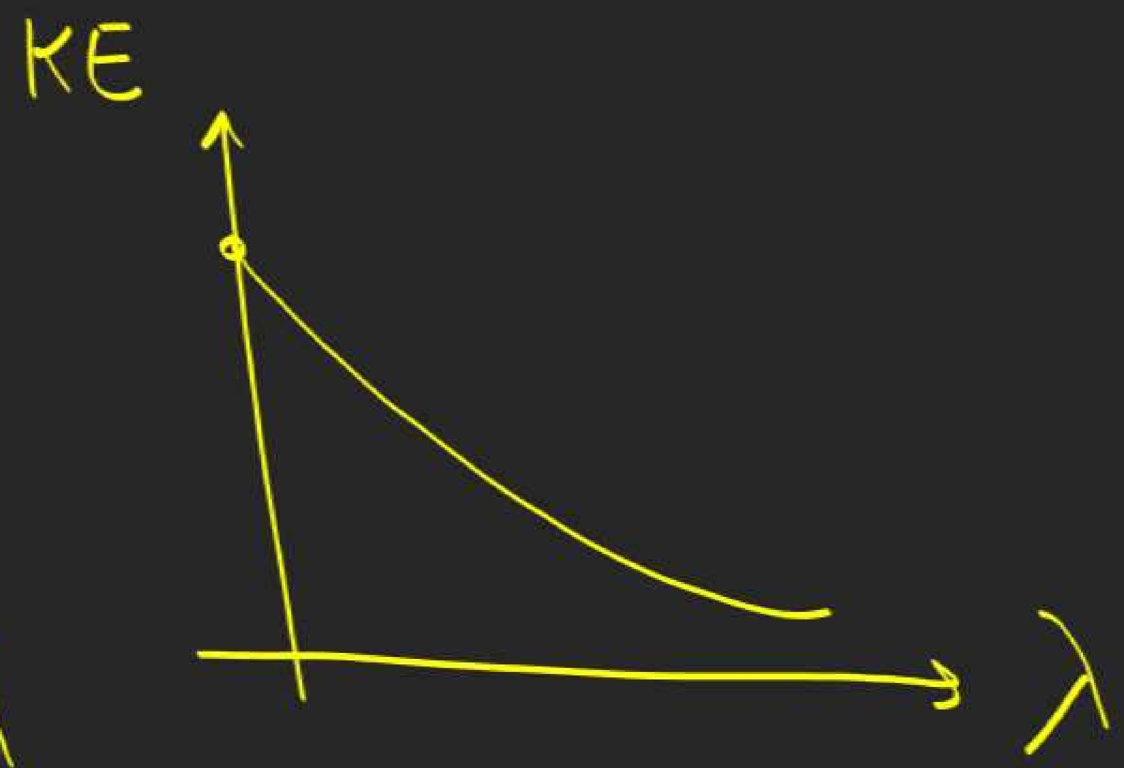
$$\Rightarrow eV_s = h\nu - h\nu_0$$

$$\Rightarrow \boxed{V_s = \frac{h}{e}\nu - \frac{h}{e}\nu_0} \quad \Rightarrow \boxed{V_s = \frac{hc}{e\lambda} - \frac{hc}{e\lambda_0}}$$

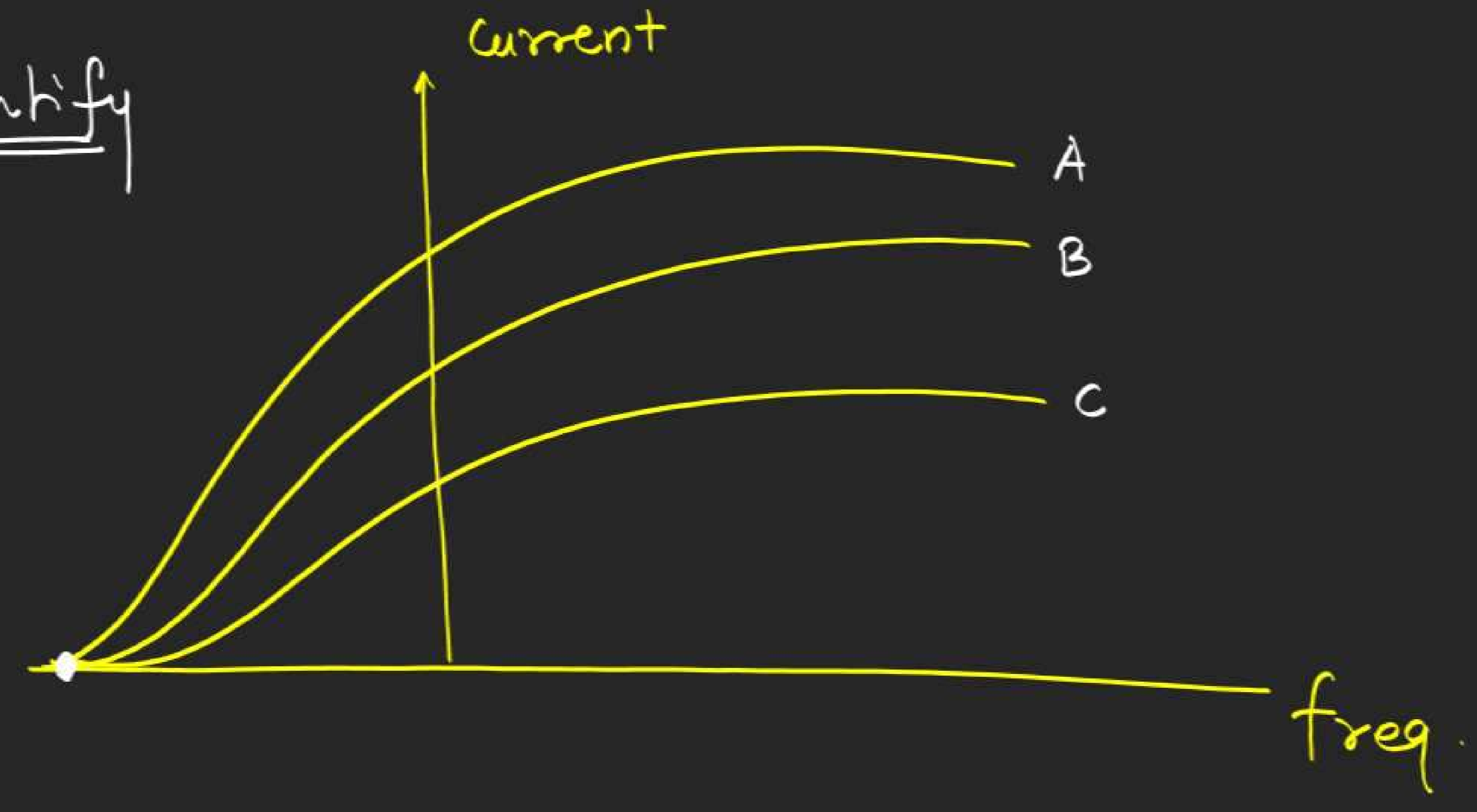








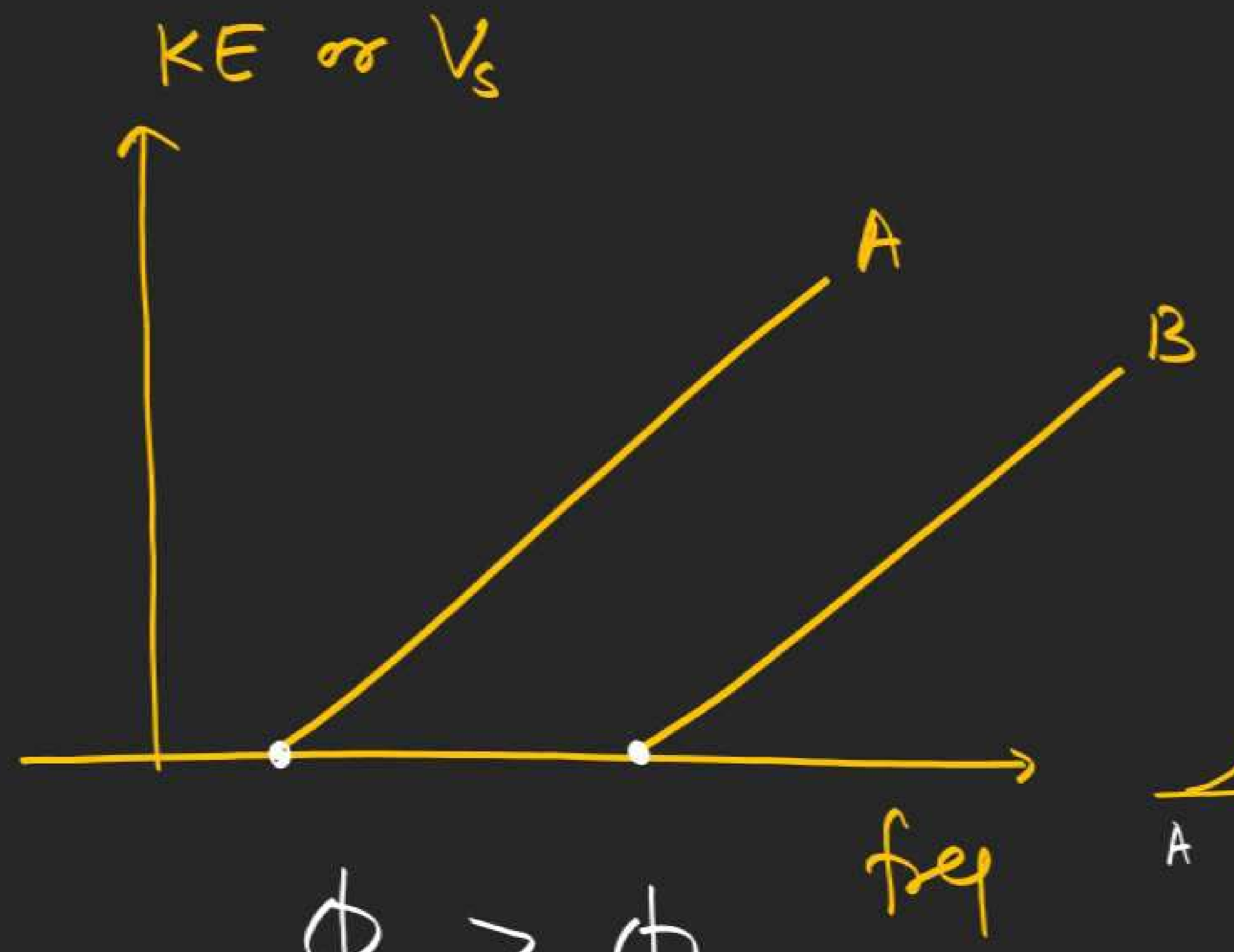
Identify



i) Same stopping potential, KE same

ii) Intensity, current diff $(A > B > C)$

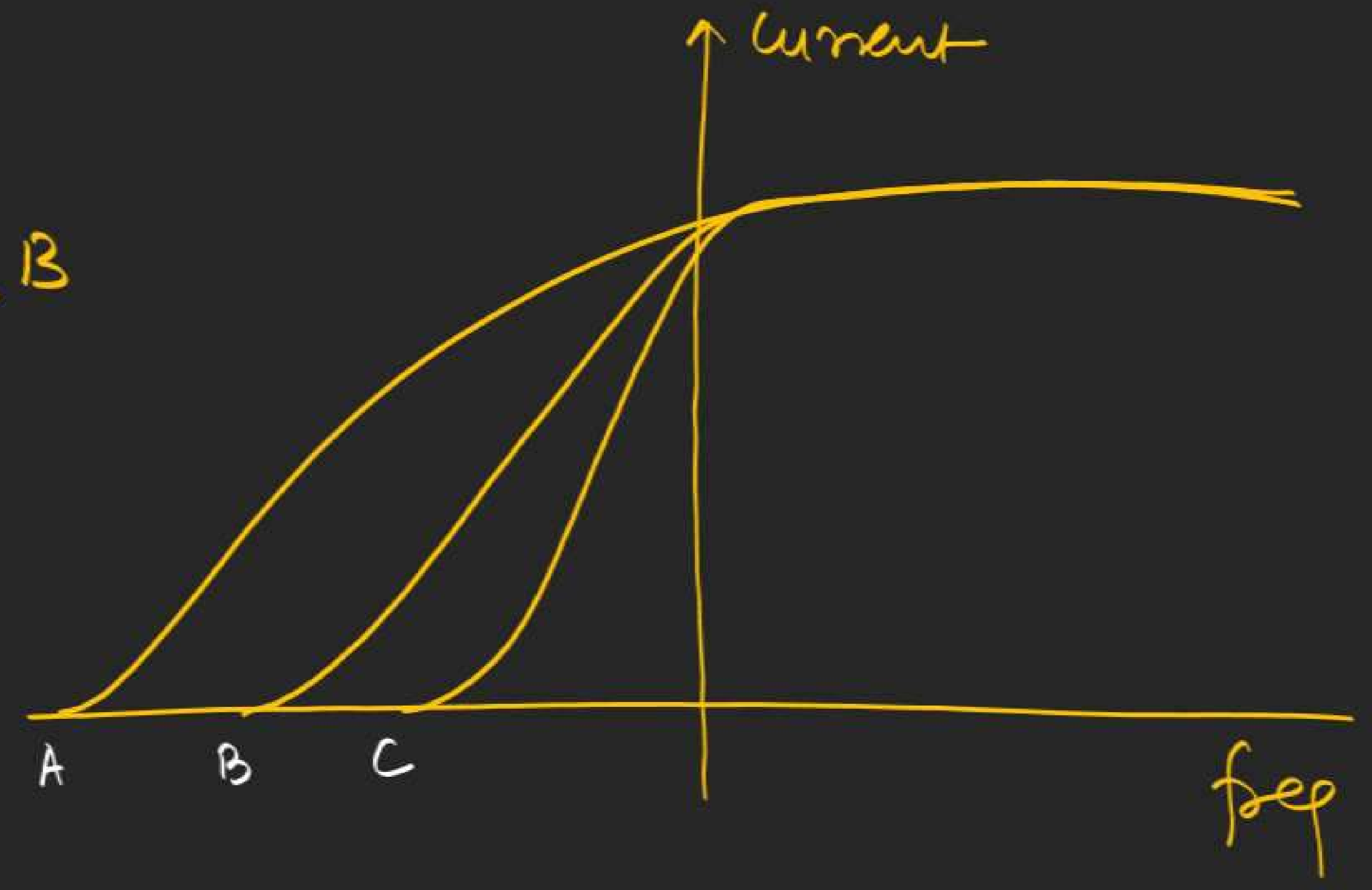
iii) ϕ can't be compared



$\phi_B > \phi_A$

$$\boxed{\begin{aligned} \nu_B &> \nu_A \\ \lambda_B &< \lambda_A \end{aligned}}$$

⟹ Threshold



i) stopping potential, KE diff $(A > B > C)$

ii) current, intensity same

Heisenberg's Uncertainty Principle

It states that it is impossible to determine simultaneously, the exact position and exact momentum (or velocity) of an electron.

There is uncertainity in value of position (Δx) & momentum (ΔP) of e

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

⇒ If error in velocity (Δv)

$$\Rightarrow \quad \Delta x (m \Delta v) \geq \frac{h}{4\pi}$$

$$\Delta v \geq \frac{h}{4\pi m \cdot \Delta x}$$

LIVE