# Rotational dynamics:-

Power(P) = $\tau\omega$ $\omega = \sqrt{\frac{k}{m}}$ $k = m\omega^2$

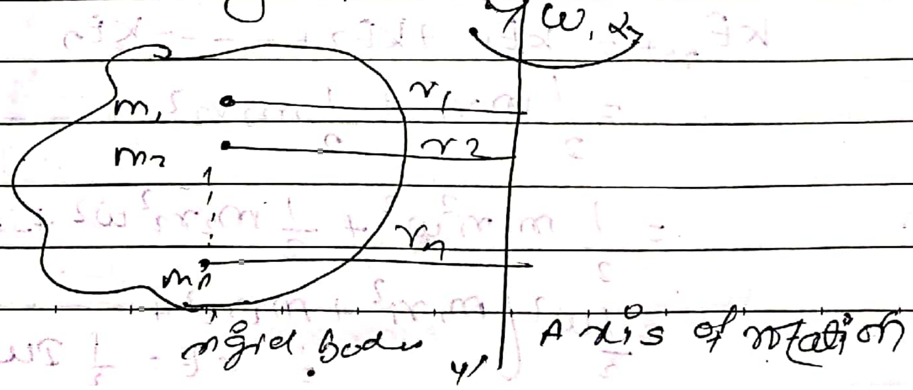
| linear motion | angular motion |
|---|---|
| linear velocity (v) | angular velocity ($\omega$), $v = r\omega$ |
| displacement (S) | displacement ($\theta$), $S = \theta r$ |
| acceleration (a) | acc$^n$ ($\alpha$), $a = \alpha r$. |
| momentum (P) | momentum (L), $L = rp$ |
| Force (F) | Force ($\tau$), $\tau = rF$ |
| Mass (M) | Moment of Inertia (I), $I = mr^2$ |

- Rigid body: A body that doesn't deform or vibrate.
- oscillatory motion: Repeated motion in which an object repeats the same moment over and over.
- Rotatory motion: Moment of any object about an axis
- Periodic motion: Motion repeated in equal interval of time
  ex: earth in its orbit around sun.
- Moment of Inertia: The product of mass of an object and the square of $\perp^r$ distance from the axis of rotation. $I = mr^2$
- Radius of gyration: ($I = mk^2$), where k = radius of gyration.

$k = \sqrt{\frac{m(r_1^2 + r_2^2 + \dots r_n^2)}{mn}}$ $k = \sqrt{\frac{r_1^2 + r_2^2 + \dots r_n^2}{n}}$

Relationship between M.I and Torque ($\tau = I\alpha$).

Torque: The turning effect of force is called torque. $\tau = Fr\sin\theta$



Let us consider a rigid body consisting 'n' number of particles having masses $m_1, m_2, \ldots m_n$. Let, $r_1, r_2, \ldots r_n$ be the perpendicular distance of each particles from axis of rotation. Let, $\omega$ and $\alpha$ be the angular velocity and angular acceleration of the rigid body.

If $\tau_1, \tau_2, \ldots \tau_n$ be the torque of particles. Then, total torque is.

$$\tau = \tau_1 + \tau_2 + \ldots + \tau_n$$

$$\text{or, } \tau = r_1 F_1 + r_2 F_2 + \ldots r_n F_n \quad [\because \tau = rF]$$

$$\text{or, } \tau = r_1 m_1 a_1 + r_2 m_2 a_2 + \ldots r_n m_n a_n$$

$$\text{or, } \tau = r_1 m_1 \alpha r_1 + r_2 m_2 \alpha r_2 + \ldots r_n m_n \alpha r_n$$

$$\text{or, } \tau = \alpha [m_1 r_1^2 + m_2 r_2^2 \ldots + m_n r_n^2]$$

$$\therefore \boxed{\tau = I\alpha} \quad [I = mr^2]$$

which is the reqd expression for ~~τ~~ I.

* Rotational kinetic energy $(KE_{rot}) = \frac{1}{2} I\omega^2$

(... All language same)

If $KE_1, KE_2, \ldots KE_n$ be the rotational KE of particles. Then, total KE is

$$KE_{rot} = KE_1 + KE_2 + \ldots KE_n$$

$$= \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 + \ldots \frac{1}{2} m_n v_n^2$$

$$= \frac{1}{2} m_1 r_1^2 \omega^2 + \frac{1}{2} m_2 r_2^2 \omega^2 + \ldots \frac{1}{2} m_n r_n^2 \omega^2$$

$$= \frac{1}{2}\omega^2 [m_1 r_1^2 + m_2 r_2^2 + \ldots m_n r_n^2]$$

$$\therefore KE = \frac{1}{2} I\omega^2 \text{ where}$$

* Relationship between moment of Inertia & angular momentum [$L = I\omega$]

=> ( ---- All language same)
If $L_1, L_2, \ldots L_n$ be the angular momentum of the particles.
Then total angular momentum

$$L = L_1 + L_2 + \cdots L_n$$
$$= r_1 p_1 + r_2 p_2 + \cdots r_n p_n$$
$$= r_1 m_1 v_1 + r_2 m_2 v_2 + \cdots r_n m_n v_n$$
$$= r_1 m_1 r_1 \omega + r_2 m_2 r_2 \omega + \cdots r_n m_n r_n \omega \quad [v = r\omega]$$
$$= \omega [m_1 r_1^2 + m_2 r_2^2 + \cdots m_n r_n^2]$$
$$\therefore \boxed{L = I\omega} \quad [I = mr^2]$$

Which ----

* Relationship between torque & angular momentum
($\tau$ & $L$) $\tau = \frac{dL}{dt}$

=> ( -- All language same)
As we know, From the relationship between M.I & angular momentum

$$L = I\omega$$

Differentiating both side w.r.to time

$$\frac{dL}{dt} = I \cdot \frac{d\omega}{dt}$$

$$\frac{dL}{dt} = I\alpha \text{ --(i)} \quad \left[\frac{d\omega}{dt} = \text{angular acc}^n, \alpha = \frac{\omega}{t}\right]$$

Also, from definition of torque

$$\tau = I\alpha \text{ --(ii)}$$

From (i) & (ii) $\boxed{\tau = \frac{dL}{dt}}$

* Conservation of angular momentum

It states that: "If The total angular momentum of a body remains constant if no external torque is applied.

ie. $L = \text{Constant}$

ie. $I\omega = \text{constant}$

Proof:

We know, from the relationship betwn $\tau$ & $L$

$$\tau = \frac{dL}{dt}$$

If no external torque is applied, $\tau = 0$

ie. $\frac{dL}{dt} = 0$

$dL = 0$

$\int dL = \int 0$

$L = \text{const.}$

or, $I\omega = \text{const}$

$$\boxed{I_1\omega_1 = I_2\omega_2}$$

* Simple Harmonic Motion (SHM)

A body is said to be ~~xx~~ executing on SHM if the accn of the body is directly proportional to the displacement and directed towards mean position.

ie. $a \propto y$

$a = -ky$ [ $k$ = force const or spring const

-ve sign show

-ve sign shows that $acc^n$ is in opposite direction to that of displacement.

* Displacement: The distance covered by the partical moving in SHM $y = r\sin\theta$ ($y = r\sin\omega t$) or, $y = r\sin(\omega t \pm \phi)$

$\phi$ = phase angle

* Amplitude: Maximum distance covered by the partical moving in SHM. If $\theta = 90°$, $\boxed{y_{max} = r}$

$\therefore a = r =$ amplitude.

* Velocity: $v = \frac{dy}{dt} = \frac{d(r\sin\omega t)}{dt} = r\cos\omega t \cdot \omega$

$= \omega r\sqrt{1-\sin^2\omega t}$

$v = \omega\sqrt{r^2 - y^2}$

Case I:
when, $y = 0$,
$v_{max} = \omega r$
~~at~~ (mean $pos^n$)

Case II
when $y = r$
$v_{min} = 0$
(at extreme or highest $pos^n$)

* $Acc^n$: Rate of change of $veloc^{ty}$.

$\frac{d}{dt}(\omega r\cos\omega t)$

$= \omega r(-\sin\omega t)\,\omega$

$a = -\omega^2 r\sin\omega t$

$\boxed{a = -\omega^2 y}$

In magnitude, $a = \omega^2 y$

Case I: $y = 0$,
$a_{min} = 0$

Case II $y = r$ (extreme $pos^n$)
$a_{max} = \omega^2 r$

* Time period:
Time taken to complete one oscillation.

$\omega = 2\pi f$

$T = \frac{2\pi}{\omega}$

But,
$a = \omega^2 y$
$\omega = \sqrt{\frac{a}{y}}$

$\therefore T = 2\pi\sqrt{\frac{y}{a}}$

$F = -ky$

## * Differential eqn of SHM. [2nd order diff eq]

Consider a particle executing in SHM. Let y be the displacement of the particle at any time t. Let, F be the restoring force. Then According to Hooke's law

$\Rightarrow F \propto y$

$ma = -ky$ [where, k = .

$\Rightarrow m \times \frac{d^2y}{dt^2} = -ky$

$\Rightarrow m \cdot \frac{d^2y}{dt^2} + ky = 0$

$\Rightarrow \frac{d^2y}{dt^2} + \left(\frac{k}{m}\right)y = 0$

$\therefore \frac{d^2y}{dt^2} + \omega^2 y = 0$ ...(i)

$\frac{d^2y}{dt^2} = -\omega^2 y$

acceleration $= -\omega^2 y$

Also,

$\text{Accel}^n = \frac{dv}{dt} = \frac{dv}{dy} \times \frac{dy}{dt}$

$= \frac{dv}{dy} \times v$ $\left[\because v = \frac{dy}{dt}\right]$

$\therefore \text{Acc}^n = v\left(\frac{dv}{dy}\right)$

$-\omega^2 y = v\left(\frac{dv}{dy}\right)$

$-\omega^2 y \, dy = v(dv)$

which is the 2nd order of diff. eqn of SHM

where, $\omega^2 = \frac{k}{m}$ $\therefore \omega = \sqrt{\frac{k}{m}}$ $[k = \omega^2 m]$

## * Mass spring system :-

It is the arrangement of mass & spring which oscillates in SHM.

## * Horizontal mass spring system :

The horizontal arrangement of mass & spring which oscillates in SHM. - - -

Integrate $\int v\,dv = -\omega^2 \int y\,dy$

$$\frac{v^2}{2} = -\frac{\omega^2 y^2}{2} + c$$

At $y = \pm r$, $v = 0$

$$\therefore c = \frac{\omega^2 r^2}{2}$$

Let, $c = \frac{\omega^2 r^2}{2}$

$$v^2 = -\omega^2 y^2 + \omega^2 r^2$$

$$v = \omega\sqrt{r^2 - y^2}$$

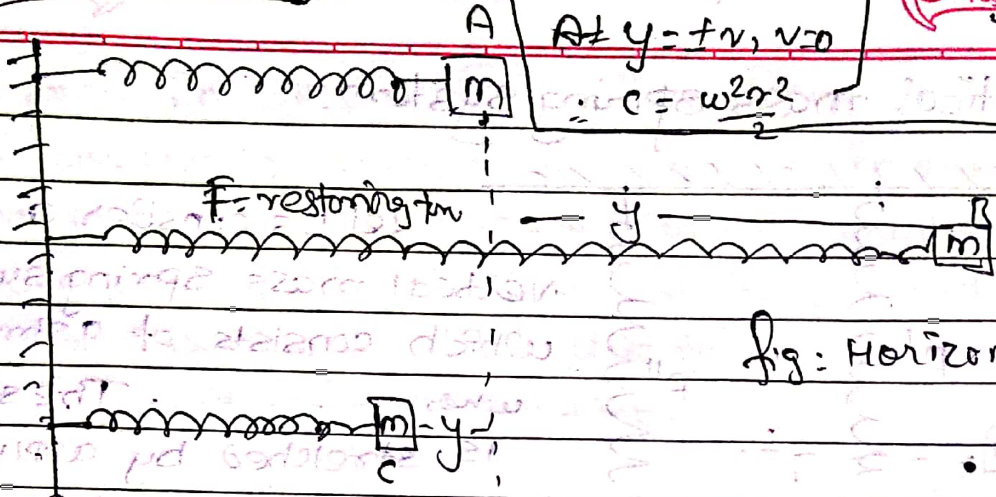



fig: Horizontal mass spr

Let us consider a horizontal mass spring system which consists of a spring whose one end is attached to a body having mass (m) and another end is attached to a rigid support. The string is stretched by applying Force (F) & ~~do~~ then released. Due to restoring force developed on the string, the system can oscillate in left & right direction. If y be the displacement then from Hooke's law:

$$F = -ky$$

[Newton's 2nd law] $ma = -ky$

$$\Rightarrow \frac{d^2y}{dt^2} + \omega^2 y = 0 \qquad \text{where, } \omega^2 =$$

Which is the 2nd order differential eqn of mass spring system & same as SHM. Hence, motion of horizontal mass spring system is SHM.

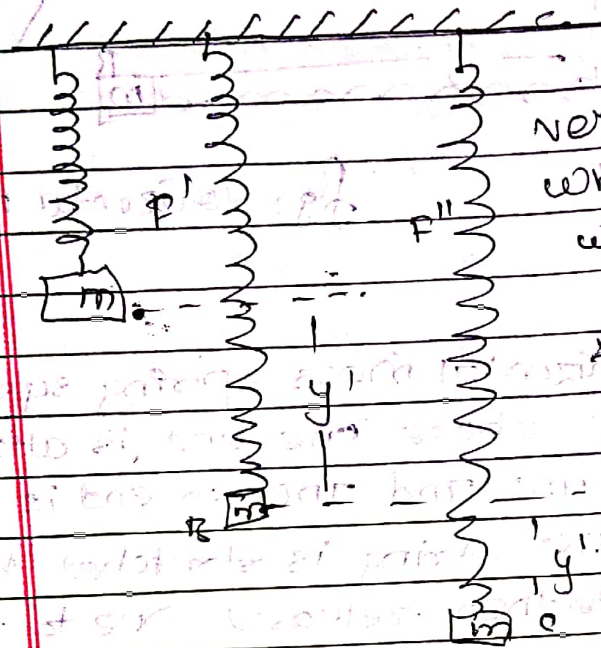
For, time period (T)

$$\omega = 2\pi f$$

$$T = \frac{2\pi}{\omega} \qquad \left[\omega = \sqrt{\frac{k}{m}}\right]$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

## * Vertical mass spring system:




Let us consider a vertical mass spring system which consists of a string which - - - - - - . The string is stretched by applying force (F'') & then released. Due to restoring force down the string oscillates up & down.

If y' be the displacement & F' be the restoring force

$$F' = -ky' \quad -(i)$$

Now, the spring is stretched down by displacement y'' & restoring Force (F'').

$$F'' = -ky''$$

$$F'' = -k(y+y') \quad -(ii)$$

Resultant Force (F) $= F'' - F'$

$$= -k(y+y') + ky'$$

$$= -ky - ky' + ky'$$

$$F = -ky$$

Same

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Page

## * Energy in SHM:-

Consider a particle is executing in SHM, having mass (m). The total energy of the particle is the sum of the KE & PE. The KE is due to the momentum of the particle & PE is due to the position of the partic

$$\therefore \text{Total}(E) = KE + PE \quad \text{---(i)}$$

~~we know~~

$$KE = \frac{1}{2} m v^2 = \frac{1}{2} m \left(\omega \sqrt{r^2 - y^2}\right)^2$$

$$= \frac{1}{2} m\omega^2 (r^2 - y^2)$$

$$\therefore KE = \frac{1}{2} m\omega^2 r^2 - \frac{1}{2} m\omega^2 y^2$$

PE

If $y$ be the displacement & $dy$ be ---

workdone = Force × distan

$$W = F \times y$$

$$= -\int_0^y F \cdot dy \quad [F = -Ky]$$

$$= -\int_0^y (-Ky) \cdot dy$$

$$= K \int_0^y y\, dy$$

$$= K \cdot \left[\frac{y^2}{2}\right]_0^y$$

$$= \frac{Ky^2}{2} = \frac{1}{2} m\omega^2 y^2$$

$\therefore$ Total E $= \frac{1}{2}m\omega^2r^2 - \frac{1}{2}m\omega^2y^2 + \frac{1}{2}m\omega^2y^2$

$E = \frac{1}{2}m\omega^2r^2$

case-I: At mean posn, $y=0$, $E_p = 0$

$\therefore E = \frac{1}{2}m\omega^2r^2$ $E_k = \frac{1}{2}m\omega^2r^2$

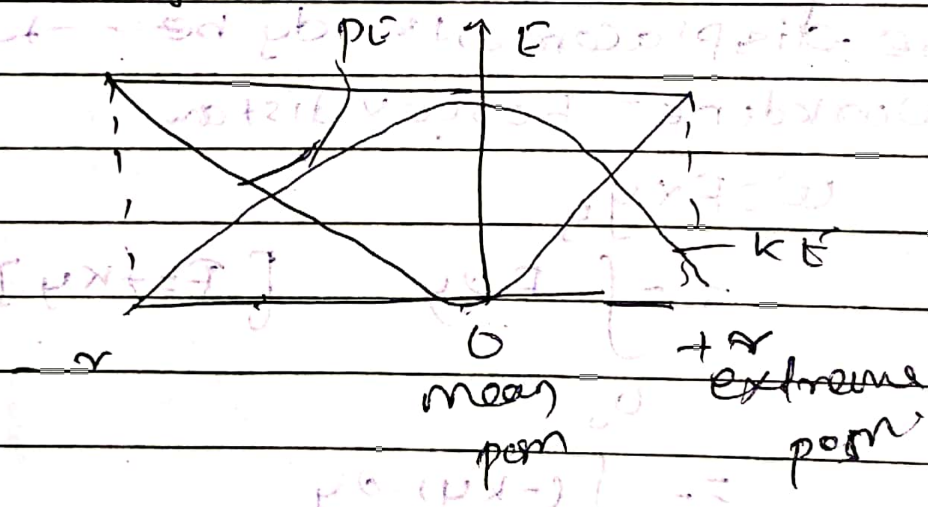
At extreme posn, $y = r$

$E_p = \frac{1}{2}m\omega^2r^2$

$E_k = 0$.

$\therefore$ Total $E = \frac{1}{2}m\omega^2y^2$

Graph.



# Chapter-4.

## Methods of Quantum Mechanics.

1) The position of quantum particle in space at any time is represented by $\psi(x, y, z)$ or $\psi(r, t)$

2) The energy of quantum particles, $E = hf$ $\left[\hbar = \frac{h}{2\pi}\right]$

$$\therefore E = \hbar\, 2\pi f$$

$$\boxed{E = \hbar\omega}$$

3) The momentum of quantum particle, $\therefore \lambda = \frac{h}{p}$ $\left[\hbar = \frac{h}{2\pi}\right]$

$$\therefore \lambda = \frac{2\pi\hbar}{p}$$

$$\boxed{p = \hbar k}, \ k = \text{wave vect}$$

4) In general, the wave eqn of the particle can be ~~Asin~~ $\sin(kx \pm \omega t)$ or $\cos(kx \pm \omega t)$ or, $y = Ae^{i(kx \pm \omega t)}$ or, $A\sin kx + B\cos kx$

1 mark.

## Schrodinger time dependant wave eqn.:

⇒ Let us consider a quantum particle moving along x-direction. Let 'm' be the mass of the particle & 'V' be its velocity. The wave eqn of particle along x-direction at any time is represented by $\psi(x, t)$. This wave eqn can be written as

$$\psi(x, t) = Ae^{i(kx - \omega t)} \quad -(i)$$

where, $k$ = wave vector.

$\omega$ = angular velocity

$A$ = constant (arbitrary)

The total energy of the quantum particles

$E = KE + PE$

$E = \frac{1}{2} mv^2 + V$

$E = \frac{m^2 v^2}{2m} + V$

$$\boxed{E = \frac{p^2}{2m} + V}$$

Multiplying the eqn by $\psi$ on both side

$E\psi = \frac{p^2 \psi}{2m} + V\psi$ — (ii)

Differentiating eqn (i) w.r. to $x$,

$\psi = Ae^{i(kx - \omega t)}$

$\therefore \frac{d\psi}{dx} = A \cdot e^{i(kx - \omega t)} \times (ik)$

Again,

$\frac{d^2\psi}{dx^2} = A \cdot e^{i(kx - \omega t)} \times (ik) \times (ik)$

$= \psi \times i^2 k^2$

$= -k^2 \psi \quad [i^2 = -1]$

But, $p = \hbar k$, $k = \frac{p}{\hbar}$

$\therefore \frac{d^2\psi}{dx^2} = -\frac{p^2}{\hbar^2} \psi$

$\therefore P^2\psi = -\hbar^2 \frac{d^2\psi}{dx^2}$ —(iii)

Now, diff. eqn (i) w.r.to t.

$\frac{d\psi}{dt} = A e^{i(kx-\omega t)} \times i \times (-\omega)$

$= A e^{i(kx-\omega t)} \times (-i\omega)$

$\frac{d\psi}{dt} = -i\omega\psi$

But, $E = \hbar\omega \quad \therefore \omega = \frac{E}{\hbar}$

$\therefore \frac{d\psi}{dt} = -i \cdot \frac{E}{\hbar} \times \psi$

$\therefore E\psi = -\frac{\hbar}{i} \frac{d\psi}{dt}$ —(iv)

From eqn (ii), (iii) & (iv)

$-\frac{\hbar}{i} \frac{d\psi}{dt} = \frac{-\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi$

$\Rightarrow i\hbar \frac{d\psi}{dt} = \frac{-\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi$

which is ~~time~~ time dependant eqn

# Electrical and magnetic field



* Coulomb's law: $|F| = k\frac{q_1 q_2}{r^2}$

$k = \frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2/c^2$, $\varepsilon_0$ = permittivity of free space = $8.85\times10^{-12}\ c^2/Nm^2$

* Permittivity ($\varepsilon$): responce of medium to the Presence of electrostatic force betn charge.

* Relative permittivity ($\varepsilon_r$) = $\varepsilon/\varepsilon_0$ = $\frac{\text{perm. of medium}}{\text{perm. of free space}}$

* electric field: The field around the charge where its effect can be felt.

* electric field intensity: Electric field intensity at a Point inside the electric field is the force experienced by unit (+ve) charge.

(The force experienced by unit +ve charge inside an electric field is called electric field intensity.) $\left(E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \frac{kq}{r^2}\right)$

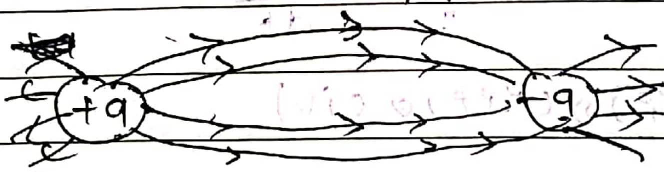
$\boxed{F = Eq}$

* electric lines of force:

The imaginary path made by a unit +ve charge when it is free to move inside an electric field.

→ It starts from positive charge (+q) & ends to −ve (−q)

→ The electric lines of force never intersect to each other




* electric flux ($\phi$):

Total no. of electric lines of force passing through the surface when it is held in the ⊥r direction to the lines of force.

$$E = \frac{\phi}{A}$$

$$\boxed{\phi = EA}$$

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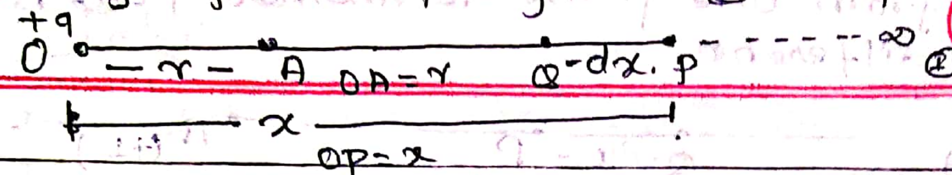
## Electric potential:

The amount of workdone in bringing unit positive charge from infinity to a given point.




Let us consider a unit +ve charge is at infinity. A point (A) is taken at the distance (r) from the +ve charge +q, where we have to determine the electric potential.

Suppose, at any time, the unit +ve charge is at P, and moves a small distance (dx) from P to Q.

∴ Small amount of workdone: $dw = -F\,dx$

(-ve sign indicates that the work is done against force)

But, $F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 \times q_2}{x^2}$

$= \dfrac{1}{4\pi\varepsilon_0}\dfrac{q \times 1}{x^2}$

$\therefore F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{x^2}$

∴ Total work done to bring +ve charge from ∞ to A is

$$w = \int_0^A dw = \int_\infty^r -\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}\,dx$$

$$= \frac{-q}{4\pi\varepsilon_0}\int_\infty^r x^{-2}\,dx$$

$$= \frac{-q}{4\pi\varepsilon_0}\left[\frac{x^{-2+1}}{-2+1}\right]_\infty^r$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{x}\right]_\infty^r$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

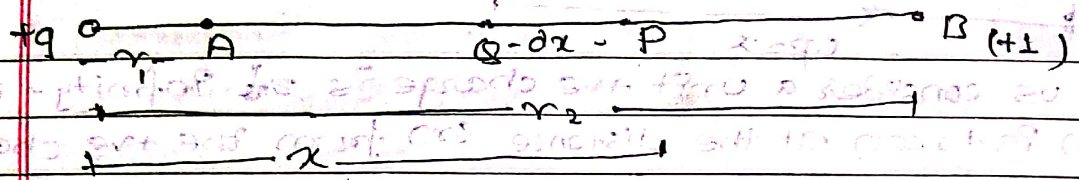
$$w = \frac{1}{r}\,\frac{q}{4\pi\varepsilon_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

This workdone represents electric potential

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

## * Potential difference:

The amount of workdone in bringing a unit the charge from one point to another point is called potential difference.




Let us consider a unit positive charge is at point B. A point (A) is taken at the distance ($r_1$) from the positive charge (+q) & the point (B) is at distance ($r_2$) from positive charge (+q).

Suppose, at any time, the unit +ve charge moves a small distance ($dx$) from P to Q.

∴ Small amount of workdone

$$(dw) = -F \cdot dx \quad (\text{where } -ve.$$

$$dw = -\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}\cdot dx$$

∴ Total workdone to move unit +ve charge from B to A

$$W = \int_B^A dw = \int_{r_2}^{r_1} -\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$$

$$= -\frac{q}{4\pi\varepsilon_0}\int_{r_2}^{r_1} x^{-2}\,dx$$

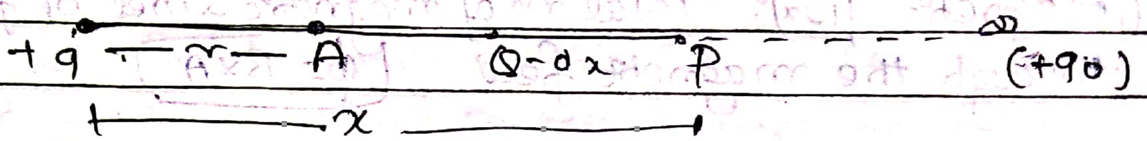
$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{x}\right]_{r_2}^{r_1}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

This workdone represents potential difference.

## * Potential Energy :-

The total amount of workdone in bringing any charge from infinity to a given point is P.E.




Let us consider a charge (+q0) is at infinity. A point (A) is taken at the distance (r) from the +ve charge +q. Suppose, at any time, the charge (+q0) moves a small distance 'dx' from P to Q.

∴ Small work done $(dw) = -F.dx$. (-ve sign

$$dw = -\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{x^2}.dx$$

∴ Total work done to move any charge from ∞ to A is

$$W = \int_{\infty}^{A} dw$$

$$= \int_{\infty}^{A} -\frac{1}{4\pi\varepsilon_0}\frac{qq_0}{x^2}$$

$$= -\frac{qq_0}{4\pi\varepsilon_0}\int x^{-2}dx$$

$$= -\frac{qq_0}{4\pi\varepsilon_0}\left[\frac{x^{-2+1}}{-2+1}\right]_{\infty}^{r}$$

$$= \frac{qq_0}{4\pi\varepsilon_0}\left[\frac{1}{r}-\frac{1}{\infty}\right]$$

$$\therefore W = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r}$$ This work done represents P.E.

# Magnetic Field:



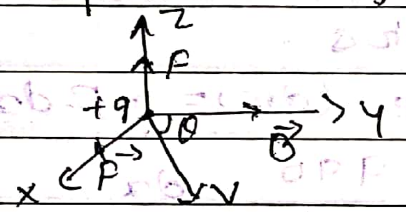
(Magnetic field): The field around which the effect of magnet can be feel.

(Magnetic lines of force): The imaginary path made by unit N-pole when it is placed inside magnetic field.
→ Magnetic lines of force never intersect each other

(Magnetic flux): Total no of magnetic lines of force passing through the magnetic field. $\boxed{\phi = B \times A}$

## * Force on a moving charge.

When a charge is moving inside a magnetic field, it experiences a force $\boxed{F = Bqv\sin\theta}$.




Let us consider a positive charge +q is moving inside the magnetic field along XY plane. Let, the +ve charge experiences force(F) due to magnetic field strength(B). Let, θ be the angle made by charge. experimentally, it is found that, the force experienced by +q charge is directly proportional:

1. Strength of magnetic field (B) i.e. $F \propto B$ – (i)
2. Magnitude of charge (q) i.e. $F \propto q$ – (ii)
3. Component of $v\sin\theta$ i.e. $F \propto v\sin\theta$ – (iii)

combining eqn (i), (ii), (iii)

$F \propto Bqv\sin\theta$

$F = k\,Bqv\sin\theta$ ; [where K is prop. constant value & is taken as unity

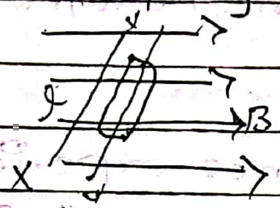
$\therefore F = Bqv\sin\theta$

Case-I If $\theta = 0°$ (charge moving parallel to mag. field
$F = 0$

Case II (charge moving ⊥r to magnetic field
$F = Bqv$

case III [If there is no charge] q=0
F=0
case IV [If charge is at rest] v=0
F=0
(F= BIl sinθ)

# Force experienced by current carrying conductor inside m...




Let us consider a conductor having length (l) & carrying current (I) is placed inside a magnetic field of strength (B). When, it is placed inside magnetic field, each free electron on the conductor experiences a force. The total force experienced by all the electrons gives the force experienced by current carrying conductor.

we know, force experienced by an electron is

$F' = Bqv\sin\theta$ [But q = ne (n=1 ∴ q=e)]

$\therefore F' = Bev\sin\theta$ -(i)

If 'n' be the total no. of electron per unit volume then

$n = \frac{N}{V}$   N = total no. of electrons
  V = volume of conductor

∴ total no. of electrons (N) = n×V

∴ Total force experienced by conductor is

$F = N \times F'$

$= n \times V \times Bev\sin\theta$

$= n \times A \times l \times Bev_d\sin\theta$

$= v_d \times e \times n \times A \times Bl\sin\theta$

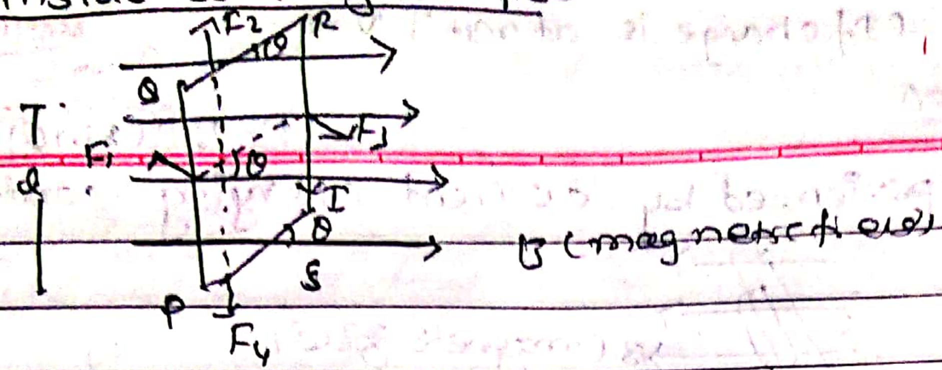
$= IBl\sin\theta$

$\therefore \boxed{F = BIl\sin\theta}$

which is the force experienced by current carrying conductor

case I (If charge is ∥)

* Torque on (rectangular) current carrying conductor inside a magnetic field.




Let $F_1, F_2, F_3, F_4$ be the force experienced by the sides PQ, QR, RS, PS. Let, $\theta$ be the angle made by the surface of the rectangular loop. & (I) be the current carried by the loop

Now, for PQ

Force experienced by side PQ inside magnetic field, is $F_1 = BIl \sin 90$ $\therefore F_1 = BIl$.

which is equal to force experienced by side RS

$\therefore F_1 = F_3 = BIl$.

For side QR,

$F_2 = BIb \sin\theta$ [breadth b

which is equal to $F_4$ $\therefore F_2 = F_4 = BIb\sin\theta$.

Here, $F_2$ & $F_4$ are equal & opposite & acting on same line, so they cancel to each other and do not produce any torque on the loop.

But, $F_1$ & $F_3$ are equal & opposite & acting at different point. so, these two forces produce torque

$\therefore$ Torque = Force x $\perp^r$ distance

$= BIl \times b\cos\theta$

$= BIlb\cos\theta$

$$\boxed{\tau = BIA\cos\theta}$$

For N no. of turns,

$$\boxed{\tau = BINA\cos\theta}$$

If normal makes an angle $\alpha$, then $\alpha = 90 - \theta$

$\therefore \tau = BINA\cos(90-\theta) = BINA\sin$

## Hall effect

The production of potential difference across an electrical conductor when magnetic field is applied in the direction perpendicular to the flow of current is called hall effect.

The voltage produced across the conductor is called hall voltage.

The field so produced is called hall field.

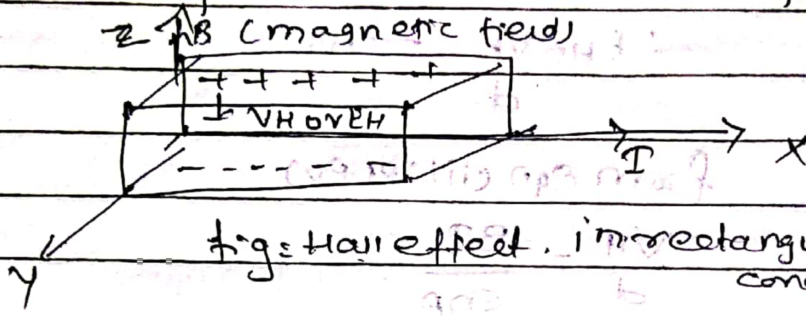



fig: Hall effect in rectangular conductor

$I = I_x$

$B = B_z$

$V_H \Rightarrow V_y$

$E_H \Rightarrow \mathcal{E}_y$

Let us consider a rectangular type of conductor carrying current (I) along x-direction. And, uniform magnetic field (B) along z-direction. And the produced hall voltage ($V_H$) along y-direction.

When magnetic field is applied to the conductor, then electrons are accumulated on lower surface producing net -ve charge and +ve charge are accumulated in upper. This combination of +ve & -ve ~~charge~~ surface charge creates a downward field called hall field. Due to hall field, ~~a~~ voltage is setup across the conductor known as hall voltage.

At eqbm condn,

$$F_M = F_e$$

$$\Rightarrow B e V_d = E e$$

$$\boxed{E_H = B V_d} \quad \text{—(i)}$$ where, $V_d$ is drift velocity.

Also, current $(I) = V_d e n A$

$$\therefore V_d = \frac{I}{enA} \quad \text{—(ii)}$$

$$\therefore E_h = \frac{BI}{enA} \quad \text{(iii)}$$

If $V_H$ be the voltage and 'd' be the separation between +ve & -ve charge.

$$\therefore E_H = \frac{V_H}{d} \quad -(iv)$$

from eqn (iii) & (iv)

$$\frac{V_H}{d} = \frac{BI}{enA}$$

$$\therefore V_H = \frac{BId}{enA} \qquad \text{But, } A = d \times t \quad [t = \text{thickness}]$$

$$\therefore V_H = \frac{BId}{endt}$$

$$\boxed{V_H = \frac{BI}{net}} \quad -(iv)$$

which is the hall voltage

* If asked hall voltage in terms of current density

$$E_H = BV_d \quad -(i)$$

$$\text{Also, } J = \frac{I}{A} = \frac{V_d enA}{A} = V_d en \quad -(v)$$

$$\therefore V_d = \frac{J}{ne}$$

From eqn (i) & (v)

$$E_H = \frac{BJ}{ne}$$

$$E_H = RBJ$$

$$\boxed{E_H = R_H BJ} \qquad \text{where, } R_H = \frac{1}{ne}$$

which gives hall field in terms of current density.

(थार्नी in case asked in 12 marks)

If ($\mu$) be the mobility of charge carrier. Then, it is defined as drift velocity per unit applied electric field

i.e. $\mu = \frac{V_d}{E}$ — (vi)

Since, $J = V_d en$

$V_d = \frac{J}{ne}$

Eqn (vi) becomes

$\mu = \frac{J}{neE}$ — (vii)

we know, $J = \sigma E$ where $\sigma$ = conductivity,

$\cancel{\sigma = \frac{J}{E}}$

Eqn (vii) become

$\mu = \frac{\sigma E}{neE}$

$\mu = \frac{\sigma}{ne}$

$\boxed{\mu = \sigma R_H}$ — (ix)

which gives mobility of charge carrier

Again,

resistivity $(\rho) = \frac{1}{\sigma}$

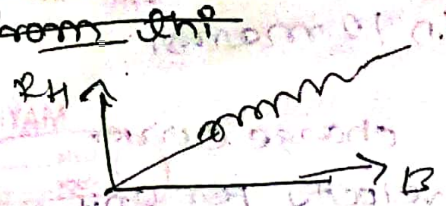
$\boxed{\mu = \frac{1}{\rho} R_H}$

Now, $V_H = \frac{BI}{net}$  $[V = IR]$  $R = \frac{V}{I}$

$\frac{V_H}{I} = \frac{B}{net}$

$R_H = \frac{B}{net}$  which gives hall resistance

~~From thi~~




From this relation, it is expected that hall resistance increases linearly with magnetic field(B) but V... Klitzing showed that the hall resistance increases with increasing in (B) as shown in fig.

## * Importance of hall effect.

i) It can be used to determine whether the given sample is metal, semiconductor or conductor insulator

ii) Mobility can be determined

iii) No. of free electrons per unit volume can be calculated from hall coefficient.

iv) It is used to measure magnetic field & is known as magnetometer.

**electromagnetic waves**

The waves which are formed when an electric field comes in contact with magnetic field are called electromagnetic waves. They travel with constant velocity of $3 \times 10^8 m/s$. They do not need a medium to travel. They are transverse wave.

o RaM, Mohan & I visited U at X-aviers Graduation ceremony.

# Plank's Theory (Planks formula) (plank's radiation)

A body which can absorb radiation of all wave length incident on it is called a perfectly black body. A perfectly black body is a hypothesis, there is no known surface which can be regarded as perfectly black body. eg: Lamb black (96%) & platinum black (98%) is a nearest approach to a perfectly black body.

In order to explain the distribution of energy in the spectrum of black body, Max plank in 1901 AD made a quantum theory of radiation. The following assumptions are to be made for plank's formula / radiation law:

① A black body radiation chamber is filled with not only radiation but also with simple harmonic oscillator of molecular dimension known as plank's oscillator which can vibrate with all possible frequency.

② The oscillator cannot radiate or absorb energy continuously but only radiate or absorb energy in the form of small packets called photon. The average energy of photon is:

$$\bar{E} = \frac{hf}{e^{hf/kt} - 1} \quad \text{---(i)}$$

$f$ = frequency
$h$ = Plank's constant
$k$ = Boltzmann const.
$t$ = absolute temp$^r$

(3) The no. of photons per unit volume in the frequency ranges:

$$n = \frac{8\pi f^2}{c^3} \cdot df \quad -(ii)$$

∴ Total energy emitted from black body radiation chamber is

$$E = n\bar{E} \quad -(iii)$$

From eqn (i) & (ii) & (iii)

$$E = \frac{8\pi f^2}{c^3} \cdot df \times \frac{hf}{e^{\frac{hf}{kt}} - 1}$$

$$= \frac{8\pi h f^3}{c^3} \times \frac{1}{(e^{hf/kt} - 1)} df \quad -(iv)$$

which is plank's radiation law

Also, $f = \frac{c}{\lambda}$ ∴ $\frac{df}{d\lambda} = -\frac{c}{\lambda^2}$

$$df = -\frac{c}{\lambda^2} \cdot d\lambda \quad -(v)$$

∴ eqn (iv) becomes

$$E = \frac{8\pi h \left(\frac{c}{\lambda}\right)^3}{c^3} \times \frac{1}{\left(e^{\frac{hc}{\lambda kt}} - 1\right)} \cdot \frac{-c}{\lambda^2} d\lambda$$

$$= \frac{-8\pi h c}{\lambda^5} \times \frac{1}{(e^{hc/\lambda kt} - 1)} d\lambda$$

Date
Page

# * De-Broglie Theory (Dual nature of matters)

Light shows phenomena such as interference, diffraction, polarisation, etc. These phenomena are evidence for wave nature. On the other hand, light shows phenomena such as photoelectric effect. These phenomena ~~are~~ is evidence for particle nature. It means light shows dual nature.

Like light, all the matter in the universe show dual nature. Sometimes, they behave as wave and sometimes as particle. Such duality of matter was succesfully explained by De-Broglie in 1924 AD known as De-Broglie theory. The wave length of matter is matter wave or De-broglie wavelength. $\lambda = h/p$

## De-Broglie wavelength of electron

Let us consider an electron moving inside an electric field having potential ($V$). Work done is $eV$ which is equal to KE gained by electron i.e.

$$eV = \frac{1}{2}mv^2$$

or, $2eV = mv^2$

or, $2meV = p^2$

$$p = \sqrt{2meV}$$

Also, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}} = \frac{h}{\sqrt{2m(KE)}}$

which is read exp

* Non-existence of electron inside nucleus.

To, explain non-existence of electron inside the nucleus. Let us assume, the electron exists inside the nucleus i.e. it the electron exists inside the nucleus, it can be found within diameter of nucleus. i.e. ($2 \times 10^{-4}$ m) : ~~It means~~

∴ By uncertainty principle

$$\Delta x = 2 \times 10^{-4} m$$

for

$$\therefore \Delta x \times \Delta p \geq \frac{h}{2\pi}$$

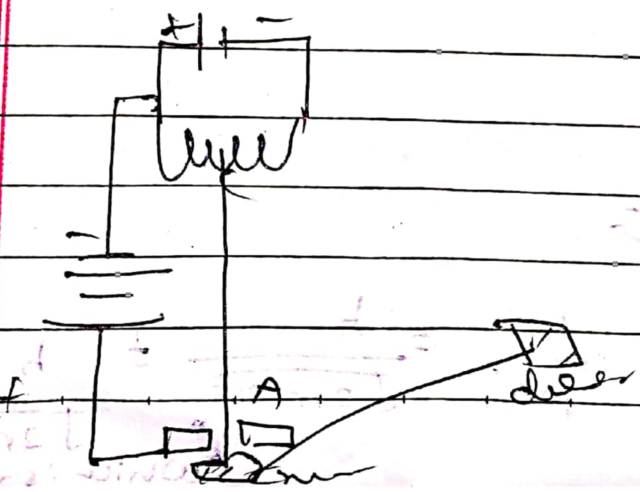
$$2 \times 10^{-4} \times m \times \Delta v = \frac{h}{2\pi}$$

$$2 \times 10^{-4} \times 9.1 \times 10^{-31} \times \Delta V = \frac{6.627 \times 10^{-34}}{2\pi}$$

$$\Delta v = 5 \times 10^{9}$$

which is greater than speed of light (c) which is impossible. Therefore, our assumption was found to be wrong.

* Experimental verification of De-Broglie hypothesis.



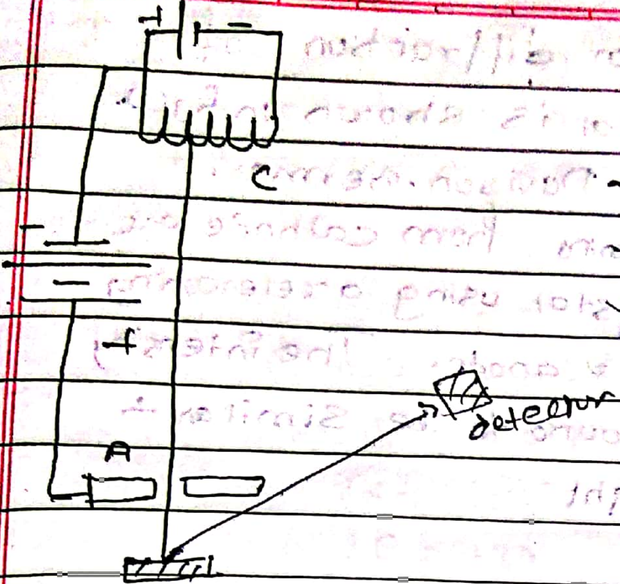



fig: Davison-Germer exp

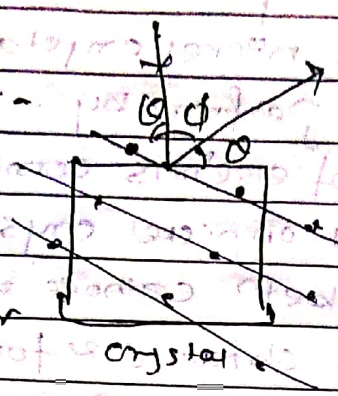



fig: Nickel crystal.

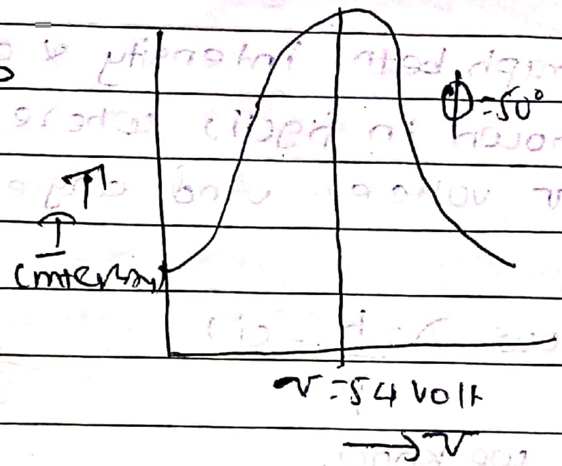



fig: Graph betn intensity & accelerating voltage.

De-Brogile assumed that

~~light shows phenomena~~

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

To prove De-Brogile hypothesis, we have to show experimentally that a beam of particles exhibit wave properties such as interference, diffraction, etc.
we choose a particle of small mass such as electron, proton etc. so that De-brogile wave length is high.

A simple experiment for diffraction of electron from nickel crystal is shown in fig(i). which was performed by - Davison-Germer. The beam of electrons coming from cathode are made to fall on nickel crystal using accelerating voltage in beth cathode & anode. The intensity pattern was obtained & found to be similar to that of diffraction of light.

A graph beth intensity & accelerating voltage is shown in fig(ii) where intensity is max at 54v voltage. And angle of diffraction $\phi = 50°$

Now, $\lambda = \frac{h}{p}$ -(i)

we know,

$ev = \frac{1}{2} mv^2$

$v = \sqrt{\frac{2ev}{m}}$ -(ii)

for v=50 volt

from (i) & (ii)

$\lambda = \frac{6.627 \times 10^{-34}}{m \times v}$

$= 1.67 \times 10^{-10}$

$\lambda = 1.67 Å$

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

$\frac{1}{2} mv^2 = ev$

$\frac{1}{2} mv^2 = 2ev$

$m^2v^2 = 2mev$

$p = \sqrt{2mev}$

$\therefore \lambda = \frac{h}{\sqrt{2mev}}$

$= \frac{6.627 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 54}}$

Again from Bragg's law,

$2d\sin\theta = n\lambda$

From fig. for 1st order

$2d\sin\theta = \lambda$

From fig (ii)

$\phi + \theta + \theta = 180^\circ$

$2\theta + \phi = 180^\circ$

$2\theta + 50 = 180$

$2\theta = 130$

$\theta = 65^\circ$

$\therefore 2 \times 0.91 \times \sin 65 = \lambda$

$\lambda = 1.65\ A^\circ$

which is nearly equal to wavelength of electron beam

Thus, exp. verified the De-Broglie hypothesis that electron have wave properties.

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MAYUR Date Page

## * Time independant schodinger wave eqn.

We know from time dependant schodinger wave eqn.

$$i\hbar \frac{d\psi}{dt} = -\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + V\psi \quad -(i)$$

Also, the wave eqn of the particle

$$\psi(x,t) = Ae^{i(kx-\omega t)}$$

$$= Ae^{ikx} \cdot e^{-i\omega t}$$

$$\Rightarrow \psi(x,t) = \psi_0 \cdot e^{-i\omega t} \quad -(ii)$$

where $\psi_0 = Ae^{ikx}$

differentiating eqn (ii) w.r.t. t.

$$\frac{d\psi}{dt} = \psi_0 \cdot e^{-i\omega t} \times (-i\omega)$$

$E = \hbar\omega$

$\omega = \frac{E}{\hbar}$

$$= -i \cdot \frac{E}{\hbar} \psi_0 e^{-i\omega t} \quad -(iii)$$

Again diff Eqn (ii) w.r.t x.

$$\frac{d\psi}{dx} = \frac{d(\psi_0 e^{-i\omega t})}{dx}$$

Again

$$\frac{d^2\psi}{dx^2} = \frac{d^2(\psi_0 e^{-i\omega t})}{dx^2} \quad -(iv)$$

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$\therefore$ From eqn (i), (ii) ...

$$i\hbar\left(\frac{-i}{\hbar}E\,\psi_0 e^{-i\omega t}\right) = -\frac{\hbar^2}{2m}\frac{d^2\psi_0}{dx^2}e^{-i\omega t} + V\psi_0 e^{-i\omega t}$$

$$E\psi_0 = -\frac{\hbar^2}{2m}\frac{d^2\psi_0}{dx^2} + V\psi_0$$

$$\frac{\hbar^2}{2m}\frac{d^2\psi_0}{dx^2} + E\psi_0 - V\psi_0 = 0$$

$$\frac{d^2\psi_0}{dx^2} + \frac{2m}{\hbar^2}(E-V)\psi_0 = 0$$

$$\frac{d^2\psi_0}{dx^2} + \frac{(E-V)\psi_0}{\frac{\hbar^2}{2m}} = 0$$

$$\boxed{\frac{d^2\psi_0}{dx^2} + \frac{2m}{\hbar^2}(E-V)\psi_0 = 0}$$

which is tm

Magnetic dipole moment($\mu$)

It is defined as the product of magnetic current and the area of loop.

i.e. $\mu = I \times A$ -(i)

We

$\tau = BINA \sin\theta$

R ~

$\tau = \mu BN \sin\theta$

for single loop, N=1

$\therefore \tau = \mu B \sin\theta$.

If the loop rotates from $\theta_1$ to $\theta_2$, then

Total work done ($W$) $= \int dw$

$= \int_{\theta_1}^{\theta_2} \tau \cdot d\theta$

$= \int_{\theta_1} \mu B \sin\theta$

$= \mu B [-\cos\theta]_{\theta_1}^{\theta_2}$

$W = -\mu B [\cos\theta_2 - \cos\theta_1]$

If $\theta_1 = 90°$, $\theta_2 = \theta$

$W = -\mu B [\cos\theta - 0]$

$W \boxed{= -\mu B \cos\theta}$

This work done represent p.e of dipole

$E_p = -\mu B \cos\theta$

MAYUR
Date
Page

## * Physical Significance (Meaning) of wave function ($\psi$):-

The position of a quantum particle in the space at any time can be represented by $\psi(x,y,z,t)$ or $\psi(r,t)$. The $\psi$ itself has no physical significance. But the product of $\psi$ with its conjugate $\psi^*$ gives certain physical meaning i.e. it gives probability density $(P) = \psi\psi^* = |\psi|^2$

Since, the binding particle in the space is 1

$$\iiint_{x\,y\,z} \psi\psi^* \, dx\,dy\,dz = 1$$

$$\text{Or: } \int \psi\psi^* \, dv = 1$$

which is called normalised condition. Using this condition, the value of arbitrary constant can be determined.

## * Application of schodinger Eqn:

Infinite Potential well (Determination of energy level & wave function of particle inside I.P.W having infinitely long wall.

(Show energy levels are quantised)

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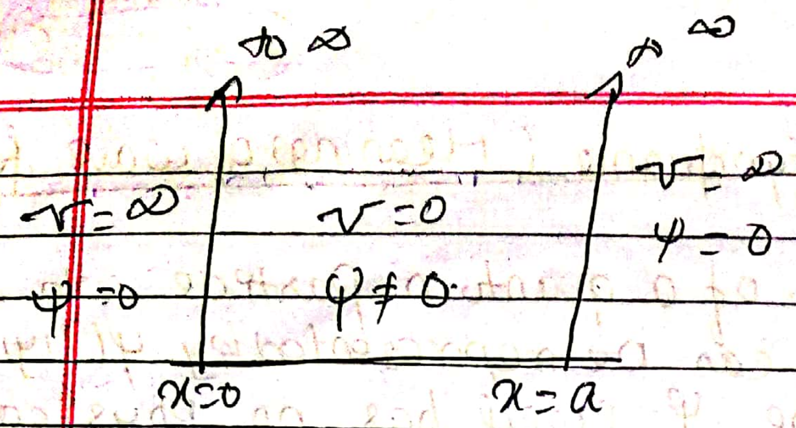


Fig: Infinite p.w.

Let us consider a particle moving inside a potential well having infinitely long wall along x-direction. Let thickness of well is 'a'. Since the wall is infinitely long, Particle cannot escape out from well.

Potential function of infinite p.w is:

$V=0, \quad 0<x<a$ (inside well)

$V=\infty \quad 0>x>a$ (outside well)

To solve this problem, we use time independent schrodinger wave eqn which is given by

$$\frac{d^2\psi}{dx^2}+\frac{2m}{\hbar^2}(E-V)\psi=0$$

Inside the potential well, $V=0$

$$\therefore \frac{d^2\psi}{dx^2}+\frac{2m}{\hbar^2}E\psi=0$$

$$\text{or, } \frac{d^2\psi}{dx^2}+\alpha^2\psi=0 \quad \left[\text{where } \alpha=\frac{2mE}{\hbar^2}\right]$$

Which is 2nd order differential eqn & the general sol^n is

$\psi = A\sin\alpha x + B\cos\alpha x$ - (ii)

where, A & B are two arbitary const.

At, $x=0$ - we get:

$0 = 0 + B$

$B = 0$ $\therefore A \neq 0$

(Both A & B cannot be 0)

$\therefore \psi = A\sin\alpha x$ - (iii)

At, $x = a$, $\psi = 0$

$\therefore 0 = A\sin\alpha a$

since, $A \neq 0$, $(B = 0)$

$\therefore \sin\alpha a = 0$

$\sin\alpha a = \sin n\pi$ $(n = 1, 2, 3 ---)$

$\alpha a = n\pi$

$\alpha = \frac{n\pi}{a}$

$\therefore \psi = A\sin\frac{n\pi x}{a}$

For, energy of partice, we have;

$\alpha^2 = \frac{2mE}{\hbar^2}$

$\frac{n^2\pi^2}{a^2} = \frac{2mE}{\hbar^2}$

$E = \frac{n^2\pi^2\hbar^2}{2ma}$

which is energy of particle inside IDBo

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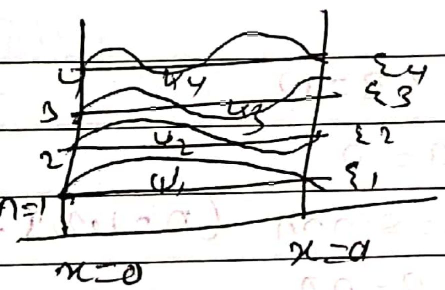
If asked (energy level) (show energy levels are quantum)

when, $n=1$, $E_1 = \frac{(1)^2\pi^2\hbar^2}{2ma^2}$ = 1st energy level

$n=2$, $E_2 = \frac{(2)^2 \cdots}{\cdots}$ $= 2^2 E_1$ = 2nd E.L

$n=n$, $E_n = \frac{n^2\pi^2\hbar^2}{\cdots}$ $= n^2 E_1$

So Energy levels are quantum




For normalised wave function

$$\int_0^a \psi\psi^* dx = 1$$

$$\Rightarrow \int_0^a A^2 \sin^2\frac{n\pi x}{a} dx = 1$$

$$A^2 \left[\int \frac{1-\cos^2\frac{n\pi x}{a}}{2} dx\right]$$

$$= \frac{A^2}{2}\left[\int_0^a dx - \int_0^a \cos^2\frac{n\pi x}{a} dx\right]$$

$$= \frac{A^2}{2}[x]_0^a \qquad \frac{A^2 \times a}{2}$$

$A = \sqrt{\frac{2}{a}}$

$\therefore \psi = \sqrt{\frac{2}{a}}$

$\therefore \psi = \sqrt{\frac{2}{a}} \times \sin\frac{n\pi x}{a}$

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# Hydrogen atom problem.

Hydrogen atom consists of a proton at nucleus & an electron is revolving around nucleus on its fixed orbit. The PE ($V$) for h. atom is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)\times(-e)}{r} \qquad [Z=1 \text{ for h atom}]$$

$$V = \frac{-e^2}{4\pi\varepsilon_0 r}$$

To solve h-atom problem, time independant schrodinger eqn is used. (in spherical polar coordinates)

In polar, $x=r,\ y=\theta,\ z=\phi$

$r$ = radial, $\theta$ & $\phi$ are angular

For 3 dimension.

$$\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}+\frac{d^2\psi}{dz^2}+\frac{2m}{\hbar^2}(E-V)\psi=0$$

$$\Rightarrow \frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{d\psi}{dr}\right)+\frac{1}{r^2\sin\theta}\frac{d}{d\theta}\left(\sin\theta\,\frac{d\psi}{d\theta}\right)+$$

$$\frac{1}{r^2\sin^2\theta}\frac{d^2\psi}{d^2\theta}+\frac{2\mu}{\hbar}(E-V)\psi_0=0 \quad -(F)$$

where, $\mu$ = reduced mass

Using separation of variables, $\psi(r,\theta,\phi)$ can be separated as radial ($r$) and angular ($\theta,\phi$) parts

$$\psi(r,\theta,\phi) = R(r)\cdot Y(\theta,\phi)$$

Here, $R(r)$ & $\phi(\theta)$ is independent to each other

$\psi = RY$ eqn (i) becomes,

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dR}{dr}\cdot Y\right) + \frac{1}{r^2\sin\theta}\frac{d}{d\theta}\left(\sin\theta\cdot\frac{dY}{d\theta}\cdot R\right) + \frac{1}{r^2\sin^2\theta}\left(\frac{d^2Y}{d\phi^2}\cdot R\right) + \frac{2\mu}{\hbar}(E-V)RY = 0$$

Dividing both sides by RY & multiplying by $r^2$

$$\frac{1}{R}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right) + \frac{1}{\sin\theta}\frac{d}{d\theta}\left(\frac{1}{Y}\sin\theta\cdot\frac{dY}{d\theta}\right) + \frac{1}{\sin^2\theta}\frac{d^2Y}{d\phi^2}\frac{1}{Y}$$

$$+\frac{2\mu r^2}{\hbar}(E-V) = 0$$

$$\Rightarrow \frac{1}{R}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right) + \frac{1}{Y}\left[\frac{1}{\sin\theta}\frac{d}{d\theta}\left(\sin\theta\cdot\frac{dY}{d\theta}\right) + \frac{1}{\sin^2\theta}\frac{d^2Y}{d\phi^2}\right]$$

$$+\frac{2\mu}{\hbar^2}r^2(E-V) = 0$$

$$\Rightarrow \frac{1}{R}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right) + \frac{2\mu r^2(E-V)}{\hbar^2} = -\frac{1}{Y}\left[\;\cdots\;\right] = \lambda$$

(say)

— (ii)

The LHS of (ii) depends on (r) & RHS depends on $\theta$ & $\phi$. both sides must be equal to separation const $\lambda$.

$$\therefore \cancel{\frac{1}{R}\frac{d}{dr}\left(r^2(1 - - - -\right) + \frac{1}{Y}\left(\frac{1}{\sin}\right.}$$

$$\frac{1}{R}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right) + \frac{2\mu}{\hbar^2}r^2(E-V) = \lambda \quad -(iii)$$

Divide by $r^2$ & multi- R.

MAYUR
Date
Page

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right)+\frac{2\mu}{\hbar^2}(E-V)R=\frac{\lambda}{r^2}R.$$

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right)+\left[\frac{2\mu}{\hbar^2}[E-V]-\frac{\lambda}{r^2}\right]R=0$$

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dR}{dr}\right)+\left[\frac{2\mu}{\hbar^2}\left(E+\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}\right)-\frac{\lambda}{r^2}\right]R=0$$

$-(iv)$

Which is radial part of h-atom

Again,

$$-\frac{1}{Y}\left[\frac{1}{\sin\theta}\frac{d}{d\theta}\left(\sin\theta\frac{dY}{d\theta}\right)+\frac{1}{\sin^2\theta}\frac{d^2Y}{d\phi^2}\right]=\lambda.$$

or,
$$\left[\frac{1}{\sin\theta}\frac{d}{d\theta}\left(\sin\theta\frac{dY}{d\theta}\right)+\frac{1}{\sin^2\theta}\frac{d^2Y}{d\phi^2}\right]+\lambda Y=0$$

$-(v)$

This angular eqn is also separated into two parts.
by putting $Y(\theta,\phi)=\Theta(\theta)\cdot\Phi(\phi)$

$$\therefore \frac{1}{\sin\theta}\frac{d}{d\theta}\sin\theta\left(\Phi\cdot\frac{d\Theta}{d\theta}\right)+\frac{1}{\sin^2\theta}\times\Theta\times\frac{d^2\Phi}{d\phi^2}+$$
$$\lambda\Theta\Phi=0$$

Dividing by $\Theta\Phi$ & mum by $\sin^2\theta$,

$$\Rightarrow \frac{1}{\Theta}\sin\theta\cdot\frac{d}{d\theta}\left(\sin\theta\frac{d\Theta}{d\theta}\right)+\frac{1}{\Phi}\frac{d^2\Phi}{d\phi^2}+\lambda\sin^2\theta$$

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$$\frac{\sin\theta}{\Theta}\frac{d}{d\theta}\left(\sin\theta\cdot\frac{d\Theta}{d\theta}\right)+\lambda\sin^2\theta=-\frac{1}{\Phi}\frac{d^2\Phi}{d\phi^2}=m^2$$

say

$\Phi$ Eqn

$$-\frac{1}{\Phi}\frac{d^2\Phi}{d\phi^2}=m^2$$

$$\frac{d^2\Phi}{d\phi^2}+m^2\Phi=0 \quad -(VI)$$

This Eqn is azimuthal

$$\frac{\sin\theta}{\Theta}\frac{d}{d\theta}\left(\sin\theta\cdot\frac{d\Theta}{d\theta}\right)+\lambda\sin^2\theta=m^2$$

Multiplying this Eqn by $\frac{\Theta}{\sin^2\theta}$ on both

$$\frac{1}{\sin\theta}\cdot\frac{d}{d\theta}\left(\sin\theta\cdot\frac{d\Theta}{d\theta}\right)+\lambda\Theta-\frac{m^2\Theta}{\sin^2\theta}=0$$

$$\frac{1}{\sin\theta}\frac{d}{d\theta}\left(\sin\theta\frac{d\Theta}{d\theta}\right)+\left(\lambda-\frac{m^2}{\sin^2\theta}\right)\Theta=0 \quad (VII)$$

which is pure angular Eqn or $\Theta$ Eqn.

H. am.

These Eqns (iv, v & vi) are radial eqns. ($\Phi$) azimuthal eqn & angular eqn ($\Theta$) eqn of H. atom

## Semi-conductor

Holes: When electrons jump from valence band to conduction band, then a deficiency of electron is created in valence band. This deficiency of electron is called Hole. These holes also cause conduction. The conductivity of S.C increases with Temp.

~~Memory~~

Memory circuit:

Memory circuit is the key element of digital ecosystem. Memory cells are also used for temporary storage of the output of combinational logic circuit in digital system. The electronic circuit whose output remains as set until something is done or changed is called memory circuit. The base on which memory circuit can be constructed is called flip flop. A flip-flop is a bistable memory element widely used in sequential logic circuit. It has two stable outputs $Q$ & $\bar{Q}$

MAYUR
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Page

(1) Flipflop is often called latches. There are various types of latch.

Rs-flipflop.
A Rs flipflop consists of two inputs R & S with output Q & $\bar{Q}$

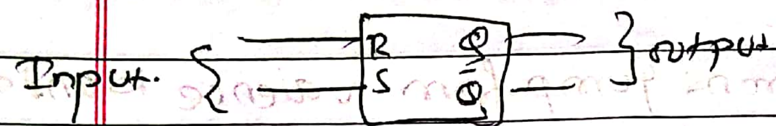
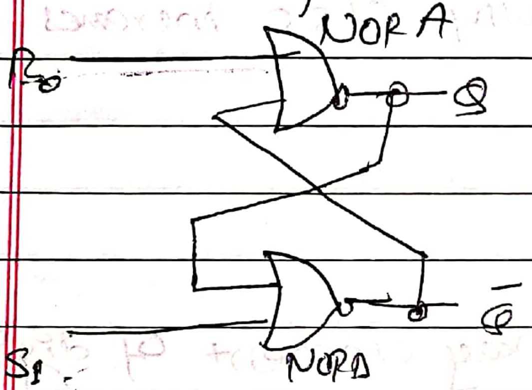


Fig: Logic symbol.

A) Rs flipflop using NOR gate.




(1) ~~When, R=0, S=0~~
⇒ Since NOR gate is high sensitive, so ~~the '0' input~~ of NOR gate has no effect on its output, it means flipflop remains unchanged

(2) When R=0, S=1
→ In this condn, the output of NOR gate B will be low. Both inputs of NOR A are low, so, output must be high. The '1' at S input is said to set flipflop and it switches to stable state when Q=1 & $\bar{Q}$=0

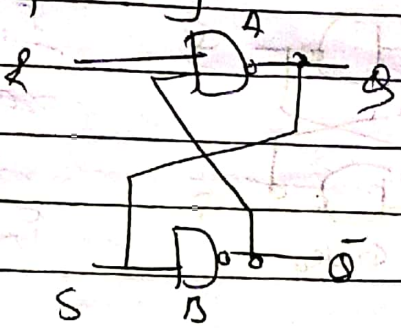
(3) When R=1 & S=0
→ In this condn, the output of A will be low. Both inputs of B are low, so output is high. Thus '1' at R input is said to reset flipflop.

(4) When R=1 & S=1

-) This in indeterminate condn as it forces outputs of both gate to be low. which voilates the basic definition of a flip flop that requires Q & $\bar{Q}$ be different.

| R | S | Q | Remarks |
|---|---|---|---|
| 0 | 0 | last state | No change |
| 0 | 1 | 1 | set |
| 1 | 0 | 0 | reset |
| 1 | 1 | ? | Indeterminate |

(B) RS flipflop using NAND gate.




| R | S | Q | Rem |
|---|---|---|---|
| 0 | 0 | ? | indet- |
| 0 | 1 | 1 | set |
| 1 | 0 | 0 | reset |
| 1 | 1 | last output | no change |

(1) When R=0 & S=0

-) In this condition, the output is not predictable. ie. Indeterminate as output of Q & $\bar{Q}$ are same which violates the combinational rule. So, this is indeterminate cond.

(2) When R=0 & S=1

-) In this condn, the output of gate B is low and gate A is high ie Q=1 & $\bar{Q}$=0 which is set condn

(3) When R=1 & S=0

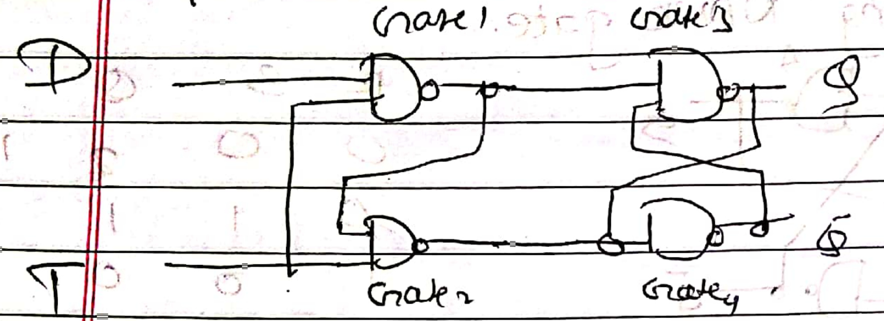
-) " ", output of gate A is low & B ~~ Q=1 & $\bar{Q}$=0 w... reset

(4) R=1, S=1

=) output is same as last output. so no change remain

# D flipflop

A D-flipflop is constructed by modifying a RS flip-flop. In RS flipflop, to obtain high output, we input 'S' high & to obtain low output we input 'R' high. In D flipflop, the data to be stored is fed only at D input with transparent T input controls the response of circuits to the data into the input. The




purpose of D flipflop is to stop the RS flipflop to get indeterminate condition.

When, T=1, the circuit stores in the Q output, the data fed at D.

When T=0, the circuit ignores the input and D remains in previous state. Let, 1 is feed to D keeping T is 1.

~~Now~~, let T=1 & D=1, the output of gate 1 will be 0, ~~out~~ and hence output of gate 2 is '1'. Since ~~the~~ the input of gate 3 is the output of gate 1 and 4. The input of gate 4 are the output of Gate 2 & 3. which results in the output Q=1 & $\bar{Q}$=0

If the T input is changed to '0', the output remain unchanged. The only way to change the output Q to logic level '0' & ~~Q to~~ is to fed '0' input at D keeping T at logic level '1'. Thus, D flipflop stores at Q, the data fed into ~~D~~ D when T=1 & keeps it until new data is fed

## Magnetic Dipole moment: ($\mu$):-

It is defined as the product of magnetic current through the loop & the area of loop.

& $\mu = I \times A$ —(i)

Also, we know

$\tau = BINA \sin\theta$ —(ii)

From (i) & (ii)

$\tau = (I \times A) BN \sin\theta$

$\tau = \mu BN \sin\theta$

For single loop, $N = 1$

$\therefore \tau = \mu B \sin\theta$.

If loop is rotated on $\theta_1$ to $\theta_2$, then total work done by torque inside magnetic field:

$$W = \int_{\theta_1}^{\theta_2} \tau \, d\theta$$

$$= \int_{\theta_1}^{\theta_2} \mu B \sin\theta$$

$$W = \mu B \left[-\cos\theta\right]_{\theta_1}^{\theta_2}$$

$$= \mu B \left[-\cos\theta_2 + \cos\theta_1\right]$$

$$W = -\mu B \left[\cos\theta_2 - \cos\theta_1\right]$$

If $\theta_1 = 90°$, $\theta_2 = \theta$

$W = -\mu B[\cos\theta - \cos 90]$

$W = -\mu B[\cos\theta - 0]$

$W = -\mu B \cos\theta$

This workdone represents the potential energy of dipole. $E_p = -\mu B \cos\theta$

→ Every moving particles such as electrons, atoms, various organic and inorganic molecules has magnetic moments.

## Space quantization

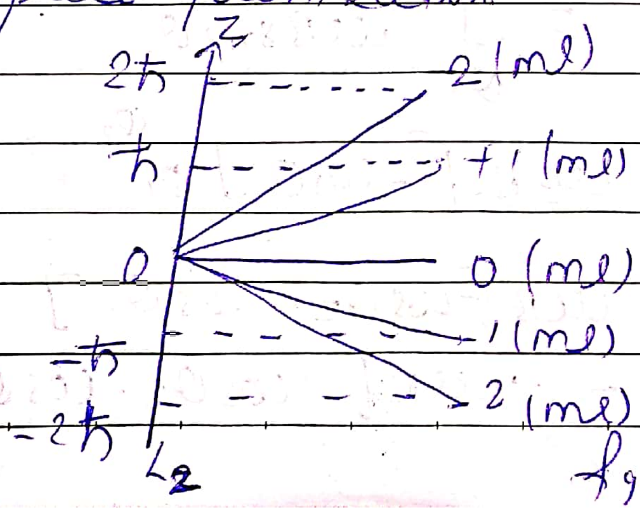
In an atom angular momentum 'L' cannot have any arbitrary orientation with respect to z-axis but rather it can have only certain discrete orientation. This fixed orientation is called space quantization.

Suppose, $l = 2$

$m_l = 0, \pm 1, \pm 2$

$l_z = -2, -1, 0, 1, 2$

$= -2\hbar, -\hbar, 0, +\hbar, +2\hbar$




for $l = 0$, $m_l = 0$, $l_z = 0\hbar$

$l = 1$, $m_l = 0, \pm 1, \pm 1$

$l_z = 0\hbar, \pm\hbar, \pm\hbar$

fig: Possible orientation of angular momentum

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# Spectral series of hydrogen atom

Any given sample of hydrogen consists of large no. of molecules - when such sample is heated or Electric discharge is passed, the hydrogen molecules split into hydrogen atoms. The electrons in different hydrogen atom absorb different amount of energy and excite from lower energy level to higher energy level. Since, the lifetime of electron in excited state is very small i.e. $10^{-7}$ sec, so they return back to the lower energy state. Different electron adapt different routes to return to ground level. As a result, they emit different amount of energy and thus produce a large number of lines in the spectrum of hydrogen.

Atomic structure of hydrogen consists of number of lines which have been grouped as follows:

1. Lyman Series [UV]

⇒ When an electron jumps from second, third --- orbit to first orbit of the atom, Lyman series is obtained which is in ultraviolet region.

Here, $n_1 = 1$ & $n_2 = 2, 3, 4, 5, 6, ---$

so that $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$ where $n = 2, 3, --- n$

(2) Balmer series [visible region]

⇒ When an electron jumps from third, fourth, fifth --- orbit to 2nd orbit ---

It is in visible region.

$n_1 = 2$, & $n_2 = 3, 4, 5, 6, ---$

$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ where $n = 3, 4, 5, --- n$

(3) Paschen series [Infrared region]

⇒ When an electron --- third, fourth --- to 3rd orbit. It is in infrared region.

$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right]$ $n = 4, 5, 6, --- n$.

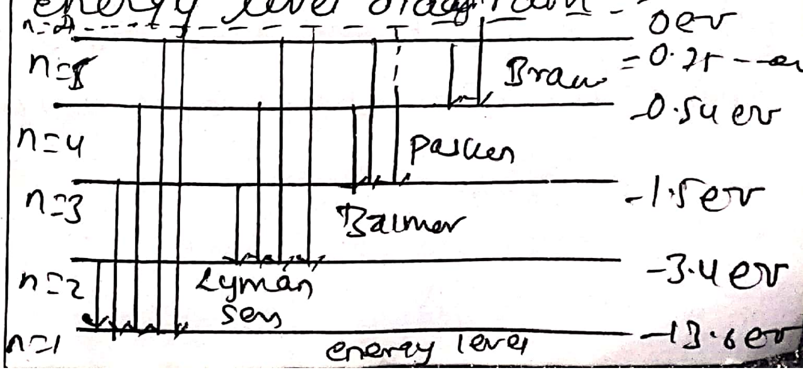
(4) Brackett series [Infrared --

$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n^2}\right]$ $n = 5, 6, 7, -- n$

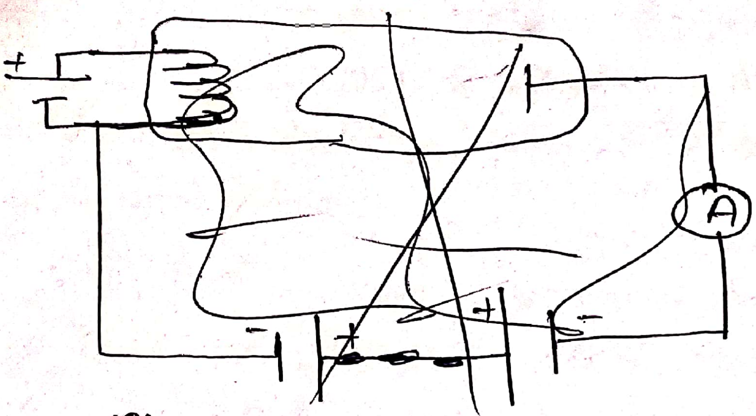
(5) P-fund series [Infrared --

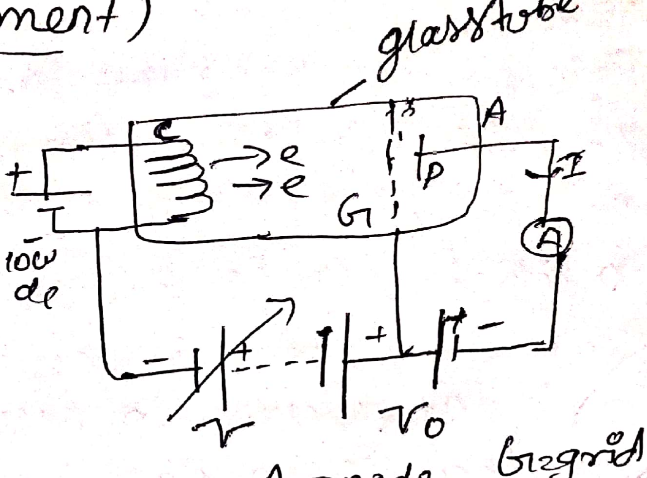
$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n^2}\right]$ $n = 6, 7, 8, -- n$

Energy level diagram:



## * Experimental Determination of critical point (Frank and Hertz experiment)




(i) Fig: Frank Hertz experiment

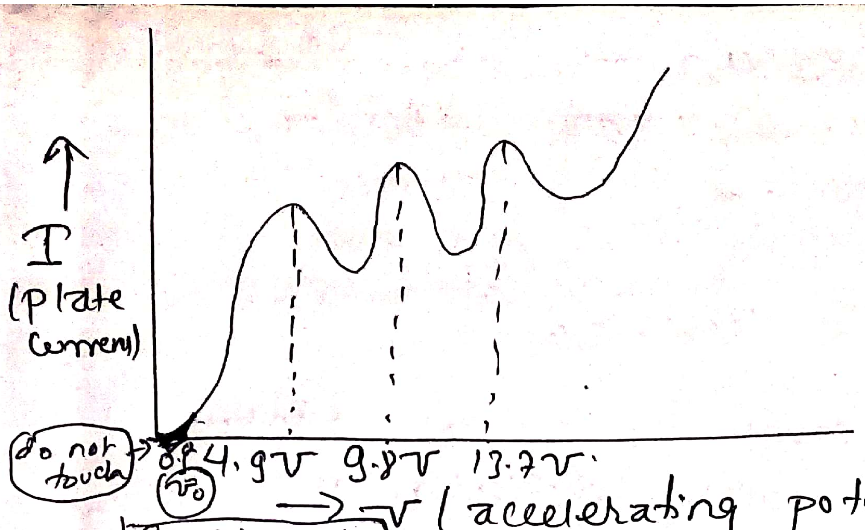
A=anode G=grid P=plate C=cathode

Frank-Hertz provided a direct evidence of discrete energy state within an atom and has studied the excitation and ionisation of atoms of mercury, helium, neon, etc. They found that the energy states ~~of the~~ within an atom are quantized in nature.

A simple experimental arrangement of Frank Hertz experiment is shown in fig (i). It consists of a glass tube containing mercury vapour at a pressure of about 1mm Hg. The tube contains three electrodes namely grid (G), ~~anode~~ cathode (C) and plate (P). The grid is kept at at positive potential (V) but the plate (P) is slightly at negative potential (V) with respect to the Grid. Thus, only those electrons from grid can reach to plate which has kinetic energy greater than the potential difference between G & P.

The ammeter (A) measures the plate current. Now, keeping "Vo" constant, (V) is gradually increased in small steps from 0..

A graph between the plate current vs the accelerating potential (V) is shown below in fig (ii)




Explanation

From this graph it is observed that, there is no plate current $V < 0.5V$. Above this, the plate current increases continuously.

- When the accelerating potential reaches to 4.9V, the current suddenly falls to minimum value. Again, when, the accelerating potential is increased, the plate current gradually increases. The same process happens for increasing accelerating potential at 9.8V, 13.7V and so on.

The fact that there is no drop in current $V = 4.9V$ indicates that, the electrons do not lose energy through collision until they have 4.9 eV of kinetic energy.

- When the electrons collide with a heavy atom such as mercury (Hg), there are two types of collisions.
  - i) Elastic
  - ii) Inelastic.

In case of elastic collision, the total energy of both particles before and after collision is same. No drop in current will be caused by this kind of collision.

In case of inelastic collision, the external kinetic energy of colliding particles ($e^-$ & Hg) becomes internal energy of (mercury atoms, absorb energy & gets excited). Some of the electrons may lose enough energy to prevent from reaching to plate by retarding potential $V_0$ i.e. drop in current should occur for any value of $V_0$. So that the

1st excited state of Hg is 4.9 eV, above the ground state. Similarly, 2×4.9 eV = 9.8 eV is the 2nd excited state and so on.

Limitations of Frank & Hertz exp:

i) Frank and Hertz observed the critical potential, but is not able to distinguish excitation and ionization potential.

ii) This method is not applicable for strong electro-negative gases like $O_2$ & Fluorine. because this gases attract electron strongly.

---

* Spin

i) The electron has an intrinsic angular momentum called the spin. Due to the spinning motion, electron has an intrinsic angular momentum (s) & spin dipole moment ($\mu_s$) such that

$$\mu_s = \frac{-|e|}{m}\vec{s}$$

The existence of spin and its behaviour enter as a postulate in Schrodinger theory. Using the spin postulates the experiment such as anamolous zeeman effect, phipps-Taylor expmt can be explained. The state of electron is now specified by four quantum number

n = principle quantum number

$l = 0$ to $n-1$

$m_l = -l$ to $l$.

$m_s = +\frac{1}{2}$ or $-\frac{1}{2}$ [spin]

# Heisenberg's Uncertainty Principle

Heisenberg's Uncertainty principle states that " The position and momentum of a particle cannot be determined simultaneously to any desired degree of accuracy."

~~The~~ mathematically

$$\Delta p \times \Delta x \geq \frac{h}{2\pi}$$

$$m \times \Delta v \times \Delta x \geq \frac{h}{2\pi}$$

where. $\Delta p$ = Uncertainty in momentum

$\Delta x$: Uncertainty in position

$h$: plank's constant

$m$ = mass of particle

$\Delta p$: Change in velocity

Similarly,

$$\Delta E \times \Delta t \geq \frac{h}{2\pi}$$

$\Delta E$ = Uncertainty in Energy

$\Delta t$: Uncertainty in time

$h$ = plank's constant

According to uncertainty principle, if the $\Delta x$ of a particle is measured accurately, then at some instance of time, $\Delta x = 0$, And then at the same instance of time, $\Delta p$ becomes infinity and vice-versa. Similarly, in all of the above cases, if one quantity is measured accurately then the measurement of another quantity becomes less accurate. Therefore, any two quantity of a particle cannot be determined simultaneously to any desired degree of accuracy according to heisenberg's Uncertainty principle.