STRAIGHT LINE

01 Slope of a Straight Line

If the line makes an angle θ with positive direction of x-axis, then tan θ is called slope of the line and is denoted by m.

02 Various forms of Line

01 **Slope intercept form:** The line with slope m and y intercept c is y=mx+c

02 **Slope point form :** The line with slope m and passing through the point (x_1, y_1) is $y-y_1=m(x-x_1)$.

03 **Two point form :** The line passing through the point (x_1, y_1) and (x_2, y_2) is

$$y-y_1=\frac{y_2-y_1}{x_2-x_1}(x-x_1)$$

04 **Intercept form :**

$$\frac{x}{a}+\frac{y}{b}=1$$

Here, a and b are x intercept and y intercept respectively which may be positive or negative

05 **Normal form :** The line whose normal makes an angle α with positive x axis and has length =p is

$$x\cos\alpha+\gamma\sin\alpha=p.$$

06 **6. Distance or parametric form :**

$$\frac{x-x_1}{\cos\theta}=\frac{y-y_1}{\sin\theta}=r$$

07 **General form of line :** The equation $ax+by+c=0$ where a and b are not simultaneously zero is called general form of line.

Note

(a) x- intercept made by $ax+by+c=0$ is $-\frac{c}{a}$.

(b) y- intercept made by $ax+by+c=0$ is $-\frac{c}{b}$.

(c) Slope of the line $ax+by+c=0$ is $\left(-\frac{a}{b}\right)$.

(d) Area of triangle which the line ax+by+c=0 makes with coordinate axes

$$=\left|\frac{c^2}{2ab}\right|.$$

03 Angle Between Two Lines

Let the slope of the lines $a_1x+b_1y+c_1=0$ and $a_2x+b_2y+c_2=0$ are respectively m_1 and m_2 and If the angle between these lines be θ, then

$$\tan\theta=\left|\frac{m_1-m_2}{1+m_1m_2}\right|=\left|\frac{a_1b_2-a_2b_1}{a_1a_2+b_1b_2}\right|$$

(a) Condition for the lines to be parallel is

$$m_1=m_2 \text{ or } \frac{a_1}{a_2}=\frac{b_1}{b_2}$$

(b) Condition for the lines to be coincidential is

$$\frac{a_1}{a_2}=\frac{b_1}{b_2}=\frac{c_1}{c_2}$$

(c) Condition for the lines to be perpendicular is

$$m_1m_2=-1$$

$$a_1a_2+b_1b_2=0$$

04 Family of Lines

01 Family of lines which are parallel to the line $ax+by+c=0$ is $ax+by+\lambda=0$ where $\lambda\in R$

02 Family of lines which is perpendicular to the line $ax+by+c=0$ is $bx-ay+\lambda=0$ where $\lambda\in R$

03 Family of lines passing through the intersection point of $L_1=a_1x+b_1y+c_1=0$ and $L_2=a_2x+b_2y+c_2=0$ is $L_1+\lambda L_2=0$ where, $\lambda\in R$

05 Distance between a Point and a line

Let (x_1, y_1) be the given point and $ax+by+c=0$ be the given line then distance between them, is

$$p=\left|\frac{ax_1+by_1+c}{\sqrt{a^2+b^2}}\right|$$

06 Distance between Two Parallel Lines

Let the equation of two parallel lines be $ax+by+c=0$ and $ax+by+c'=0$,

then distance between them is given by $P=\left|\frac{c-c'}{\sqrt{a^2+b^2}}\right|$

Note

01 If the foot of perpendicular drawn from point (x_1, y_1) to the line $ax+by+c=0$ be (h,k), then,

$$\frac{h-x_1}{a}=\frac{k-y_1}{b}=-\left(\frac{ax_1+by_1+c}{a^2+b^2}\right)$$

02 If the image of point (x_1, y_1) in the line mirror $ax+by+c=0$ be (α,β), then $\frac{\alpha-x_1}{a}=\frac{\beta-y_1}{b}=-2\left(\frac{ax_1+by_1+c}{a^2+b^2}\right)$

07 Concurrent Lines

Three or more lines are said to be concurrent if they have only one point in common Let the three concurrent lines are $a_rx+b_ry+c_r=0$ where $r=1,2,3,$ then

$$\Delta=\begin{vmatrix}a_1 & b_1 & c_1\\ a_2 & b_2 & c_2\\ a_3 & b_3 & c_3\end{vmatrix}=0$$

Note

If lines are concurrent Δ must be zero but $\Delta=0$ not necessarily imply the lines are concurrent.

08 Comparison of Two Points with Respect to a Line

Let the given line be $L(x,y)=ax+by+c=0$ and the points are $P(x_1, y_1)$ and $Q(x_2, y_2)$, then

1. If $L(x_1,y_1).L(x_2,y_2)>0$ points P and Q lies on the same side of line L=0

2. If $L(x_1,y_1).L(x_2,y_2)<0$ points P and Q lies on the opposite side of line L=0

09 Angle Bisectors of Angle Between Two Lines

The equations of angle bisectors of the angle between the lines $a_1x+b_1y+c_1=0$ and $a_2x+b_2y+c_2=0$ is given by

$$\frac{a_1x+b_1y+c_1}{\sqrt{a_1^2+b_1^2}}=\pm\frac{a_2x+b_2y+c_2}{\sqrt{a_2^2+b_2^2}}$$

Note

In the above equation if c_1 and c_2 are of same sign, then taking the sign same as the sign of $a_1a_2+b_1b_2$ we always get angle bisector of the given lines. Also by taking + in above formula we get the bisector of that angle region which contains origin.

1. Equation of straight line passing through given point (x_1, y_1) and making a given angle α with the given line

$y=mx+c$, are $y-y_1=\frac{m-\tan\alpha}{1+m\tan\alpha}(x-x_1)$ or $y-y_1=\frac{m+\tan\alpha}{1-m\tan\alpha}(x-x_1)$

2. The image of the line $ax+by+c=0$ in the line $x=\lambda$ is $a(2\lambda-x)+by+c=0$

3. The image of the line $ax+by+c=0$ in the line $y=\lambda$ is $ax+b(2\lambda-y)+c=0$

10 Non-homogeneous equation of degree 2

The equation $ax^2+2hxy+by^2+2gx+2fy+c=0$... (i) is called non-homogeneous equation of degree 2.

Let, $\Delta=\begin{vmatrix} a & h & g \\ h & b & f \\ g & f & c \end{vmatrix}$

1. Equation (I) represents a pair of straight lines if $\Delta=0,\ h^2\geq ab,\ g^2\geq ac$ and $f^2\geq bc$.

2. If lines given by (I) have from $y=m_1x+c_1$ and $y=m_2x+c_2$ then $m_1+m_2=\frac{2h}{b}$, $m_1m_2=\frac{a}{b}$, $|m_1-m_2|=\left|\frac{2\sqrt{h^2-ab}}{a+b}\right|$

3. If angle between the lines given by (I) be θ, then $\tan\theta=\left|\frac{2\sqrt{h^2-ab}}{a+b}\right|$

Condition for line pair (I) to represents a pair of parallel lines is $h^2=ab$
Condition for line pair (I) to represents a pair of perpendicular lines is $a+b=0$

4. If the line pair given by (I) be the pair of parallel lines, then distance between them is $=2\sqrt{\frac{g^2-ac}{a(a+b)}}$ or $2\sqrt{\frac{f^2-bc}{b(a+c)}}$

5. Condition for the line pair (I) to represent coincidental lines is $h^2=ab$ and $g^2=ac$ and $f^2=bc$

6. Point of intersection of the lines given by (I) is $\left(\frac{hf-bg}{ab-h^2}, \frac{hg-af}{ab-h^2}\right)=(\alpha,\beta)$

7. Equation of angle bisector of the angle between line pair (I) is $\frac{(x-\alpha)^2-(y-\beta)^2}{a-b}=\frac{(x-a)(y-\beta)}{h}$

Note

In homogeneous case, $ax^2+2hxy+by^2=0$ replace g, f , c by 0.

11 Points to Remember

01 Equation of lines perpendicular to the lines $ax^2+2hxy+by^2=0$ is given by $bx^2-2hxy+ay^2=0$

02 Two pair of straight lines viz. $a_1x^2+2h_1xy+b_1y^2=0$ and $a_2x^2+2h_2xy+b_2y^2=0$ have

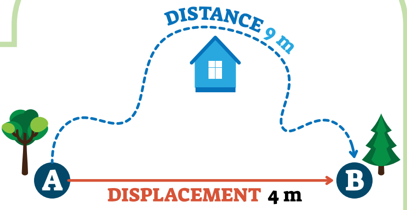
(a) a line in common if $\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}^2=4\begin{vmatrix} a_1 & h_1 \\ a_2 & h_2 \end{vmatrix}\begin{vmatrix} h_1 & b_1 \\ h_2 & b_2 \end{vmatrix}$

(b) both lines in common if $\frac{a_1}{a_2}=\frac{h_1}{h_2}=\frac{b_1}{b_2}$.

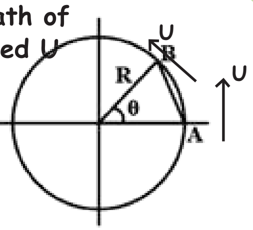
03 Equation of line pair joining the point of intersection of curve $ax^2+2hxy+by^2+2gx+2fy+c=0$ and line $lx+my=1$ with origin is given by $ax^2+2hxy+by^2+(2gx+2fy)(lx+my)+c(lx+my)^2=0$

MOTION ALONG A STRAIGHT LINE

- Distance = Length of actual path
- Displacement = Length of shortest path
- Distance ≥ |displacement|



A particle moves from A to B in a circular path of radius R covering an angle θ with uniform speed U



- Distance $=\widehat{AB}=R\theta$
- Displacement $=AB=2R\sin\left(\frac{\theta}{2}\right)$
- Ratio of Displacement to Distance $=\dfrac{\sin\left(\frac{\theta}{2}\right)}{\frac{\theta}{2}}$
- Time $t=\dfrac{R\theta}{U}$
- Average Velocity $=\dfrac{2U\sin\left(\frac{\theta}{2}\right)}{\frac{\theta}{2}}$
- Average Acceleration $=\dfrac{U^2\sin\left(\frac{\theta}{2}\right)}{R\frac{\theta}{2}}$

- **For uniform motion**

Displacement = velocity x time

Average speed = |average velocity|=|instantaneous velocity|

- **Time average speed**

$$v^{av}=\frac{\text{Total distance covered}}{\text{Totaltime elapsed}}=\frac{s_1+s_2+s_3+\dots+s_n}{t_1+t_2+t_3+\dots+t_n}=\frac{v_1t_1+v_2t_2+v_3t_3+\dots\dots}{t_1+t_2+t_3+\dots\dots}$$

If $t_1=t_2=t_3=\dots\dots=t_n$

then

$$v_{av}=\frac{v_1+v_2+v_3+\dots\dots+V_n}{n}$$

for v_1 & v_2,

$$V_{avg}=\frac{v_1+v_2}{2}\quad\text{(Arithmetic mean of speeds)}$$

- **Distance average speed**

$$v_{av}=\frac{\text{Total distance covered}}{\text{Totaltime elapsed}}=\frac{s_1+s_2+s_3+\dots\dots+s_n}{t_1+t_2+t_3+\dots+t_n}=\frac{s_1+s_2+s_3+\dots\dots+s_n}{\frac{s_1}{v_1}+\frac{s_2}{v_2}+\frac{s_3}{v_3}+\dots\dots+\frac{s_n}{v_n}}$$

If $s_1=s_2=s_3=\dots\dots s_n$

then

$$v_{av}=\frac{n}{\frac{1}{v_1}+\frac{1}{v_2}+\frac{1}{v_3}+\dots\dots+\frac{1}{v_n}}$$

for v_1 & v_2,

$$V_{avg}=\frac{2V_1V_2}{V_1+V_2}\quad\text{(Harmonic mean of speeds)}$$

Instantaneous Velocity $v=\dfrac{dx}{dt}$ $\Delta x=\int v\,dt$

Instantaneous Acceleration $a=\dfrac{dv}{dt}$ $\Delta v=\int a\,dt$

Case 1	Case 2	Case 3
$v=f(t)$ or $x=f(t)$	$V=f(x)$	$t=f(x)$ then
$a=\dfrac{dv}{dt}=\dfrac{d^2x}{dt^2}$	$a=V\dfrac{dV}{dx}$	$a=-$(double diff. of t w.r.t. x) $\times V^3$

Displacement
Differentiation
Integration
Velocity
Differentiation
Integration
Acceleration

Motion with constant acceleration: Equations of motion

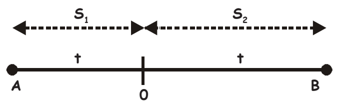
(i) $v=u+at$

(ii) $S=ut+\frac{1}{2}at^2$

- A Person travels from A to B covers unequal distances in equal interval of time with constant acceleration a then

initial velocity $U=\dfrac{3S_1-S_2}{2t}$

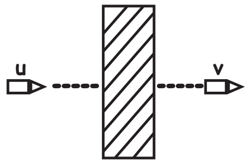
Acceleration $a=\dfrac{S_2-S_1}{t^2}$



(iii) $v^2=u^2+2a.s$

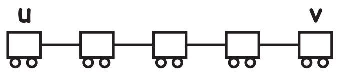
- The number of planks required to stop the bullet

$$N=\frac{u^2}{u^2-v^2}$$

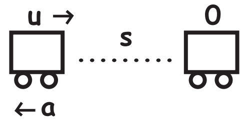


- The two ends of a train moving with constant acceleration pass a certain point with velocities u and v. The velocity with which the middle point of the train passes the same point is

$$V_{Mid}=\sqrt{\frac{u^2+v^2}{2}}$$



- Calculation of stopping distance $s=\dfrac{u^2}{2a}$

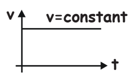
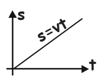
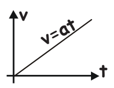
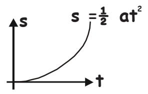
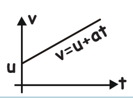
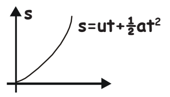
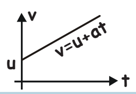
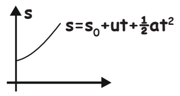
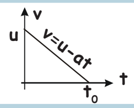
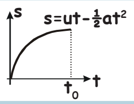
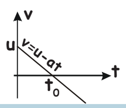
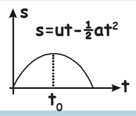


(iv) $s_n=u+\frac{a}{2}(2n-1)$

- Ratio of distance travelled in equal interval of time in a uniformly accelerated motion from rest is

$$S_1:S_2:S_3=1:3:5$$

- for uniform accelerated motion $V_{avg}=\dfrac{u+v}{2}$

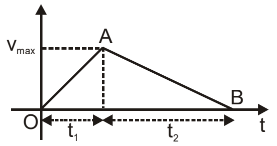
Different Cases	v-t graph	s-t graph
1. Uniform motion		
2. Uniformly accelerated motion with u =0 at t=0		
3. Uniformly accelerated with $u\neq0$ at t=0 & s=0 at t=0		
4. Uniformly accelerated motion with $u\neq0$ and $s=s_0$ at t=0		
5. Uniformly retarded motion till velocity becomes zero		
6. Uniformly retarded then accelerated in opposite direction		

Important points about graphical analysis of motion

- Instantaneous velocity is the slope of position-time curve $\left[v=\dfrac{dx}{dt}\right]$
- Area of v-t curvegives displacement. $\left[\Delta x=\int v\,dt\right]$
- Slope of velocity-time curve = instantaneous acceleration $\left[a=\dfrac{dv}{dt}\right]$
- Area of a-t curve gives change in velocity. $\left[\Delta v=\int a\,dt\right]$

A car accelerates from rest at a constant rate α for some time, after which it decelerates at a constant rate β, to come to rest. If the total time elapsed is t, then

$$V_{max}=\frac{\alpha\beta}{\alpha+\beta}t\qquad\text{Total Distance}=\frac{1}{2}\left(\frac{\alpha\beta}{\alpha+\beta}\right)t^2$$



MOTION UNDER GRAVITY

Sign Convention

(i) initial velocity

+ve = upward motion
-ve = downward motion

(ii) Acceleration

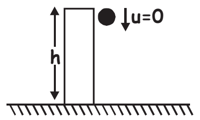
Always -ve

(iii) Displacement

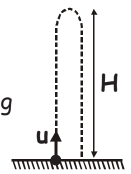
+ve = final position is above initial position
-ve = final position is below initial position
Zero = final position & initial position are at same level

$\frac{1}{n}$

- Object is dropped from top of a tower
  - (i) Ratio of displacement in equal interval of time $S_1:S_2:S_3\dots=1:3:5\dots$
  - (ii) Ratio of time of covering equal distance $t_1:(t_2-t_1):(t_3-t_2):\dots\dots:(t_n-t_{n-1})=1:(\sqrt{2}-\sqrt{1}):(\sqrt{3}-\sqrt{2}):\dots:(\sqrt{n}-\sqrt{n-1}$
  - (iii) Ratio of total distance covered at the end of time $t:2t:3t:\dots=1^2:2^2:3^2\dots$



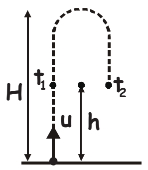
- If a body is thrown vertically up with a velocity u in the uniform gravitational field (neglecting air resistance) then
  - (i) Maximum height attained $H=\dfrac{u^2}{2g}$
  - (ii) Time of ascent = time of descent $\dfrac{u}{g}$
  - (iii) Total time of flight = $\overline{g}2u$
  - (iv) Velocity of fall at the point of projection = u (downwards)



- At any point on its path the body will have same speed for upward journey and downward journey. If a body thrown upwards crosses a point in time t_1 & t_2 respectively then

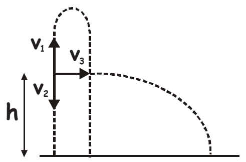
height of point $h=\frac{1}{2}gt_1t_2$ Maximum height $H=\dfrac{1}{8}g(t_1+t_2)^2$

Time of flight $=t_1+t_2=\dfrac{2u}{g}$



- A body is thrown upward, downward & horizontally with same speed takes time t_1, t_2 & t_3 respectively to reach the ground then

$t_3=\sqrt{t_1t_2}$ & height from where the particle was throw is $h=\frac{1}{2}gt_1t_2$



PHYSICS WALLAH

01

Which of the following statements is/are incorrect?
I. Aqueous solution of sugar conducts electricity.
II. Conductance of electricity increases with an increase in concentration of common salt in aqueous glucose solution.
III. Aqueous solution of acetic acid mainly contains unionized acetic acid molecules and only some CH_3COO^- and H_3O^+ ions.
(a) III only (b) I only
(c) II and III only (d) I, II and III

ELECTROLYTE

Substance which allow the flow of electricity through their aqueous solution or through their molten form.

01 STRONG ELECTROLYTE
electrolyte which dissociates completely into ions.
eg : HCl, NaOH

02 WEAK ELECTROLYTE
electrolyte which dissociates partially into ions.
eg : CH_3COOH, NH_4OH

IONIC EQUILIBRIUM

Equilibrium established in between ions and unionised Salt in a weak electrolyte.

Eg. In weak electrolytes, equilibrium is established between ions and the unionized molecules. This type of equilibrium I.involves ions in aqueous solution. II.is called physical equilibrium. III.is due to complete ionization IV.is called ionic equilibrium.
The correct statement(s) is/are
(A) I and IV only (B) II and III only (C) IV only (D) I, II, III and IV
ANS : (A)

02

Which of the following is conjugate acid of SO_4^{2-}?
(a) HSO_4^- (b) H^+
(c) H_2SO_4 (d) SO_4^{2-}

ACID-BASE CONCEPTS

01 ARRHENIUS CONCEPT
Acids are H^+ ions donors and bases are OH^- ion donors.
- $HCl \rightarrow H^+ + Cl^-$ (acid)
- $NaOH \rightarrow Na^+ + OH^-$ (base)

02 BRONSTED - LOWRY CONCEPT
Acids are protons (H^+ion) donors and bases are proton acceptors.

$$\text{Eg : } \underset{\text{acid}}{CH_3COOH} + \underset{\text{base}}{H_2O} \rightleftharpoons \underset{\text{Base}}{CH_3COO^-} + \underset{\text{acid}}{H_3O^+}$$

base + $H^+ \rightarrow$ Conjugate acid	acid - $H^+ \rightarrow$ Conjugate base

- Conjugate acid of $H_20 \rightarrow H_3O^+$
- Conjugate base of $H_20 \rightarrow OH^-$

03 LEWIS CONCEPT
Bases are lone pair e^- donors & acids are lone pair e^- acceptors.
- Lewis acid - Substances having Vacant space in their valence shell to accomodate lone pair of e^-
  Eg : BF_3, $AlCl_3$, H^+, Ag^+
- Lewis base - Substances having lone pair of e^- in their valence shell
  Eg : NH_3, H_2O, Cl^-, OH^-

03

Which of the following species can act both as an acid as well as a base?
(a) SO_4^{2-} (b) HSO_4^-
(c) PO_4^{3-} (d) Cl^-

IONISATION AND IONISATION CONSTANT

In all ionisation reactions concentration of water $[H_2O]$ is taken as constant

01 IONISATION OF WATER

$$H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$$

Ionisation constant of water, $K_w = [H_3O^+][OH^-]$
or $K_w = [H^+][OH^-]$

02 IONISATION OF ACID

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

Ionisation constant, $K_a = \dfrac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$

or $K_a = \dfrac{[CH_3COO^-][H^+]}{[CH_3COOH]}$

03 IONISATION OF BASE
Eg : NH_4OH

Ionisation constant of base $K_b = \dfrac{[NH_4^+][OH^-]}{[NH_4OH]}$

04

What will be the pH of a soft drink if hydrogen ion concentration in sample is 3.8×10^{-3} M?
(a) 3.8 (b) 5.04
(c) 2.42 (d) 9.2

VALUE OF IONIC PRODUCT

At 25°C, $K_w = [H_3O^+][OH^-] = 1 \times 10^{-14}$

01 If $[H^+] = [OH^-] = 1 \times 10^{-7}$ mol/L : solution will be neutral

02 If $[H^+] > [OH^-]$ i.e $[H^+] > 1 \times 10^{-7}$ mol/L solution will be acidic

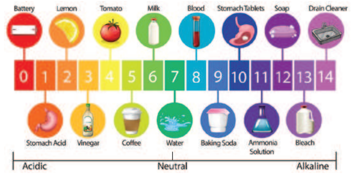
03 If $[H^+] < [OH^-]$ i.e $[H^+] < 1 \times 10^{-7}$ mol/L solution will be basic

pH

$$\boxed{pH = -\log[H^+]}$$

- pH of a neutral solution is 7
- pH of an acidic solution is < **7**
- pH of a basic solution is > 7

pH SCALE



05

What will be the ionisation constant of formic acid if its 0.01 M solution is 14.5% ionised?
(a) 2.1×10^{-4} (b) 14.5
(c) 0.145 (d) 1.45×10^{-4}

IMPORTANT EQUATIONS

- $pH = -\log[H^+]$
- $pKa = -\log[K_a]$
- $pOH = -\log[OH^-]$
- $pKb = -\log[K_b]$
- $pKw = pH + pOH = 14$
- $K_a x K_b = K_w = 1 \times 10^{-14}$ at 25°C
- $pKa + pKb = 14$ at 25°C

DEGREE OF DISSOCIATION (α)

$$\boxed{\alpha = \frac{\text{Number of moles ionised}}{\text{Total no. of moles}}}$$

Eg : 30% ionisation means $\alpha = \dfrac{30}{100} = 0.3$

Weak acid	Weak base
$K_a = C\alpha^2$	$K_b = C\alpha^2$
$\alpha = \sqrt{K_a/c}$	$\alpha = \sqrt{K_b/c}$
$[H_3O^+] = C\alpha$	$[OH^-] = C\alpha$
$[H^+] = \sqrt{K_a \cdot c}$	$[OH^-] = \sqrt{K_b \cdot c}$

IONIC EQUILIBRIUM

06

Equimolar solutions of HF, HCOOH and HCN at 298 K have the values of K_a as 6.8×10^{-4}, 1.8×10^{-4} and 4.8×10^{-9} respectively. What will be the order of their acidic strength?
(a) HF > HCN > HCOOH
(b) HF > HCOOH > HCN
(c) HCN > HF > HCOOH
(d) HCOOH > HCN > HF

ACID STRENGTH

- acid strength α K_a
- acid strength α $\dfrac{1}{pKa}$

For an acid HA

- As HA bond strength decreases, acid strength increases
- As we move from top to bottom, size of anion increases
  ∴ HA bond strength decreases & acid strength increases.
  eg :- Acid strength of HI > HBr > HCl > HF
- As we move from left to right, electronegativity increases
  ∴ HA bond becomes more polar & acid strength increases.
  eg :- Acid strength of HF > H_2O > NH_3 > CH_4

07

For a polybasic acid, the dissociation constants have a different values for each step, *e.g.*,

$$H_3A \rightleftharpoons H^+ + H_2A^-;\ K = K_{a_1}$$
$$H_2A^- \rightleftharpoons H^+ + HA^{2-};\ K = K_{a_2}$$
$$HA^{2-} \rightleftharpoons H^+ + A^{3-};\ K = K_{a_3}$$

What is the observed trend of dissociation constants in successive stages?
(a) $K_{a_1} > K_{a_2} > K_{a_3}$ (b) $K_{a_1} = K_{a_2} = K_{a_3}$
(c) $K_{a_1} < K_{a_2} < K_{a_3}$ (d) $K_{a_1} = K_{a_2} + K_{a_3}$

POLYPROTIC ACIDS & POLYHYDROXY BASES

- Acids having ionisable hydrogen are known as protic acids or basic acids. eg :- HCl, H_2SO_4, $H_2C_2O_4$, H_3PO_4, CH_3COOH etc
- Here H_2SO_4, $H_2C_2O_4$ & H_3PO_4 are having more than one ionisable hydrogen, they are known as polyprotic acids
- Polyprotic acids ionises in stepwise.
- Here the removal of H^+ ion from neutral molecule is easy, but it is difficult to remove further H^+ ions from their corresponding anions ∴$Ka_1 > Ka_2 > Ka_3$
- In case of polyhydroxy bases or polyacidic bases like $Fe(OH)_3$, $Ba(OH)_2$ etc $Kb_1 > Kb_2 > Kb_3$

08

Which of the following salts does not show its correct nature mentioned against it?
(a) NaCl solution - Neutral
(b) NaCN solution - Acidic
(c) NH_4NO_3 solution - Acidic
(d) KF solution - Basic

HYDROLYSIS OF SALTS

$$\boxed{\text{Salt} + H_2O \xrightarrow{\text{hydrolysis}} \text{acid} + \text{base}}$$

- SALT OF STRONG ACID & STRONG BASE
  Strong acid (SA) & strong base (SB) → Neutral, It's pH = 7
  eg :- NaCl $\quad \underset{SB}{NaOH} + \underset{SA}{HCl} \rightarrow$ Neutral
  $Na_2SO_4 \quad \underset{SB}{NaOH} + \underset{SA}{H_2SO_4} \rightarrow$ Neutral
  Note : Neutral salts do not undergo hydrolysis
- SALT OF STRONG ACID & WEAK BASE. (SA + WB → acidic), It's pH < 7
  eg :- NH_4Cl $\quad \underset{WB}{NH_4OH} + \underset{SA}{HCl} \rightarrow$ acidic (cationic hydrolyses)
- SALT OF WEAK ACID & STRONG BASE (WA + SB → Basic), It's pH > 7
  eg :- CH_3COONa $CH_3COOH + NaOH \rightarrow$ Basic (anionic hydrolysis)
- SALT OF WEAK ACID & WEAK BASE
  WA + WB → slightly acidic/basic

$$\boxed{pH = 7 + \frac{1}{2}[pKa - pKb]}$$

eg : $(NH_4)_2CO_3$

09

Which one of the following pairs of solution is not an acidic buffer?
(a) CH_3COOH and CH_3COONa
(b) H_2CO_3 and Na_2CO_3
(c) H_3PO_4 and Na_3PO_4
(d) $HClO_4$ and $NaClO_4$

COMMON ION EFFECT

Ionisation of a weak electrolyte can be suppressed by the addition of salt which contain common ion.

- Ionisation of a weak acid, CH_3COOH can be suppressed by the addition of a salt like CH_3COONa. Common ion : CH_3COO^-
- Ionisation of a weak base, NH_4OH can be suppressed by the addition of a salt like NH_4Cl. Common ion : NH_4^+

BUFFER SOLUTIONS

Solution which can resist the change in pH on addition of small drops of acids or base.

1. Acidic buffer : Mixture of equimolar concentrations of a weak acid and it's salt with a strong base. CH_3COOH / CH_3COONa.

$$\boxed{pH = pKa + \log\frac{[\text{salt}]}{[\text{acid}]}}$$

Henderson - Hasselbalch equation

2. Basic buffer : Mixture of equimolar concentrations of a weak base and it's salt with a strong acid. NH_4OH / NH_4Cl.

$$\boxed{pOH = pKb + \log\frac{[\text{salt}]}{[\text{base}]}}$$

10

The solubility of $AgCl_{(s)}$ with solubility product 1.6×10^{-10} in 0.1 M NaCl solution would be
(a) 1.26×10^{-5} M (b) 1.6×10^{-9} M
(c) 1.6×10^{-11} M (d) zero.

SOLUBILITY PRODUCT

- Solubility is the concentration of an ion in a saturated solution(S)
- Solubility product is the equilibrium constant for solubility equilibrium
- Sparingly soluble salt → salts which can dissolve only slightly into ions
  eg: AgCl, $BaSO_4$, $PbCl_2$, etc.
- K_{sp} can be calculated easily by using a sparingly soluble salt.

Consider the ionisation of a sparingly soluble salt AgCl

$$AgCl \rightleftharpoons \underset{S}{Ag^+} + \underset{S}{Cl^-}$$

$$K_{sp} = [Ag^+][Cl^-] = S \times S = S^2$$

- If the value of ionic product = K_{sp}, solution is saturated.
- If the value of ionic product < K_{sp}, solution is unsaturated.
- If the value of ionic product > K_{sp}, solution is super saturated, here precipitation takes place

PHYSICS WALLAH

01

▪ RATE OF A CHEMICAL REACTION

$$\frac{\text{decrease in conc of reactant}}{\text{Time taken}} \text{ OR } \frac{\text{Increase in conc of reactant}}{\text{Time taken}}$$

▪ AVERAGE RATE

Consider a reaction: $A + B \longrightarrow C + D$

$$-\frac{\Delta[A]}{\Delta t} = -\frac{\Delta[B]}{\Delta t} = \frac{\Delta[C]}{\Delta t} = \frac{\Delta[D]}{\Delta t}$$

▪ INSTANTANEOUS RATE

Consider a reaction: $aA + bB \longrightarrow cC + dD$

$$-\frac{1}{a}\frac{d[A]}{dt} = -\frac{1}{b}\frac{d[B]}{dt} = \frac{1}{c}\frac{d[C]}{dt} = \frac{1}{d}\frac{d[D]}{dt}$$

$\boxed{\text{Unit of Rate} = \text{mol litre}^{-1}\ \text{s}^{-1}}$

Q During the decomposition of H_2O_2 , 48 g O_2 is formed per minute at a certain point of time. The rate of formation of water at this point is

(a) 0.75 mol min^{-1} (b) 1.5 mol min^{-1}

(c) 2.25 mol min^{-1} (d) 3.0 mol min^{-1}

02

▪ FACTORS INFLUENCING RATE OF REACTION

Factors	Effect on reaction rate
Increase in concentration	Increases
Increase in temperature	Increases
Presence of catalyst	Increases

Q Which of the following will lead to an increase in the rate of the reaction?

a) Decrease in temperature
b) Decreasing concentration of reactants
c) Addition of catalyst
d) Addition of inhibitor

03

▪ RATE LAW

Consider a general reaction,

$aA + bB \longrightarrow \text{product}$

Rate $= k[A]^a [B]^b$ (law of mass action)

Rate $= k[A]^x [B]^y$ (rate law expression)

x & y are determined experimentally and may or may not be equal to a & b

x & y represents the order of reaction with respect to A & B

▪ RATE CONSTANT

- Larger the value of k, faster is the reaction.
- The value of k changes only with temperature for given reaction.

$\boxed{\text{unit of rate constant} = (\text{mol})^{1-n}\ L^{n-1}\ s^{-1}}$

Q The rate constant of a zero-order reactions has the unit

(a) s^{-1} (b) mol L^{-1} s^{-1}

(c) L^2 mol^{-2} s^{-1} (d) L mol^{-1} s^{-1}

04

▪ ORDER AND MOLECULARITY

Consider a general reaction,

$aA + bB \longrightarrow \text{product}$

Rate $= k[A]^x [B]^y$

molecularity $= a + b$

order $= x + y$

Molecularity	Order
Theoretical concept.	An experimentally determined quantity.
It cannot be zero, fractional, infinite and imaginary.	It can be equal to zero positive, negative and fractional.

Q When the rate of the reaction is equal to the rate constant, the order of the reaction is

(a) zero order
(b) first order
(c) second order
(d) third order

05

▪ PSEUDO ORDER REACTIONS

Consider the reaction

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

In these reactions, concentration of water (one of the reactants) is in excess and its concentration remains constant throughout the reaction.

Thus, rate $\propto [C_{12}H_{22}0_{11}]$

Therefore, order= 1

Q For a pseudo first-order reaction, what is the unit of the rate of the reaction?

(a) s^{-1}
(b) mol $L^{-1}s^{-1}$
(c) mol^{-1} L s^{-1}
(d) mol^{-2} L^2 s^{-1}

CHEMICAL KINETICS

06

▪ ELEMENTARY & COMPLEX REACTIONS

- Reactions occurring only in one step are called elementary reactions while that involving a sequence of elementary reactions, are called complex reactions.
- In case of complex reactions, the slowest step is called rate determining step.

Note Consider the reaction

$2O_3 \longrightarrow 3O_2$

Step - 1

$O_3 \rightleftharpoons O_2 + O$ (fast)

Step - 2

$O + O_3 \longrightarrow 2O_2$ (slow)

From slow step

$r = k\,[O]\,[O_3]$

Here

$[O] \propto \frac{[O_3]}{[O_2]}$; From fast step

$r = k\,[O_3]^2\,[O_2]^{-1}$

Q Suppose the reaction: $A + 2B \longrightarrow AB_2$ occurs by the following mechanism:

Step 1 : $A + B \longrightarrow AB$ slow
Step 2 : $AB + B \longrightarrow AB_2$ fast
Overall $A + 2B \longrightarrow AB_2$

(a) k[A] (b) k[B] (c) k[A][B] (d) $k[B]^2$

07

▪ INTEGRATED RATE EQUATIONS

Zero order

$$k = \frac{[A]_0 - [A]_t}{t}$$

First order

$$k = \frac{2.303}{t}\log\frac{[A]_0}{[A]_t}$$

Second order

$$k = \frac{1}{t}\left[\frac{1}{[A]_t} - \frac{1}{[A]_0}\right]$$

Q A first order reaction has a specific reaction rate of 10^{-2} sec^{-1} . How much time will it take for 20 g of the reactant to reduce to 5 g?

(a) 138.6 sec (b) 346.5 sec

(c) 693.0 sec (d) 238.6 sec

08

▪ HALF LIFE PERIOD

Zero order

$$t_{\frac{1}{2}} = \frac{[A]_0}{2k}$$

First order

$$t_{\frac{1}{2}} = \frac{0.693}{k}$$

Second order

$$t_{\frac{1}{2}} = \frac{1}{k\,[A]_0}$$

FIRST ORDER TRICKS

$$t_{75\%} = 2t_{\frac{1}{2}}$$

$$t_{90\%} = \frac{2.303}{k}$$

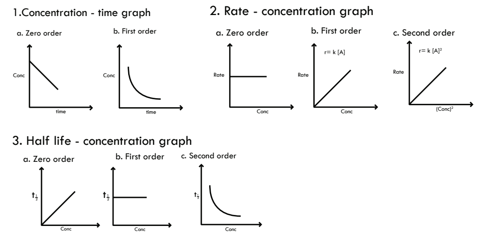
$$t_{99.9\%} = 10t_{\frac{1}{2}}$$

Q The half-life period of zero order reaction is directly proportional to the ____________

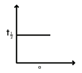
a) Rate constant
b) Initial concentration of reactants
c) Final concentration of reactants
d) Concentration of products

09

▪ GRAPHICAL REPRESENTATION



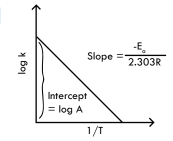
Q The graph of $t_{\frac{1}{2}}$ versus initial concentration 'a' is for



a) First order
b) Second order
c) Zero order
d) Can't predict

10

▪ ARRHENIUS EQUATION



$\boxed{k = Ae^{-Ea/RT}}$

$\boxed{\log k = \log A - \frac{E_a}{2.303R}\left(\frac{1}{T}\right)}$

NOTE

- For every 10° rise in temperature, rate becomes double and hence, rate constant becomes double.
- A reaction with higher value of E_a will have smaller value of rate constant.

Q The slope of Arrhenius plot (ln k vs $\frac{1}{T}$) of first order reaction is - 5 x 10^3 K. The value of E_a of the reaction is [Given: R=8.314 J K^{-1} mol^{-1})

(a) -83 kJ mol^{-1} (b) 41.5 kJ mol^{-1}

(c) 83 kJ mol^{-1} (d) 166 kJ mol^{-1}

LAWS OF MOTION

INERTIA

A body cannot change its state of rest or uniform motion along a straight line. This property is called inertia. Inertia has no unit and no dimension.

INERTIA
- Inertia of Rest
- Inertia of Motion
- Inertia of Direction

- Inertia of Rest

Inability to change state of rest by itself.

- Inertia of Motion

Inability of a body to change its state of uniform motion by itself.

- Inertia of Direction

Inability of a body to change direction of motion by itself.

Newton's Second Law

F_{net} = Rate of change of linear momentum.

Instantaneous

$$\vec{F} = \frac{d\vec{p}}{dt}$$

Average

$$\vec{F}_{av} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\vec{p}_f - \vec{p}_i}{\Delta t}$$

MOMENTUM

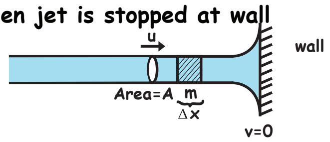
$$\vec{P} = m\vec{v}$$

-It is a vector quantity having direction same as that of velocity

-Unit is kg m/s.

LIQUID JETS

When jet is stopped at wall

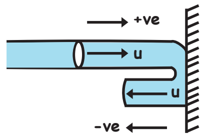


$$F_{jet} = \frac{P_f - P_i}{\Delta t} = \frac{m\times 0 - mu}{\Delta t}$$

$$= \frac{-mu}{\Delta t} = -\rho A u^2 \left(m = \rho A \Delta x, \frac{\Delta x}{\Delta t} = u\right)$$

$$F_{wall} = \rho A u^2$$

When liquid jet bounce back

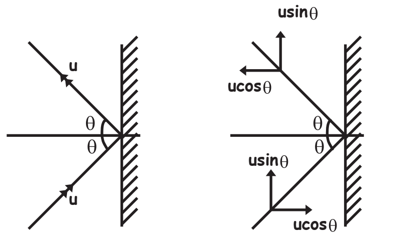


$$F_{jet} = \frac{P_f - P_i}{\Delta t} = \frac{-2mu}{\Delta t}$$

$$F_{jet} = -2\rho A u^2$$

$$F_{wall} = 2\rho A u^2$$

When liquid jet strikes obliquely



$F_{jet} = -2\rho A u^2 \cos\theta$ $F_{wall} = 2\rho A u^2 \cos\theta$

Change in momentum=-2mu cos θ

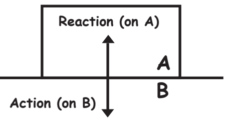
NEWTON'S THIRD LAW

-To every action, there is always an equal (in magnitude) and opposite (in direction) reaction.
- Forces in nature always occur in pairs.
- A single isolated force is not possible.
- Counter force experienced by a body- reaction
- Action and reaction never act on the same body

* Force exerted on body A by body B (action)

* force exerted on body B by body A (reaction)

$$\boxed{\vec{F}_{Action} = -\vec{F}_{Reaction}}$$

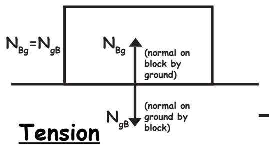


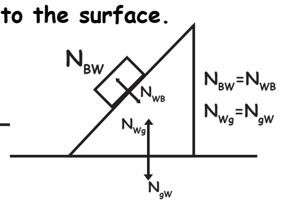
Some common forces

1.Normal Reaction

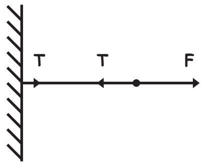
- Occurs when two surfaces are in contact with each other

Always perpendicular to the surface.



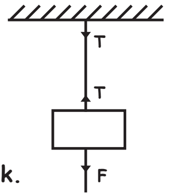


Tension



Restoring force developed when a longitudnal force is applied on a body

Ideal Rope



*Massless

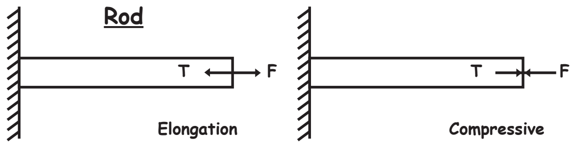
*Tension is same everywhere

*Opposes only elongation

*On compression it becomes slack.

*Tension always acts away from the object.

Rod



can support both elongation and compression

SINGLE BLOCK

Horizontal Force

Acceleration is along x-axis only

Along y-axis $a_y=0$,

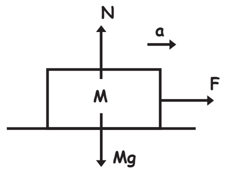
$N - Mg = Ma_y$

$\because a_y=0$

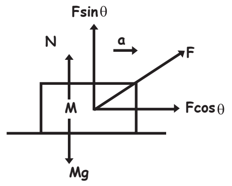
$N = Mg$

Along x-axis

$F - 0 = Ma$ $a = \frac{F}{M}$



Inclined Forces



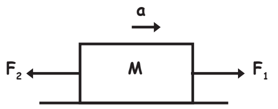
- If, Fsinθ <Mg block remains in contact with ground & accelerates horizontally
- If, Fsinθ =Mg block just leaves contact with ground
- If, Fsinθ >Mg the block leaves contact with ground and it begins to accelerate obliquily.

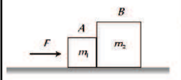
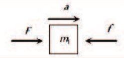
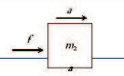
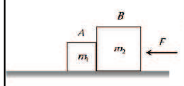
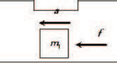
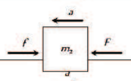
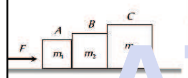
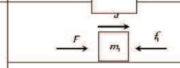
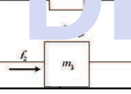
MOTION OF CONNECTED BODIES

$F_1 > F_2$

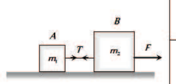
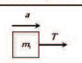
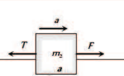
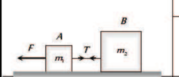
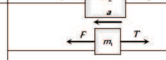
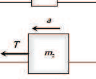
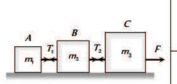
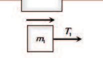
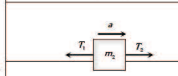
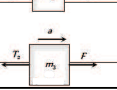
$F_1 - F_2 = Ma$

$a = \frac{F_1 - F_2}{M}$



Condition	Free body diagram	Equation	Force and acceleration
		$F - f = m_1 a$	$a = \frac{F}{m_1 + m_2}$
		$f = m_2 a$	$f = \frac{m_2 F}{m_1 + m_2}$
		$f = m_1 a$	$a = \frac{F}{m_1 + m_2}$
		$F - f = m_2 a$	$f = \frac{m_1 F}{m_1 + m_2}$
 here, f, f_1 and f_2 are normal reactions between blocks		$F - f_1 = m_1 a$	$a = \frac{F}{m_1 + m_2 + m_3}$
		$f_1 - f_2 = m_2 a$	$f_1 = \frac{(m_2 + m_3)F}{m_1 + m_2 + m_3}$
		$f_2 = m_3 a$	$f_2 = \frac{m_3 F}{m_1 + m_2 + m_3}$

MOTION OF BLOCKS CONNECTED BY MASSLESS STRING

Condition	Free body diagram	Equation	Tension and acceleration
		$T = m_1 a$	$a = \frac{F}{m_1 + m_2}$
		$F - T = m_2 a$	$T = \frac{m_1 F}{m_1 + m_2}$
		$F - T = m_1 a$	$a = \frac{F}{m_1 + m_2}$
		$T = m_2 a$	$T = \frac{m_2 F}{m_1 + m_2}$
		$T_1 = m_1 a$	$a = \frac{F}{m_1 + m_2 + m_3}$
		$T_2 - T_1 = m_2 a$	$T_1 = \frac{m_1 F}{m_1 + m_2 + m_3}$
		$F - T_2 = m_3 a$	$T_2 = \frac{(m_1 + m_2)F}{m_1 + m_2 + m_3}$

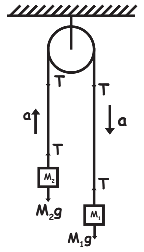
PULLEY-BLOCK SYSTEM

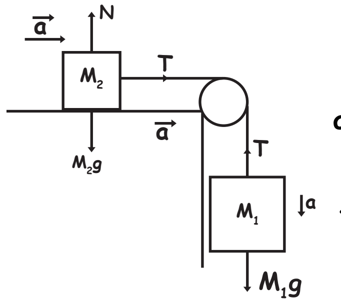
Ideal pulley

$M_1 > M_2$

$$a = \frac{F}{M} = \frac{M_1 - M_2}{M_1 + M_2} g$$

$$T = \frac{2M_1M_2}{M_1 + M_2} g$$

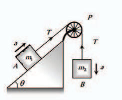
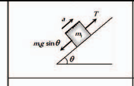
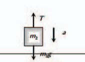
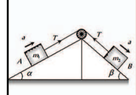
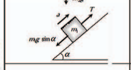
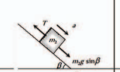
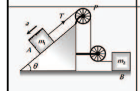
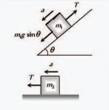




$$a = \frac{M_1 g}{M_1 + M_2}$$

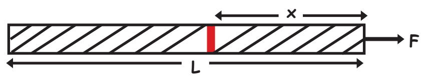
$$T = \frac{M_1M_2}{M_1 + M_2} g$$

INCLINED PLANE + PULLEY

		$m_1 a = T - m_1 g \sin\theta$	$a = \left[\frac{m_2 - m_1 \sin\theta}{m_1 + m_2}\right] g$
		$m_2 a = m_2 g - T$	$T = \frac{m_1 m_2 (1 + \sin\theta)}{m_1 + m_2} g$
		$T - m_1 g \sin\alpha = m_1 a$	$a = \frac{(m_2 \sin\beta - m_1 \sin\alpha)}{m_1 + m_2} g$
		$m_2 a = m_2 g \sin\beta - T$	$T = \frac{m_1 m_2 (\sin\alpha + \sin\beta)}{m_1 + m_2} g$
		$m_1 g \sin\theta - T = m_1 a$ $T = m_2 a$	$a = \frac{m_1 g \sin\theta}{m_1 + m_2}$ $T = \frac{m_1 m_2 \sin\theta g}{m_1 + m_2}$

THICK ROPE

Tension will be different at different points.



Mass per unit length$=\frac{M}{L}$

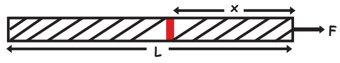
Mass of x length of rope $= \frac{M}{L} x$

Note :

Mass of given length$= \frac{\text{total mass}}{\text{total length}} \times$ given length

$\frac{\text{mass}}{\text{length}}$ = constant

$a_{rope} = \frac{F}{M}$



$\frac{M}{L}(L-x) = m_2$ $\frac{M}{L} x = m_1$

For(L-x) rope length,

$\vec{F} = m\vec{a} \Rightarrow T = m_2 \frac{F}{M}$

LIFT PROBLEMS

Apparent weight of body in a lift

Reading of weighing machine = reaction force exerted b weighing machine

Apparent weight ,$(W_{apparent})$ = Reaction force (R)

Case 1: Lift is at rest

$R = mg$, $W_{apparent} = W_{actual} = mg$

Case 2: Lift moving up or down with constant velocity

$R = mg$, $W_{apparent} = W_{actual} = mg$

Case 3: Accelerated upward at a rate of 'a'

$R - mg = ma \Rightarrow R = m(g+a) = W_{app}$

$W_{apparent} > W_{actual}$ → Feels over weight

Accelerated upward at a rate of 'g'

$R - mg = mg$, $R = 2mg$, $W_{app} = 2 \times W_{act}$

Case 4: Accelerated downward at a rate of 'a'

$mg - R = ma$, $R = m(g-a) = W_{app}$, $W_{app} < W_{act}$

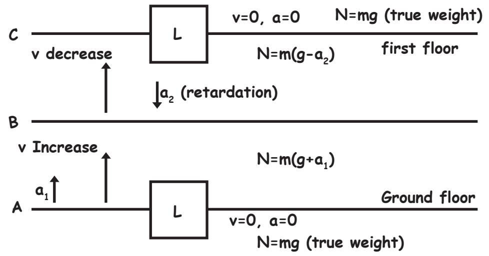
Accelerated downward at a rate of 'g' [Freefall]

$mg - R = mg$, $R = mg - mg = 0$, $W_{app} = 0$

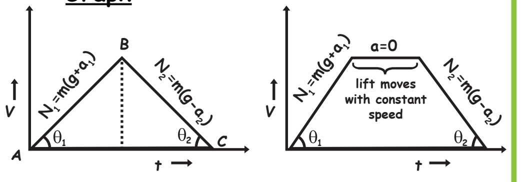
If $a > g$:

body leaves contact from ground and begins free-fall

Lift moves from ground floor to first floor



Graph



Acceleration, $a_1 = \tan\theta_1$

Retardation, $a_2 = \tan\theta_2$

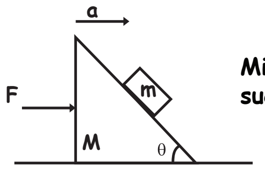
FRAME OF REFERENCE & PSEUDO FORCE

Frame of Reference

A frame in which observer is situated and makes his observation

Inertial frame of reference	Non-Inertial frame of reference
At rest or moving with uniform velocity along straight line. i.e unaccelerated	Accelerated frame of reference.
Newton's law of motion hold's $\vec{F}_{net} = m\vec{a}$	Newton's law of motion not applicable. $\vec{F}_{net} + \vec{F}_{pseudo} = m\vec{a}$ $\vec{F}_{pseudo} = -m\vec{a}_o$

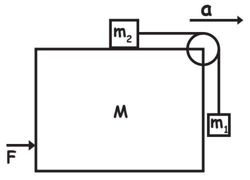
RELATIVE SLIPPING



Minimum force required to push the inclined plane such that “m” does not slip with respect to “M”

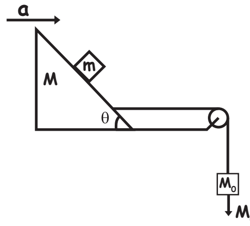
$F = (m+M)\,g\tan\theta \quad , \quad a = g\tan\theta$

Minimum acceleration of “M” such that there is no relative slipping.



$a = \left(\frac{m_1}{m_2}\right)g$

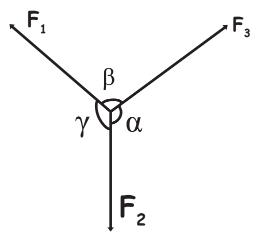
Minimum mass M_o such that there is no relative slipping



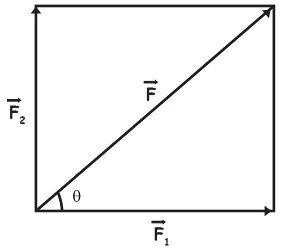
$M_o = \frac{M+m}{\cot\theta - 1}$

EQUILLIBRIUM & LAMI’S THEOREM

$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$



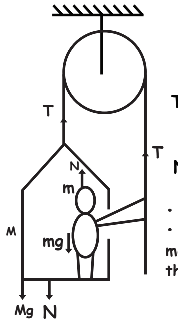
PARALLELOGRAM LAW



$\vec{F} = \vec{F_1} + \vec{F_2}\ ,\ F = \sqrt{F_1^2 + F_2^2}\ ,\ \tan\theta = \frac{F_2}{F_1}$

MAN-CAGE PROBLEM

Man holds the cage stationary



$T = \left(\frac{m+M}{2}\right)g$

$N = \left(\frac{m-M}{2}\right)g$

- m<M
- if m>M

man cannot hold the cage stationary

IMPULSE

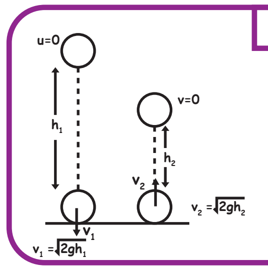
If a large force acting for short period of time, there will be a sudden change in momentum

$\vec{F}_{imp} = \frac{d\vec{p}}{dt}$

$\vec{P}_f - \vec{P}_i = \int_{0}^{t} \vec{F}_{imp}\, dt$ = area under F-t graph

$\vec{I}$ = Impulse $= \vec{P}_f - \vec{P}_i = \int_0^t \vec{F}_{imp}\, dt$ = area of F-t graph

Case-1



Impulse

$I = P_f - P_i$

$= mV_2 - (-mV_1)$

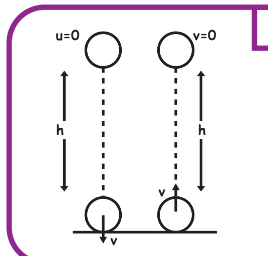
$I = m\,(V_1 + V_2)$

Average impulsive force

$F_{avg} = \frac{\text{impulse}}{t_o} = \frac{\Delta P}{t_o}$

$= \frac{m(v_1+v_2)}{t_o}$

Case-2



Impulse

$m(v+v) = J$

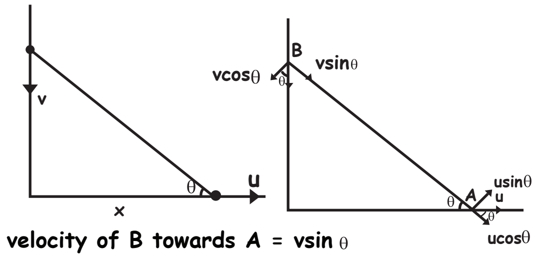
$= m(2v)$

$J = 2mv$

Average impulsive force

$F_{avg} = \frac{\Delta P}{\Delta t} = \frac{2mv}{t_o}$

ROD SLIDING ON A WALL



velocity of B towards A = vsinθ

velocity of A away from B = ucosθ

these velocities should be equal,

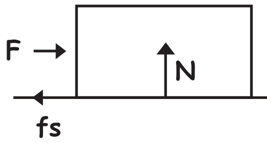
$\Rightarrow v\sin\theta = u\cos\theta$

$\Rightarrow \quad v = u\cot\theta$

FRICTION

Static friction

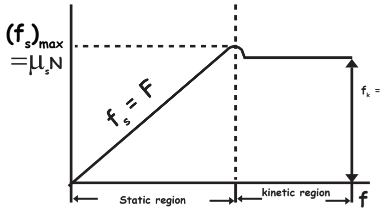
- It is a self adjusting force.
- The opposing force that comes into play, when object tends to slip over the surface of other object, but slipping has not yet started.
- As applied force increases static friction also increases.
- The body doesn’t move until a maximum value of static friction is attained
- This value is called limiting friction or $(f_s)_{max}$



$(f_s)_{max} = \mu_s N$

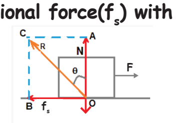
Kinetic friction

If the applied force is increased further and slipping between surfaces start, the friction opposing force is called kinetic friction.



ANGLE OF FRICTION

Angle(θ) made by resultant of normal (N) & frictional force(f_s) with normal



$R = \sqrt{N^2 + f_s^2}$ R is resultant

$\tan\theta = \frac{f_s}{N}$

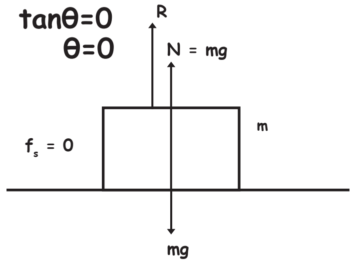
When $f_s = (f_s)_{max}$ $R = N\sqrt{1+\mu_s^2}$

$\tan\theta = \mu_s$, μ_s is Coefficient of friction

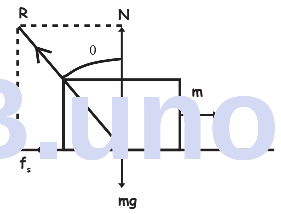
i) $f = 0$

$\tan\theta = 0$

$\theta = 0$



ii) $0 < f_s < (f_s)_{max}$

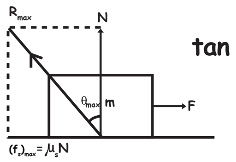


$0 \leq \tan\theta \leq \mu_s$

$N < R < N\sqrt{1+\mu_s^2}$

iii) $f_s = (f_s)_{max}$

$R_{max} = N\sqrt{1+\mu_s}$

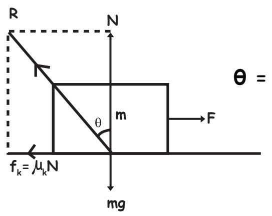


$\tan\theta_{max} = \mu_s$

iv) When slipping has started,

$f = f_k$

$R_{max} = N\sqrt{1+\mu_k^2}$



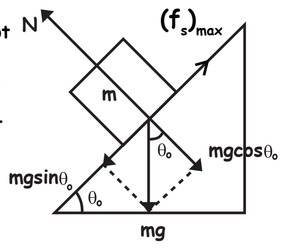
θ = Angle of kinetic friction

ANGLE OF REPOSE

Angle made by inclined plane such that a block kept on it just begins to slide

Depends only on μ_s and is independent of mass.

$\tan\theta_0 = \mu_s$



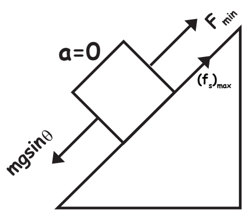
Variation of R

As angle of inclined plane increases, R remains constant (=mg) and when sliding starts R starts decreasing.

Variation of angle of friction.

As angle of inclined plane increases, angle of friction will also increase and as sliding starts its value becomes constant and $\tan\theta = \mu_k$

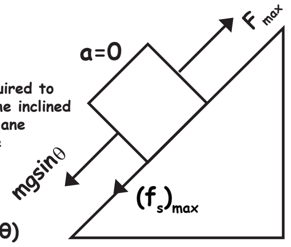
Minimum & Maximum force (applied parallel to inclined plane)



$F_{min} = mg\,(\sin\theta - \mu_s\cos\theta)$

F_{min} is the minimum force required to keep the block stationary if the angle of inclined plane is greater than angle of repose

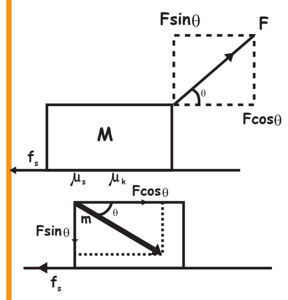
F_{max} is the maximum force required to keep the block stationary on the inclined plane if the angle of inclined plane is greater than angle of repose



$F_{max} = mg\,(\sin\theta + \mu_s\cos\theta)$

$mg(\sin\theta - \mu_s\cos\theta) \leq F \leq mg\,(\sin\theta + \mu_s\cos\theta)$

PULLING FORCE & PUSHING FORCE



$F\cos\theta \geq \mu_s(mg - F\sin\theta)$

$F \geq \frac{\mu_s mg}{\cos\theta + \mu_s\sin\theta}$

$F_{pulling} = \frac{\mu_s mg}{\cos\theta + \mu_s\sin\theta}$

$F\cos\theta \geq \mu_s(mg + F\sin\theta)$

$F \geq \frac{\mu_s mg}{\cos\theta - \mu_s\sin\theta}$

$F_{pushing} = \frac{\mu_s mg}{\cos\theta - \mu_s\sin\theta}$

$$\boxed{F_{pushing} > F_{pulling}}$$

HORIZONTAL TRUCK BOX

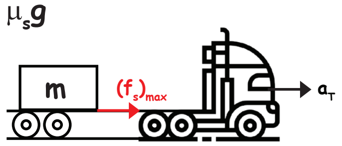
Case-1

Box does not slip.

$f_s \leq \mu_s N$

$\Rightarrow ma_T \leq \mu_s mg$

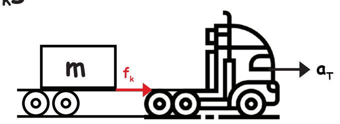
$\Rightarrow a_T \leq \mu_s g$



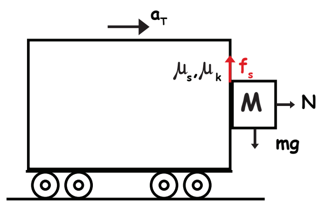
Case-2

Box slips

$a_T \geq \mu_k g$



VERTICAL TRUCK BOX



Case-1

Box does not slip.

$f_s \leq \mu_s N$

$\Rightarrow mg \leq \mu_s ma_T$

$\Rightarrow \mu_s \geq \frac{g}{a_T}$

Case-2

Box slips

$\mu_k \leq \frac{g}{a_T}$

LAWS OF MOTION

NEWTON'S LAW OF GRAVITATION

$$F = \frac{Gm_1m_2}{r^2}$$

G - Universal gravitational constant

Value of G

$6.67\times10^{-11}\ Nm^2Kg^{-2}$ (SI or MKS)

6.67×10^{-8} dyne cm^2g^{-2} (CGS)

Dimensional formula [G]

$M^{-1}L^3T^{-2}$

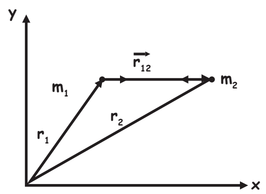
IMPORTANT POINTS ABOUT GRAVITATIONAL FORCE

1. Gravitational force
* Always attractive in nature
* Independent of the nature of medium between masses
* Independent of presence or absence of other bodies

2. Are central forces, acts along the centre of gravity of two bodies.
3. Conservative force
4. Force between any two masses - Gravitational force

Force between earth and any other body - Force of gravity

VECTOR FORM



$\vec{F}_{21}$ force on 2 due to 1

$\vec{r}_{12}$ vector from m_1 to m_2

$$\vec{F}_{21} = \frac{G\,m_1m_2}{r_{12}^{\ 2}}\left(-\hat{r}_{12}\right) \text{ or } -\frac{G\,m_1m_2}{r_{12}^{\ 3}}\vec{r}_{12}$$

Similarly

$\vec{F}_{12}$ force on 1 due to 2

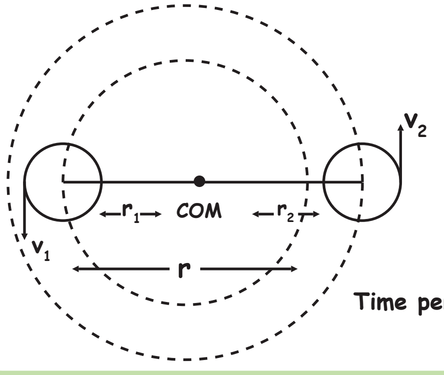
$$\vec{F}_{21} = \frac{G\,m_1m_2}{r_{12}^{\ 2}}\left(\hat{r}_{12}\right) \text{ or } \frac{G\,m_1m_2}{r_{12}^{\ 3}}\vec{r}_{12}$$

Clearly

Newtons third law $\vec{F}_{21} = -\vec{F}_{12}$

Gravitational force is a two body interaction. Force between two particles does not depend on the presence or absence of other particles. The principle of superposition is valid here. "Force on a particle due to a no. of particles is the resultant of forces due to individual particles."

ROTATION OF 2 MASSES UNDER MUTUAL GRAVITATIONAL FORCE OF ATTRACTION



$$V_1 = \sqrt{\frac{Gm_2^{\ 2}}{(m_1+m_2)\,r}}$$

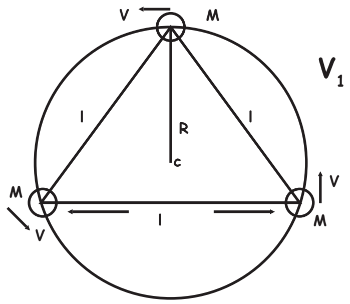
$$V_2 = \sqrt{\frac{Gm_1^{\ 2}}{(m_1+m_2)\,r}}$$

$$T^2 = 4\pi^2\frac{r^3}{G(m_1+m_2)}$$

Time period

or $\boxed{T^2 \propto r^3}$

THREE MASSES(EQUAL) REVOLVING UNDER MUTUAL GRAVITATIONAL FORCE

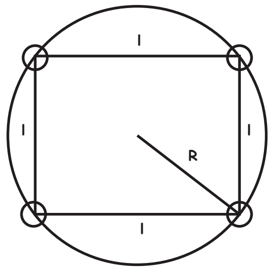


$$V_1 = \sqrt{\frac{GM}{l}} = \sqrt{\frac{GM}{R\sqrt{3}}}$$

Time period

$T^2 \propto l^3$

FOUR EQUAL MASSES UNDER MUTUAL GRAVITATIONAL FORCE



$$V = \sqrt{\frac{GM}{2\sqrt{2}\,l}(2\sqrt{2}+1)}$$

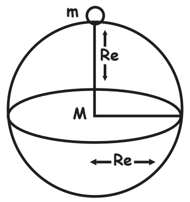
$$V = \frac{1}{2}\sqrt{\frac{GM}{R}(2\sqrt{2}+1)}$$

$T^2 \propto l^3$ Here $R = \frac{l}{\sqrt{2}}$

GRAVITY

Acceleration due to gravity

On the surface of earth $g = \frac{GM_e}{R_e^{\ 2}}$



M - mass of earth

R - Radius of earth

[Put $GM_e = g\,R_e^{\ 2}$ to solve problems easily]

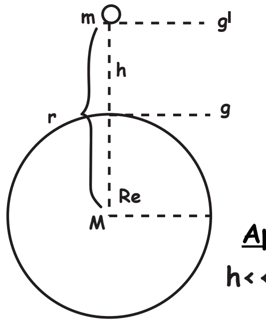
g IN TERMS OF DENSITY OF EARTH

$g = 4\pi G\rho R_e$ $\quad g \propto \rho R_e$

"If density is mentioned use the

VARIATION IN THE VALUE OF ACCELERATION DUE TO GRAVITY

- Variation due to height 'h'



$$g' = \frac{GM}{(R+h)^2}$$

$$g' = \frac{gR^2}{(R+h)^2}$$

General Equation

Approximate equation

h<<<<<<R (h < 100 km)

use, $g' = g\left(1-\frac{2h}{R}\right)$

Note the point

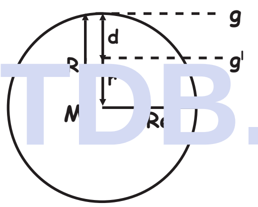
If h<<<<R, then decrease in the value of g with height

Absolute decrease $= \Delta g = g - g' = \frac{2hg}{R}$

Fractional decrease $= \frac{\Delta g}{g} = \frac{g-g'}{g} = \frac{2h}{R}$

Percentage decrease $= \frac{\Delta g}{g} = \frac{g-g'}{g}\times100 = \frac{2h\times100}{R}$

- Variation due to depth 'd'



$$g' = g\left[1-\frac{d}{R}\right]$$

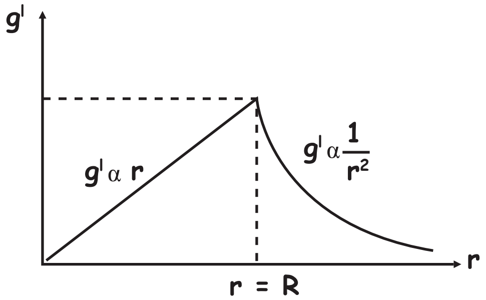
Absolute decrease $= \frac{\Delta g}{g} = g - g' = \frac{dg}{R}$

Fractional decrease $= \frac{\Delta g}{g} = \frac{g-g'}{g} = \frac{d}{R}$

Percentage decrease $= \frac{\Delta g}{g}\times100 = \frac{d}{R}\times100$

Very imp graph

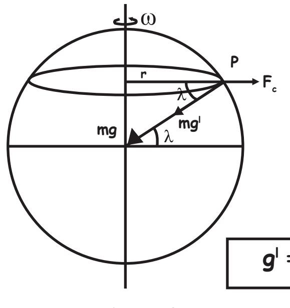
The graphical representation of change in the value of g' with height and depth



for $r \le R$, $g' = \frac{gr}{R}$ $\quad$ for $r \le R$, $g' = \frac{gR^2}{r^2}$

GRAVITATION

- Variation of g due to rotation of earth



Latitude -

Angle which the line joining the point to the centre of earth makes with the equatorial plane

$$\boxed{g' = g - \omega^2R\cos^2\lambda}$$

Note ⇒ value of $\omega^2R = 0.034$

For poles $\lambda = 90°$ $\quad g' = g$

There is no effect of rotational motion of the earth on the value of g at poles.

For equator $\lambda = 0°$ $\quad g' = g - \omega^2R$

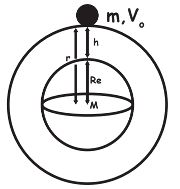
The effect of rotational motion of the earth on the value of g at the equator is maximum.

When a body of mass m is moved from equator to the poles, weight increases by an amount

$m(g_p - g_e) = m\omega^2R$

ORBITAL VELOCITY

Orbit at a height 'h' from the surface



$$V_o = \sqrt{\frac{GM}{(R+H)}} = \sqrt{\frac{gR^2}{(R+H)}}$$

$$V_o = \sqrt{\frac{GM}{R}} = \sqrt{gR}$$

If orbit is closer to earth's surface(neglect 'h') $V_o = \sqrt{\frac{GM}{R}} = \sqrt{gR}$

(called minimum orbit, velocity-first cosmic velocity)

Note - for easy calculations

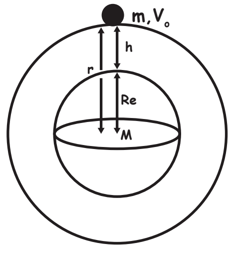
$\sqrt{gR} = 8$ km/s or $\sqrt{\frac{GM}{R}} = 8$ km/s $= 8\times10^3$ m/s

or $\frac{GM}{R} = 64\times10^6$

KE, PE OR TE FOR AN ORBITING SATELLITE

$KE = \frac{GMm}{2r}$ $\quad U = -\frac{GMm}{r}$

$TE = -\frac{GMm}{2r}$

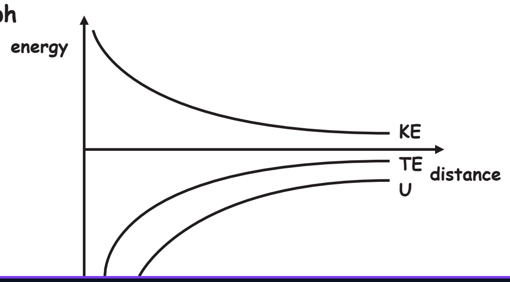


Relation KE, U & TE

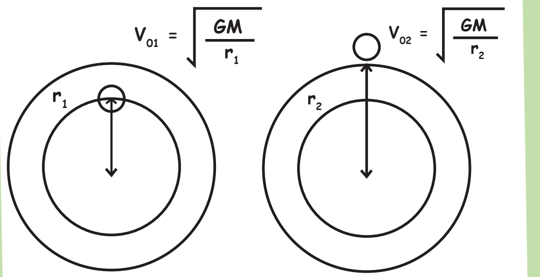
U = 2 x T.E

K.E = - T.E

Graph



WORK DONE IN MOVING OBJECT FROM ONE ORBIT TO ANOTHER

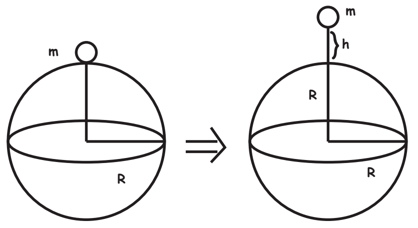


$$V_{01} = \sqrt{\frac{GM}{r_1}} \qquad V_{02} = \sqrt{\frac{GM}{r_2}}$$

CONCEPT - WORK DONE BY EXTERNAL AGENT = CHANGE IN MECHANICAL ENERGY

$$W = E_2 - E_1 = \frac{GMm}{2}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

WORK DONE IN MOVING OBJECT FROM SURFACE OF EARTH TO HEIGHT h ABOVE SURFACE



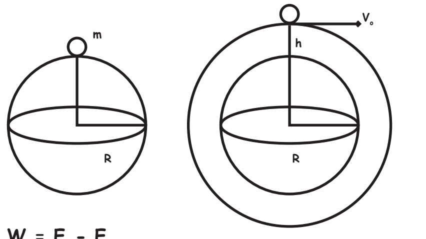
$$W = (U_f - U_i) = \frac{-GMm}{R} - \left[\frac{-GMm}{R+h}\right]$$

Or, $\boxed{W = mgh\frac{R}{R+h}}$

Work done to move object to a height h = R $\quad \boxed{W = \frac{mgR}{2}}$

Work done to move object to a height h = R/2 $\quad \boxed{W = \frac{mgR}{3}}$

WORK DONE IN MOVING OBJECT FROM SURFACE TO CIRCULAR ORBIT



$W = E_f - E_i$

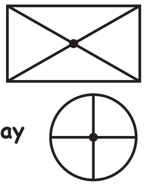
$W = E_{total} - U_i$

$$W = \frac{-GMm}{2(R+h)} + \frac{GMm}{R}$$

PHYSICS

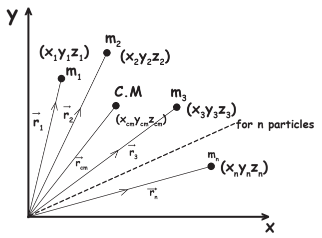
Centre of Mass

- Avg. position of all the parts of the system, weighted according to their mass
- For homogeneous objects, centre of mass lies at their geometric centre
- Centre of mass may or may not lie inside the object



Centre of Mass For System of n Particles

$$\vec{r}_{cm} = \frac{\Sigma m\vec{r}}{\Sigma m}$$



General Equation

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3 + \text{-----} m_n\vec{r}_n}{m_1 + m_2 + m_3 + \text{------} + m_n}$$

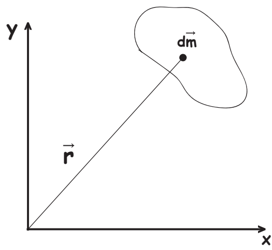
In terms of Cartesian co-ordinates

$$x_{cm} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \text{-----} m_nx_n}{m_1 + m_2 + m_3 + \text{------} + m_n}$$

$$y_{cm} = \frac{m_1y_1 + m_2y_2 + m_3y_3 + \text{-----} m_ny_n}{m_1 + m_2 + m_3 + \text{------} + m_n}$$

$$z_{cm} = \frac{m_1z_1 + m_2z_2 + m_3z_3 + \text{-----} m_nz_n}{m_1 + m_2 + m_3 + \text{------} + m_n}$$

Centre Of Mass For Continuous Body



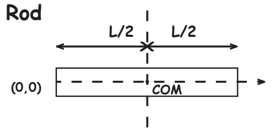
$$\vec{r}_{cm} = \frac{\int dm.\vec{r}}{\int dm}$$

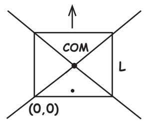
λ= mass per unit length
σ= mass per unit area
ρ= mass per unit volume

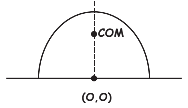
1) Mass distributed over length ⇒ $dm=\lambda\, dl$
2) Mass distributed over area ⇒ $dm=\sigma\, dA$
3) Mass distributed over volume ⇒ $dm= \rho dV$

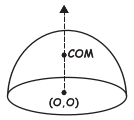
Centre of mass for various shapes

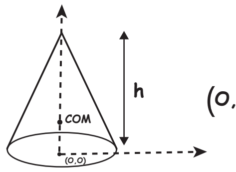
Uniformly distributed mass	centre of mass
1) Rod	$\left(\frac{L}{2},0\right)$
2) Square Lamina	$\left(\frac{L}{2},\frac{L}{2}\right)$
3) Semicircular Ring	$\left(0,\frac{2R}{\pi}\right)$
4) Hemispherical shell	$\left(0,\frac{R}{2}\right)$
5) Solid circular cone	$\left(0,\frac{h}{4}\right)$
6) Solid hemisphere	$\left(0,\frac{3R}{8}\right)$

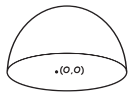






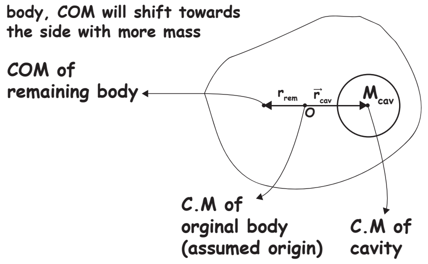






Cavity in object

If some mass is removed from a body, COM will shift towards the side with more mass



Assuming COM of original body is at the origin

$$\vec{r}_{rem} = \frac{-M_{cav} \times \vec{r}_{cav}}{M_{rem}}$$

Motion of centre of mass

velocity of centre of mass

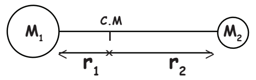
$$\vec{V}_{cm} = \frac{M_1\vec{V}_1 + M_2\vec{V}_2 + M_3\vec{V}_3 + \text{--}}{M_1+M_2+M_3+\text{------}}$$

Acceleration of centre of mass

$$\vec{a}_{cm} = \frac{M_1\vec{a}_1 + M_2\vec{a}_2 + M_3\vec{a}_3 + \text{--}}{M_1+M_2+M_3+M_4\text{------}}$$

Isolated System

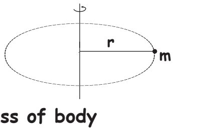
- No net external force acting on the system
- bodies within the system can have mutual force between then



$M_1r_1=M_2r_2$ $a_{cm}=0, v_{cm}=\text{constant}$

Moment of Inertia (for a point object)

$I=mr^2$

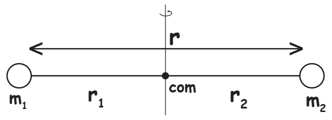


m= Mass of body
r= Perpendicular distance of the bodyfrom the axis of rotation

Moment of Inertia
- Tensor Quantity
- $I=mr^2$
- Rotational analogous of mass

Two Point Masses

$$I_{COM}= m_1r^2_1 + m_2r^2_2$$



$$r_1 = \frac{m_2r}{m_1+m_2}, \quad r_2 = \frac{m_1r}{m_1+m_2}$$

$$I_{com} = m_{red}\, r^2, \quad m_{red} = \frac{m_1m_2}{m_1+m_2}$$

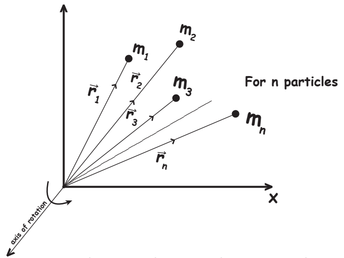
Factors Affecting Moment of Inertia

- Mass of the body
- Axis of rotation
- Mass distribution

ROTATIONAL MOTION 01

Moment of Inertia

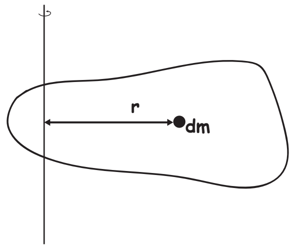
i) for discrete system of particles



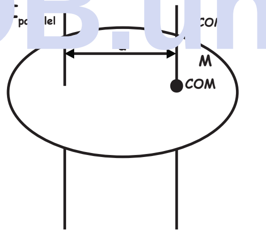
$$I = \frac{m_1r_1^2 + m_2r_2^2 + m_3r_3^2+\text{---}m_nr_n^2}{m_1+m_2+m_3+\text{------}m_n}$$

ii) for continuous body

$$I = \int dI = \int r^2dm$$



Parallel Axis Theorm



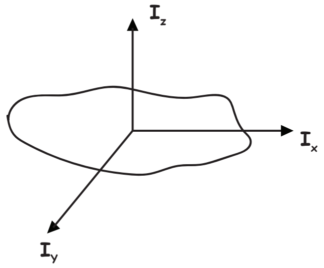
$$I_{parallel}=I_{COM}+Ma^2$$

Conditions:-
1) the two axes must be parallel to each other
2) One of the axis must pass through centre of mass

Perpendicular axis theorem

$I_z=I_x + I_y$ (Only valid for laminar bodies)

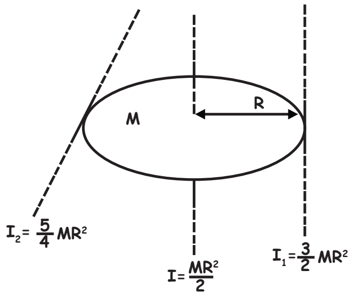
Note:-
X and Y axis must lie in the plane of body
Z- axis must be ⊥ to the plane of the body
Axes need not pass through center of mass



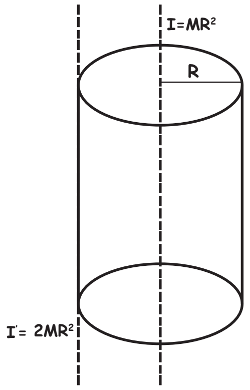
PHYSICS WALLAH

Moment Of Inertia For Various Objects

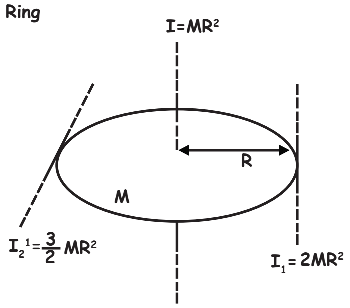
Disc



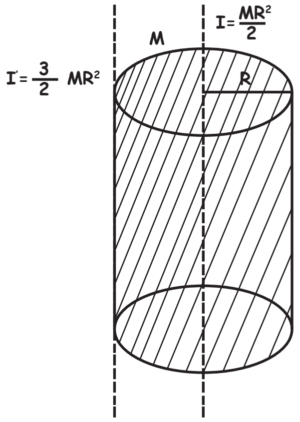
Hollow cylinder



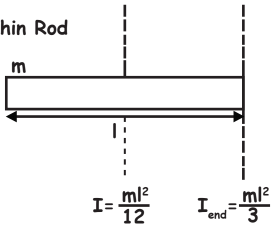
Ring



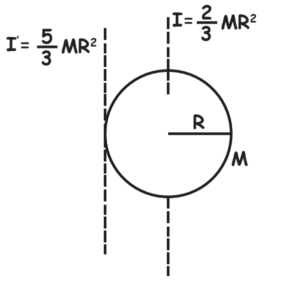
Solid cylinder



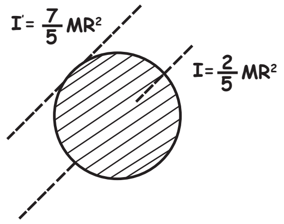
Thin Rod



Hollow sphere

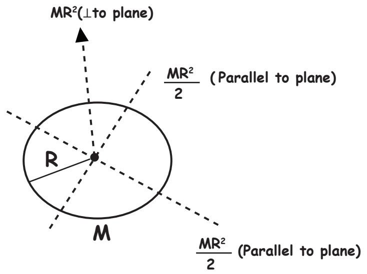


Solid sphere

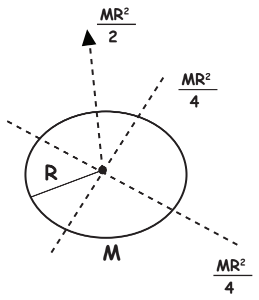


Moment of Inertia along the centre of mass and perpendicular to the plane surface

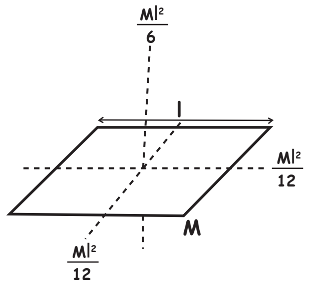
1) Ring



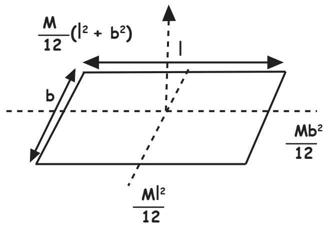
2) Disc



3) Square sheet

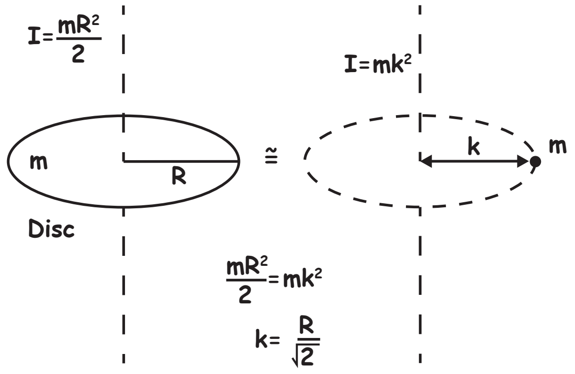


4) Rectangular sheet



Radius of Gyration

Definition: The distance of a point mass from the axis whose mass is equal to the mass of whole body and whose moment of inertia is equal to moment of inertia of the body about that axis



$I=\frac{mR^2}{2}$

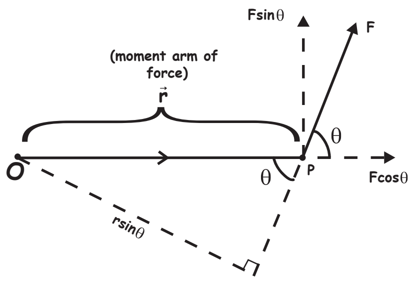
$I=mk^2$

$\frac{mR^2}{2}=mk^2$

$k=\frac{R}{\sqrt{2}}$

k is the radius of gyration

Torque



Torque $\tau_O = r\,F\sin\theta$

$= F\sin\theta \times r = F_\perp r$ (1)

$= F \times r\sin\theta = F\,r_\perp$ (2)

$\vec{\tau}_O = \vec{r} \times \vec{F}$ (Vector form)

If force is radial i.e. $\theta = 0°$ or $180°$

Torque $\tau = 0$

If force is tangential and ⊥ to radius vector i.e. $\theta = 90°$

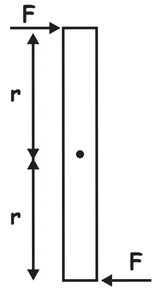
Torque, $\tau = \tau_{max} = rF$

ROTATIONAL MOTION

02

Equilibrium

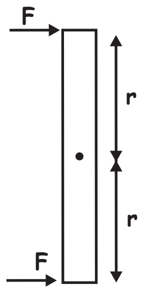
For translational equilibrium



$F_{net} = 0$

τ_{net} may or maynot be zero

Rotational Equilibrium



$\tau_{net} = 0$

F_{net} may or maynot be zero

Static Equilibrium

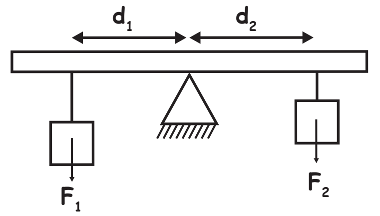
Combination of both translational and rotational equilibrium

$F_{net} = 0 \Rightarrow$ Forces are balanced

$\tau_{net} = 0 \Rightarrow \tau_{clockwise} = \tau_{anticlockwise}$

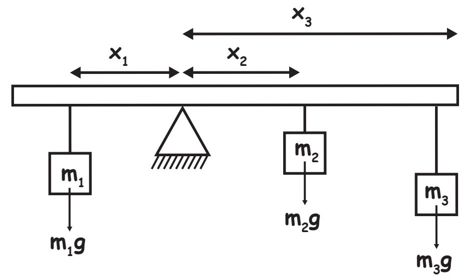
Principle of moments

When a body is in rotational equilibrium sum of clock wise moments about any point is equal to sum of anticlockwise moments about that point

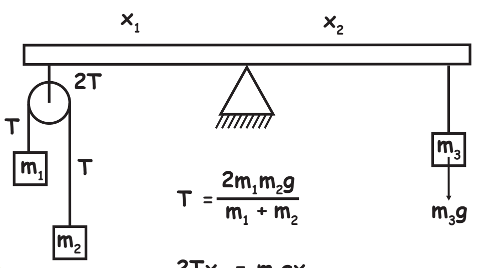


$F_1 \times d_1 = F_2 \times d_2$

Load × load arm = Effort × effort arm



$m_1gx_1 = m_2gx_2 + m_3gx_3$



$T = \frac{2m_1m_2g}{m_1+m_2}$

$2Tx_1 = m_3gx_2$

Angular acceleration

$\tau = I\alpha$

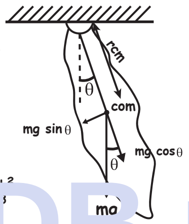
τ - torque

I moment of inertia

α angular acceleration

Initial angular acceleration when a rod is released

Initial angular acceleration when a body is released from an angle θ



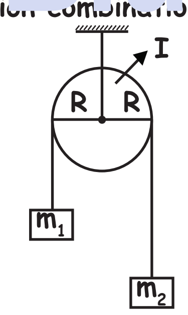
$\tau = I\alpha$

$(mg\sin\theta)\,r_{cm} = I\alpha$

$\alpha = \frac{(mg\sin\theta)r_{cm}}{I}$

For rod $r_{cm} = \frac{L}{2}$

Translation - rotation combination



$\alpha = \frac{\tau_{applied} - \tau_{opposition}}{\text{Total } I}$

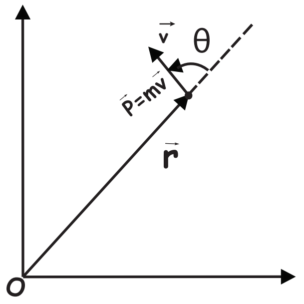
$\alpha = \frac{m_2Rg - m_1Rg}{m_1R^2 + m_2R^2 + I}$

$m_2 > m_1$

Angular momentum & its conservation

Angular momentum of a point mass:-

Angular momentum about origin



$\vec{L}_o = \vec{r} \times \vec{P}$

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

$\vec{P} = m\vec{v}$

1) When $\theta = 0°$ or $180°$

$L_0 = mvr\sin 180° = 0$

OR $mvr\sin 0° = 0$

Angular momentum is minimum

1) When $\theta = 90°$

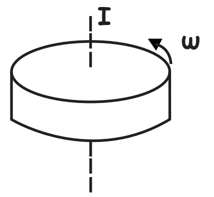
$|\vec{L}| = r\,p\sin\theta$

$= rp\sin 90°$

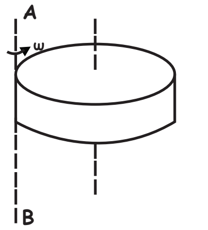
$= rp$

$= L_{max}$

Spin angular momentum



$L_{axis} = I\omega$



$L_{AB} = I_{AB}\omega$

Conservation of Angular momentum

If there is no external torque, angular momentum is conserved

- $\tau = \frac{dL}{dt}$
- If $\tau = 0 \Rightarrow \frac{dL}{dt} = 0$

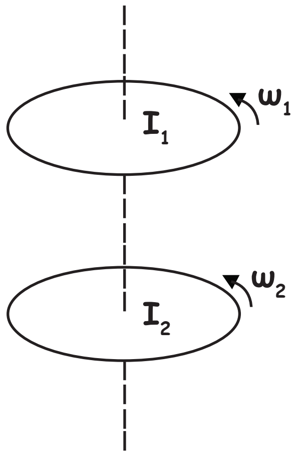
  L=constant

  Iω=constant
- $I_1\omega_1 = I_2\omega_2$
- If moment of inertia increases angular velocity decreases and if moment of inertia decreases angular velocity increases

Moment of inertia when two discs are joined

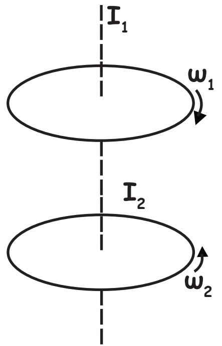
Discs initially rotating in same direction:-

$\omega_f = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$



Discs initially rotating in opposite direction:-

$\omega_f = \frac{I_1\omega_1 - I_2\omega_2}{I_1 + I_2}$



Work, Energy & Power in rotation

1) Work done by a torque,

$W = \tau\theta$ (if torque is uniform)

$= \int \tau\,d\theta$ (if torque is non uniform)

2) K.E for are rotating body $= \frac{1}{2}I\omega^2$

$= \frac{L^2}{2I}$

$= \frac{1}{2}L\omega$

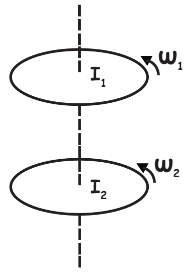
3) Work-Energy theorm

$\Sigma W = \Delta K = \frac{1}{2}I(\omega_2^2 - \omega_1^2)$

Energy loss when 2 discs are joined:-

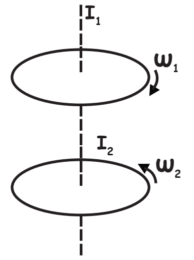
1) Same direction:-

$E_{lost} = \Delta K.E = \frac{I_1I_2}{2[I_1+I_2]}(\omega_1 - \omega_2)^2$

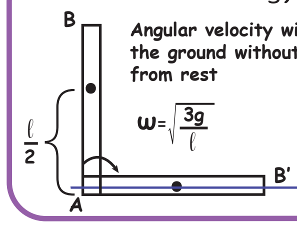


2) Opposite direction:-

$E_{lost} = \Delta K.E = \frac{I_1I_2}{2[I_1+I_2]}(\omega_1 + \omega_2)^2$



Mechanical energy conservation



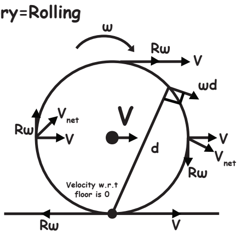
Angular velocity with which the rod hits the ground without slipping, released from rest

$\omega = \sqrt{\frac{3g}{\ell}}$

Rolling Motion

Translatory+Rotatory=Rolling

Velocity in rolling



- Condition for rolling without slipping:- V=Rω
- Velocity of any point on rolling object, V_P

  $= \omega d = \frac{vd}{R}$

d is the distance from point of contact

Energy in rolling motion

1) Translatory Motion

$T_{K.E} = \frac{1}{2}mv^2$

2) Spinning motion/rotational motion

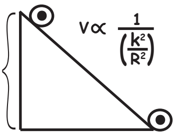
$R_{K.E} = \frac{1}{2}I\omega^2 = \frac{1}{2}mk^2\frac{V^2}{R^2} = \frac{1}{2}mv^2 \times \left(\frac{k^2}{R^2}\right)$

3) Rolling motion

$T_{K.E} + R_{K.E} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 \times \frac{k^2}{R^2} = \frac{1}{2}mv^2\left(1 + \frac{k^2}{R^2}\right)$

$\frac{k_{total}}{k_{trans}} = \left(1 + \frac{k^2}{R^2}\right)$

Motion on an inclined plane



$V \propto \frac{1}{\left(\frac{k^2}{R^2}\right)}$

Velocity at bottom $= \sqrt{\frac{2gh}{1 + \frac{k^2}{R^2}}}$

$v \propto \frac{1}{\sqrt{1 + \frac{k^2}{R^2}}}$

$\frac{k^2}{R^2}\uparrow \Rightarrow V\downarrow \Rightarrow \text{Time}\uparrow$

Velocity: solid sphere>Disc>Hollow>Sphere>Ring

Time to reach bottom: Ring>Hollow sphere >Disc>solid sphere

Value of velocity:-

1) Ring/Hollow cylinder $= \sqrt{gh}$

2) Disc/Solid cylinder $= \sqrt{\frac{4}{3}gh}$

3) Hollow sphere $= \sqrt{\frac{6}{5}gh}$

4) Solid sphere $= \sqrt{\frac{10}{7}gh}$

Acceleration

$a = \frac{g\sin\theta}{1 + \frac{k^2}{R^2}}$ $\qquad a \propto \frac{1}{1 + \frac{k^2}{R^2}}$

Time of descend:-

$t = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}\left(1 + \frac{k^2}{R^2}\right)}$

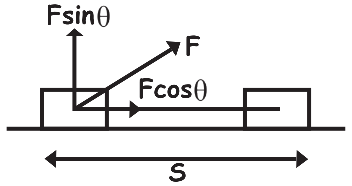
$t \propto \sqrt{1 + \frac{k^2}{R^2}}$

Ring>Hollow sphere>Disc>solid sphere

PHYSICS WALLAH

Work is said to be done when a force applied on the body displaces the body through a certain distance

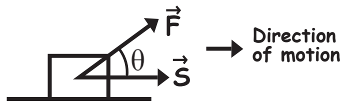
WORK DONE BY CONSTANT FORCE



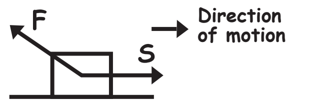
$W = F\cos\theta \times S$
$= FS\cos\theta = \vec{F}.\vec{S}$

NATURE OF WORK DONE

1) Positive work ($0° \le \theta < 90°$)



2) Negative work ($90° < \theta \le 180°$



2) Zero work
Work done becomes 0 for three conditions
1. Force is perpendicular to displacement
2. if there is no displacement
3. if there is no force acting on the body

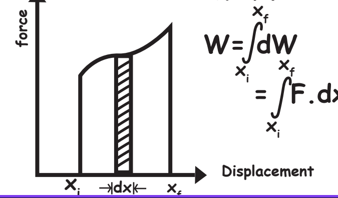
WORK DONE BY VARIABLE FORCE

$d W = \vec{F}.\vec{ds}$
$W = \int \vec{F}.\vec{ds} = \int F ds \cos\theta$

in terms of rectagular components

$\vec{F} = F_x \hat{i} + F_y \hat{j} + F_z \hat{k}$
$\vec{ds} = dx \hat{i} + dy \hat{j} + dz \hat{k}$
$W = \int F_x dx + \int F_y dy + \int F_z dz$

Graphical representation of work done

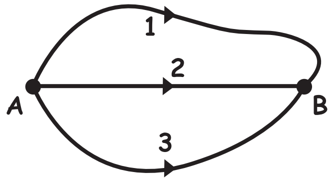


$dW = F.dx$
$W = \int_{x_i}^{x_f} dW$
$= \int_{x_i}^{x_f} F.dx$

CONSERVATIVE & NON CONSERVATIVE FORCE

Conservative: work done doesnot depend on path followed

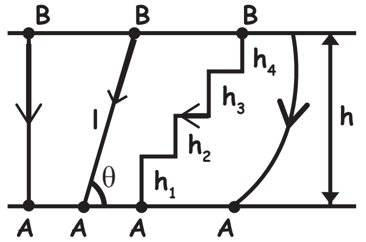
Non-conservative: work depends on the path followed



- $W_{A\to B}(\text{Path } 1) = W_{A\to B}(\text{Path } 2) = W_{A\to B}(\text{Path } 3)$
  (for conservative force)
- $W_{A\to B}(\text{Path } 1) \ne W_{A\to B}(\text{Path } 2) \ne W_{A\to B}(\text{Path } 3)$
  (for non conservative force)

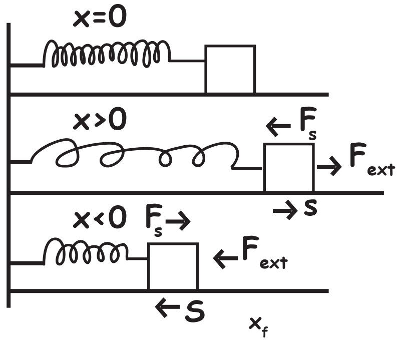
Note :
Work done for a complete cycle for a conservative force is zero

WORK DONE BY DIFFERENT FORCES



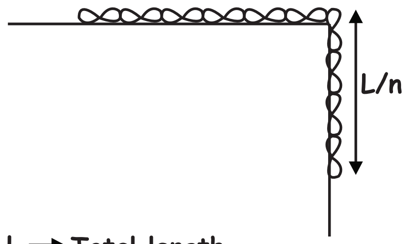
$W_1 = mgh = mgh$
$W_2 = mg \times l \sin\theta = mg \times l \times \frac{h}{l}$
$= mgh$
$W_3 = mgh_1 + 0 + mgh_2 + 0 + mgh_3 + 0 + mgh_4$

<u>Work done by spring force</u>
magnitude of spring force, $F_s = -kx$



$W_s = \int \vec{F_s}.\vec{dx} = -\int_{x_i}^{x_f} kx dx$
$= -\frac{1}{2} K (x_f^2 - x_i^2)$

THE CHAIN



L → Total length
$(1/n)^{th}$ part of length hanging
M → Mass of chain
Work done in pulling the hanging portion back on the table

$$W = \frac{MgL}{2n^2}$$

WORK ENERGY & POWER

ENERGY

- Capacity of doing work
- Scalar quantity
- Dimension ML^2T^{-2}

Relation between different units
$1eV = 1.6 \times 10^{-19}$ Joules
$1kWh = 3.6 \times 10^6$ Joules
1calorie = 4.18Joules
1 Joule = 10^7erg

Kinetic Energy

- Energy possessed by virtue of motion

$$K.E = \frac{1}{2} mv^2$$

- Always positive
- Depends on frame of reference

<u>Work Energy Theorm</u>

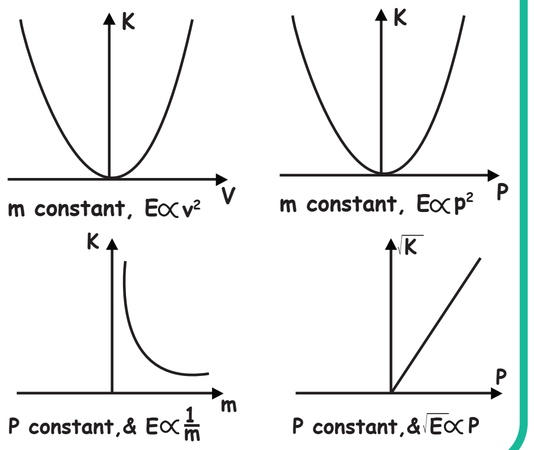
Change in kinetic energy of a body is equal to network done on the body

$$K_2 - K_1 = \int \vec{F}.\vec{dr}$$

ENERGY WITH OTHER QUANTITIES

Linear momentum:- $P = \sqrt{2m K}$

Variation of graph of kinetic Energy



m constant, $E \propto v^2$
m constant, $E \propto p^2$
P constant, & $E \propto \frac{1}{m}$
P constant, & $\sqrt{E} \propto P$

POTENTIAL ENERGY

- Defined only for conservative force
- Energy possessd by a body by virtue of its position/configuration
- Can either be positive, negative or zero according to point of reference
- Force always acts from higher potential to lower potential

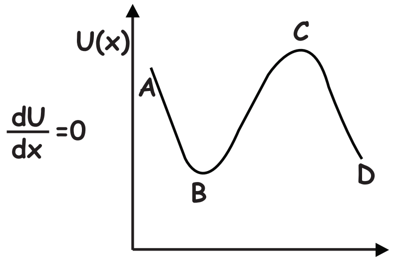
Identifying forces with the help of potential energy

1) Force opposing the motion:-
On increasing x, if U increases
$\frac{dU}{dx}$ = positive
(BC portion of graph)

2) Force supporting the motion:-
On increasing x, if U decreases
$\frac{dU}{dx}$ = negative
(AB portion of graph)

3) Zero force:-
On increasing x, if U doesnot change

$\frac{dU}{dx} = 0$



B,C points on the graph

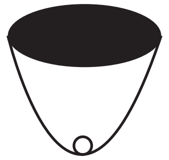
Types of Potential Energy
-Elastic Potential Energy
-Electric Potential Energy
-Gravitational Potential Energy

- Types of equilibrium

If net force acting on a particle is zero it is said to be in equillibrium

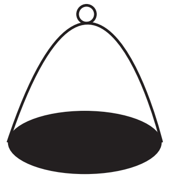
STABLE

- If particle displaced from equillibrium position, force acting will try to bring the particle back to the equilibrium position
- Potential energy is minimum at stable equilibrium
- $F = \frac{-dU}{dx} = 0$
- $\frac{d^2U}{dx^2}$ = positive



UNSTABLE

- If particle displaced from equillibrium position, force acting on it tries to displace it further away from equillibrium position
- Potential energy is maximum at unstable equilibrium
- $F = \frac{-dU}{dx} = 0$
- $\frac{d^2U}{dx^2}$ = negative



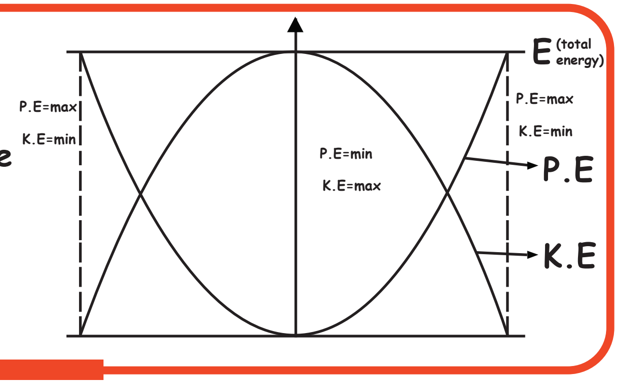
NUETRAL

- If particle is slightly displaced from equillibrium, then it does not experience a force or continues to be in equillibrium
- Potential energy is constant
- $F = \frac{-dU}{dx} = 0$
- $\frac{d^2U}{dx^2} = 0$

CONSERVATION OF ENERGY

For an isolated system or body in the presence of only conservative forces, the sum of kinetic and potential energies at any point remains constant throughout the motion

K.E+P.E=constant



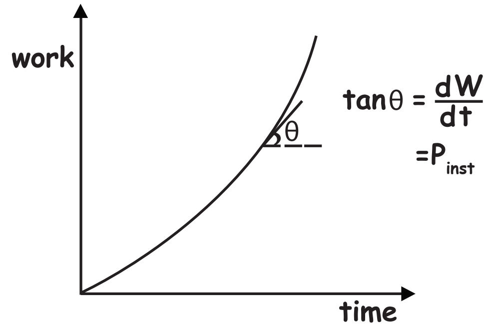
POWER

- Rate at which body does work
- Average power$(P_{av}) = \frac{W}{t}$
- Instanteneous power

$$(P_{inst}) = \frac{dW}{dt} = \frac{\vec{F}.\vec{ds}}{dt} = \vec{F}.\vec{v}$$

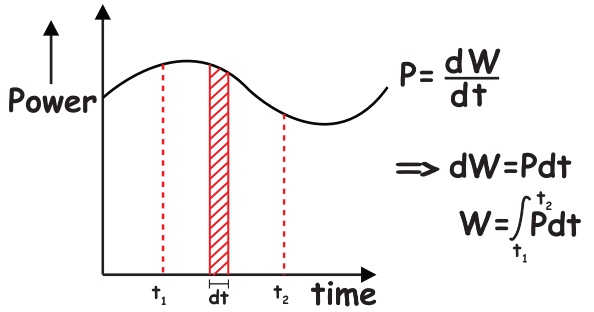
Relation between units:

- 1 watt = 1joule/sec = 10^7 erg/sec
- 1 HP = 746watt, 1MW = 10^6 watt
- 1 KW = 10^3 watt
- If work done by two bodies is same then power $\propto \frac{1}{\text{time}}$
- Unit of power multiplied by time always gives work
  1 KWh = 3.6×10^6 Joules
- Slope of work-time curve gives instanteneous power



$\tan\theta = \frac{dW}{dt}$
$= P_{inst}$

- Area under power-time graph gives work done



$P = \frac{dW}{dt}$
$\Rightarrow dW = Pdt$
$W = \int_{t_1}^{t_2} Pdt$

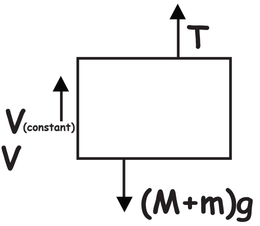
W = Area under P-t graph

Position and velocity in terms of power (P=constant)

1) Velocity, $V=\left[\frac{2Pt}{m}\right]^{1/2}$

2) Position, $S=\left[\frac{8P}{9m}\right]^{1/2}t^{3/2}$

Power delivered by an elevator



$a=0,\ T=(M+m)g$

$\vec{P}=\vec{T}.\vec{V}$

$=TV$

Power, $P=(M+m)gV$

Power of a water drawing pump

- Power, $P=\frac{dW}{dt}=\frac{dm}{dt}\left[gh+\frac{V^2}{2}\right]$
- h=height of water level

$\frac{dm}{dt}\Rightarrow$ mass flow rate of pump

V → velocity of the water outlet

- Power required to just lift water, V=0

$P=gh\left(\frac{dm}{dt}\right)$

Efficiency of pump

$$\mu=\frac{\text{Output Power}}{\text{Input Power}}$$

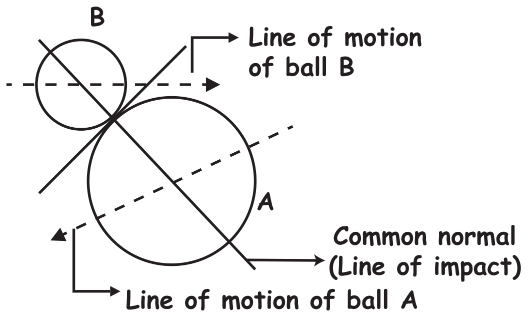
WORK ENERGY& POWER

COLLISION

Collision is the event in which impulsive force acts between two or more bodies which results in change of their velocities.

Line of impact

Line passing through common normal to surfaces in contact during impact



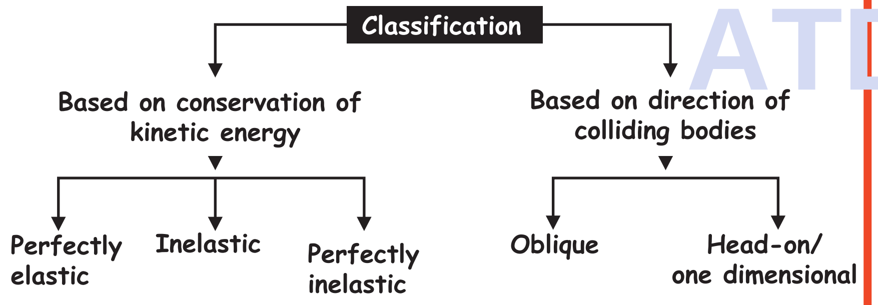
Coefficient of restitution (e)

$$e=\frac{\text{Velocity of separation along the line of impact}}{\text{Velocity of approach along the line of impact}}$$

$$=\frac{\text{Relative velocity along the line of impact after collision}}{\text{Relative velocity along the line of impact before collision}}$$

Conditions

1. For elastic collision: e=1
2. For inelastic collision: e<1
3. For perfectly inelastic collision: e=0



Classification

Based on conservation of kinetic energy
- Perfectly elastic
- Inelastic
- Perfectly inelastic

Based on direction of colliding bodies
- Oblique
- Head-on/ one dimensional

Perfectly elastic collision

K.E before and after collision is same

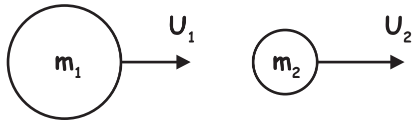
Inelastic collision

K.E before and after collision is not same

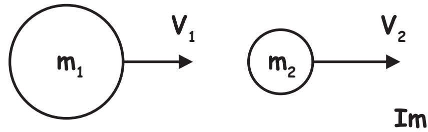
Head-on collision / One dimensional collision

Initial velocities of the bodies are along the line of impact.

Before collision



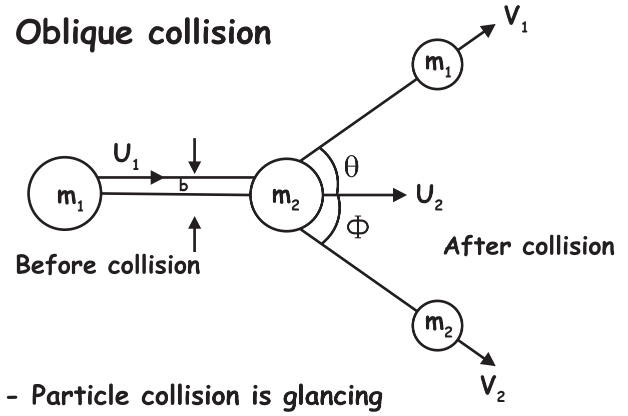
After collision



Impact porameter b=0

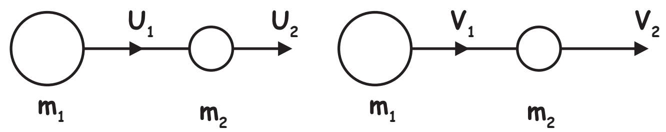
If initial velocities of the bodies are not along the line of impact.

Oblique collision



- Particle collision is glancing
- Directions of motion after collision are not along initial line of motion
- Impact parameter $0<b<(r_1+r_2)$ where r_1,r_2 are radii of colliding bodies

Perfectly elastic Head-on collission



Before collision

After collision

Velocity after collision

$$V_1=U_1\left[\frac{m_1-m_2}{m_1+m_2}\right]+\frac{2m_2U_2}{m_1+m_2}$$

$$V_2=U_2\left[\frac{m_2-m_1}{m_1+m_2}\right]+\frac{2m_1U_1}{m_1+m_2}$$

Special cases:

1) Projectile and target having same mass $m_1=m_2$,then $v_1=u_2, v_2=u_1$, the velocities get interchanged.

2) If massive projectile collides with a light target i.e. $m_1>>>m_2$,then $v_1=u_1, v_2=-u_2+2u_1$

3) If a light projectile collides with a very heavy target, $m_1<<m_2$,then $v_1=-u_1+2u_2, v_2=u_2$

Energy transfer from projectile to target

1) Fractional decrease in kinetic energy of projectile (If target is at rest)

$$\frac{\Delta K}{K}=\frac{4m_1m_2}{(m_1-m_2)^2+4m_1m_2}$$

Greater the difference in masses, less will be transfer of K.E and vice versa

Transfer of K.E will be maximum when difference in masses is maximum

If $m_2=nm_1$ $\frac{\Delta K}{K}=\frac{4n}{(1+n)^2}$

Inelastic collision

$e=\frac{V_2-V_1}{U_1-U_2}$ $\frac{\text{Relative velocity of seperation}}{\text{Relative velocity of approach}}$

Velocity after collision $V_1=\frac{(1+e)\,m_2U_2}{m_1+m_2}+\frac{(m_1-em_2)U_1}{m_1+m_2}$

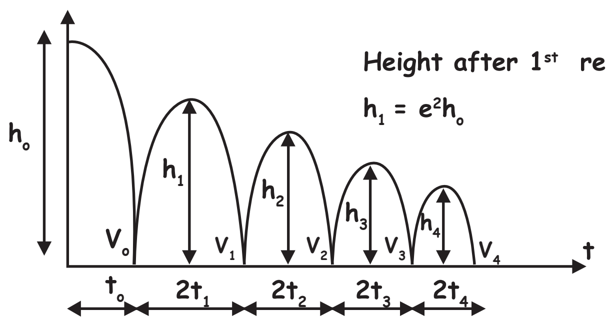
$V_2=\frac{(1+e)\,m_1U_1}{m_1+m_2}+\frac{(m_2-em_1)U_2}{m_1+m_2}$

Ratio of velocities

$\frac{V_1}{V_2}=\frac{1-e}{1+e}$

Loss in kinetic energy $\Delta K=\frac{1}{2}\left[\frac{m_1m_2}{m_1+m_2}\right](1-e^2)\,(U_1-U_2)^2$

Rebounding of ball



Height after 1st rebound

$h_1=e^2h_o$

Total height covered by the ball before it stops bouncing

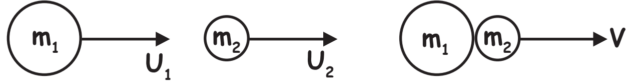
$$H=h_o\left[\frac{1+e^2}{1-e^2}\right]$$

Total time taken by the ball until ot stops bouncing $T=\left(\frac{1+e}{1-e}\right)\frac{2h_o}{g}$

Perfectly inelastic collision

Colliding bodies stick together

After collision are moving in the same



$$V=\frac{m_1U_1+m_2U_2}{m_1+m_2}$$

Loss in kinetic energy $\Delta k=\frac{1}{2}\frac{m_1m_2}{m_1+m_2}(U_1-U_2)^2$

Colliding bodies are moving in the opposite direction

$V=\frac{m_1U_1-m_2U_2}{m_1+m_2}$, Change in kinetic enargy $\Delta K=\frac{1}{2}\frac{m_1m_2}{m_1+m_2}(U_1-U_2)^2$

ELECTROCHEMISTRY

PHYSICS WALLAH

① Electrochemical Cell

Left side	Right side
Oxidation	Reduction
Anode	Cathode
Negative	Positive

② Representation of cell

$Zn | Zn^{2+} || Cu^{2+} | Cu$

$R_a | P_a || R_c | P_c$

Product at anode

Reactant at cathode

- Electrode potential ($E_{M^{n+}/M}$)

E.P= Reduction Potential (R.P)
= -Oxidation potential (O.P)

If R.P=x, then O.P=-x

Representation of Reduction half reaction:

$M^{n+} + ne^- \longrightarrow M$

- Standard Reduction Potential(SRP) ($E^0_{M^{n+}/M}$)

R.P at 1M and 298K.
SRP is calculated by using SHE

Respresentation of SHE

$H^+_{(1M)} | H_{2\,(g, 1\,bar)} | Pt_{(s)}$, $E^0_{SHE} = 0$

③ Electrochemical series

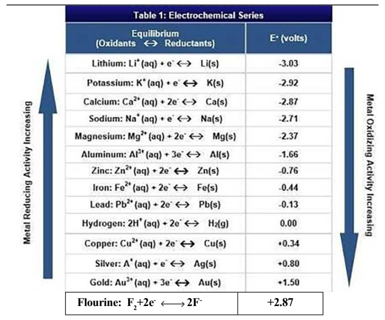


Table 1: Electrochemical Series

Equilibrium (Oxidants ⟷ Reductants)	E° (volts)
Lithium: $Li^+(aq) + e^- \leftrightarrow Li(s)$	-3.03
Potassium: $K^+(aq) + e^- \leftrightarrow K(s)$	-2.92
Calcium: $Ca^{2+}(aq) + 2e^- \leftrightarrow Ca(s)$	-2.87
Sodium: $Na^+(aq) + e^- \leftrightarrow Na(s)$	-2.71
Magnesium: $Mg^{2+}(aq) + 2e^- \leftrightarrow Mg(s)$	-2.37
Aluminum: $Al^{3+}(aq) + 3e^- \leftrightarrow Al(s)$	-1.66
Zinc: $Zn^{2+}(aq) + 2e^- \leftrightarrow Zn(s)$	-0.76
Iron: $Fe^{2+}(aq) + 2e^- \leftrightarrow Fe(s)$	-0.44
Lead: $Pb^{2+}(aq) + 2e^- \leftrightarrow Pb(s)$	-0.13
Hydrogen: $2H^+(aq) + 2e^- \leftrightarrow H_2(g)$	0.00
Copper: $Cu^{2+}(aq) + 2e^- \leftrightarrow Cu(s)$	+0.34
Silver: $A^+(aq) + e^- \leftrightarrow Ag(s)$	+0.80
Gold: $Au^{3+}(aq) + 3e^- \leftrightarrow Au(s)$	+1.50
Flourine: $F_2 + 2e^- \longleftrightarrow 2F^-$	+2.87

SRP↑=O.A.
SRP↓= R.A.

Metals with high SRP = less reactive
Metals with low SRP = highly reactive

④ EMF of a cell

$E^0_{cell} = E^0_{Cathode} - E^0_{Anode}$

$E_{cell} = RP_{Cathode} - RP_{Anode}$

$E_{cell} = RP_{Cathode} + OP_{Anode}$

$E_{cell} = OP_{Anode} - OP_{Cathode}$

In cell, Cathode with high RP ,Anode with low RP makes spontaneous reactions

⑤ Nernst equation

$$E_{cell} = E^0_{Cell} - \frac{0.0591}{n} \log\left[\frac{Product}{Reactant}\right]$$

For $Zn | Zn^{2+} || Cu^{2+} | Cu$

$$E_{cell} = E^0_{Cell} - \frac{0.0591}{2} \log\left[\frac{Zn^{2+}}{Cu^{2+}}\right]$$

For $Ni | Ni^{2+} || Ag^+ | Ag$

$$E_{cell} = E^0_{Cell} - \frac{0.0591}{2} \log\left[\frac{Ni^{2+}}{(Ag^+)^2}\right]$$

$R_1 | P_1 || R_2 | P_2$

If $R_2 \uparrow, P_1 \downarrow$ then $E_{cell} \uparrow$

⑥ Application of Nernst Equation

- Electrode Potential

$$E_{M^{n+}/M} = E^0_{M^{n+}/M} - \frac{0.0591}{n} \log \frac{1}{[M^{n+}]}$$

- Nernst equation in SHE

1) $E_{H^+/H_2} = -\frac{0.0591}{2} \log \frac{P_{H_2}}{[H^+]^2}$

2) If, $P_{H_2} = 1$ atm

(R.P.)= $E_{H^+/H_2} = -0.0591$ pH

(O.P.)= $E_{H_2/H^+} = +0.0591$ pH

- Concentration Cells

$Zn | Zn^{2+}_{(C_1)} || Zn^{2+}_{(C_2)} | Zn$

$$E_{cell} = \frac{0.0591}{n} \log\left(\frac{cathode.C_2}{anode.C_1}\right)$$

$$\frac{C_2}{C_1} > 1 \Rightarrow \log\left(\frac{C_2}{C_1}\right) > 0 \quad \therefore E_{cell} > 0$$

⑦ EMF; K_c & ΔG

$E^0_{cell} = \frac{0.0591}{n} \log K_c$, $\log K_c = \frac{nE^0_{cell}}{0.0591}$

$\Delta G = -nFE_{cell}$

Spontaneous	Non-spontaneous
$\Delta G < 0$	$\Delta G > 0$
$E^0_{cell} > 0$	$E^0_{cell} < 0$
$\log K_c > 0$	$\log K_c < 0$
$K_c > 1$	$K_c < 1$

Galvanisation is applying coating of Zn

③ Faraday's law

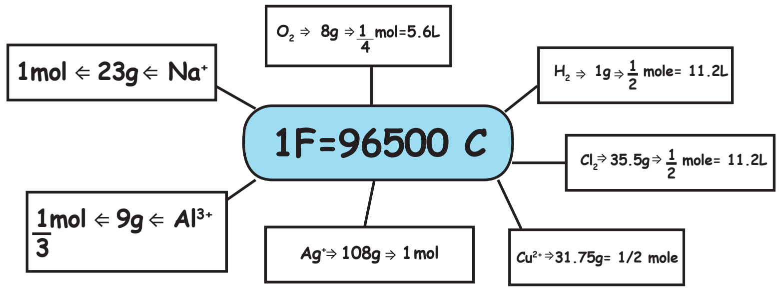
Product formed

$$m = \frac{EM}{96500} \times It$$

$$EM = \frac{AM}{valency}$$

1F=charge of 1 mole of e^-

=96500 C



1F=96500 C

$1mol \Leftarrow 23g \Leftarrow Na^+$

$O_2 \Rightarrow 8g \Rightarrow \frac{1}{4} mol = 5.6L$

$H_2 \Rightarrow 1g \Rightarrow \frac{1}{2} mole = 11.2L$

$Cl_2 \Rightarrow 35.5g \Rightarrow \frac{1}{2} mole = 11.2L$

$\frac{1}{3} mol \Leftarrow 9g \Leftarrow Al^{3+}$

$Ag^+ \Rightarrow 108g \Rightarrow 1 mol$

$Cu^{2+} \Rightarrow 31.75g = 1/2$ mole

$Na^+ + e^- \rightarrow Na \Rightarrow 1F$
$Mg^{2+} + 2e^- \rightarrow Mg \Rightarrow 2F$
$Al^{3+} + 3e^- \rightarrow Al \Rightarrow 3F$

1F displaces & gives 1 equivalent of product

① Electrolytic cell

ANODE	CATHODE
• Anion goes to anode	• Cation goes to cathode
• +ve electrode	• -ve electrode
• Oxidation	• Reduction
• $A \rightarrow A^+ + e^-$	• $B + 1e^- \rightarrow B^-$
• $A \rightarrow A^{n+} + ne^-$	• $B^n + ne^- \rightarrow B^-$

② Product of electrolysis

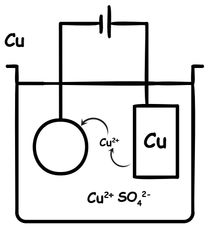
Deposition order of cation: (order of R.P)

$Li^+ < K^+ < Ca^{2+} < Na^+ < Mg^{2+} < Al^{3+} < Zn^{2+} < Fe^{2+} < Ni^{2+} < H^+ < Cu^{2+} < Hg^{2+} < Ag^+ < Au^{3+}$

Deposition order of anion

$SO_4^{2-} < NO_3^- < OH^- < Cl^- < Br^- < I^-$

Note:

1) For conc. H_2SO_4	3) For $CuSO_4$ with Cu electrode
Anode: $H^+ + 1e^- \rightarrow 1/2\ H_2$ Cathode: $2SO_4^{2-} \rightarrow S_2O_8^{2-} + 2e^-$ (peroxo disulphate ion)	Anode: $Cu \rightarrow Cu^{2+} + 2e^-$ Cathode: $Cu^{2+} + 2e^- \rightarrow Cu$  Electroplating
2) Very dil. NaCl(H_2O>>NaCl)	
Anode: $H^+ + 1e^- \rightarrow 1/2\ H_2$ Cathode: $2OH^- \rightarrow 1/2\ O_2 + H_2O + 2e^-$	

④ Electrolytic conduction

Resistance(R)= $\rho \frac{l}{A}$

Conductance(C) = $\frac{1}{R}$

Conductivity(K) = $\frac{1}{\rho}$

Unit of R = Ω
$\rho = \Omega m$
$C = \Omega^{-1} = S = mho$
$K = \Omega^{-1}m^{-1}$ or Sm^{-1}
$1Scm^{-1} = 100\ Sm^{-1}$

Molar Conductivity (λ_m)	Equivalent Conductivty (λ_{eq})
$\lambda_m = \frac{1000\ K}{M}$	$\lambda_{eq} = \frac{1000\ K}{N}$
$K \rightarrow Scm^{-1}$	$K \rightarrow Scm^{-1}$
$M \rightarrow mol\ L^{-1}$	$N \rightarrow eq\ L^{-1}$
$\lambda_m \rightarrow Scm^2\ mol^{-1}$	$\lambda_{eq} \rightarrow Scm^2\ eq^{-1}$

$1Scm^2\ mol^{-1} = 10^{-4}\ Sm^2mol^{-1}$

$\boxed{\lambda_m = \lambda_{eq} \times Z}$

$N > M \therefore \lambda_m > \lambda_{eq}$

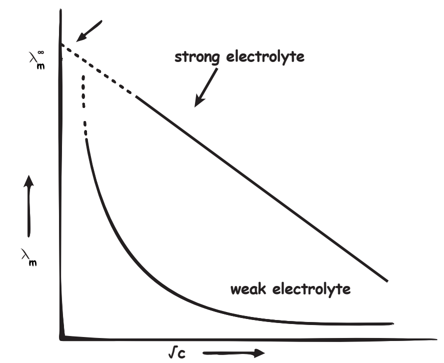
For H_2SO_4, Z = 2 ($2H^+$)
NaCl, Z = 1 ($1Na^+$)
$Al_2(SO_4)_3$, Z = 6 ($2Al^{3+}$)

λ_m for SE increases with dilution (interionic attraction decreases)

$\boxed{\lambda_m = \lambda^\infty_m - b\sqrt{c}}$ (Debye-Huckel Onsagar equation)

At $\sqrt{c} = 0$, $\lambda_m = \lambda^\infty_m$ (limiting molar conductivity)

λ_m of weak electrolytes increases with dilution (degree of dissociation increases)



λ^∞_m order : KCl > NaCl > LiCl

Conductance $\propto \frac{1}{Hydrated\ Radii}$

⑤ Kohlrausch's law

$\lambda^\infty_M(AB_2) = \lambda^\infty_M(A^{2+}) + 2\lambda^\infty_M(B^-)$

$\lambda^\infty_{eq}(AB_2) = \lambda^\infty_M(A^{2+}) + \lambda^\infty_{eq}(B^-)$

For $Al_2(SO_4)_3$

$\lambda^\infty_M(Al_2(SO_4)_3) = 2\lambda^\infty_M(Al^{3+}) + 3\lambda^\infty_M(SO_4^{2-})$

$\lambda^\infty_{eq}(Al_2(SO_4)_3) = \lambda^\infty_{eq}(Al^{3+}) + \lambda^\infty_{eq}(SO_4^{2-})$

Application

$\lambda^\infty_M NH_4OH = \lambda^\infty_M NH_4Cl + \lambda^\infty_M NaOH - \lambda^\infty_M NaCl$

$\lambda^\infty_M CH_3COOH = \lambda^\infty_M CH_3COONa + \lambda^\infty_M HCl - \lambda^\infty_M NaCl$

$\lambda^\infty_M BaSO_4 = \lambda^\infty_M BaCl_2 + \lambda^\infty_M Na_2SO_4 - 2\lambda^\infty_M NaCl$

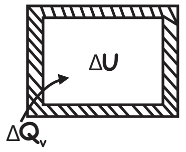
THERMODYNAMICS

Internal Energy(U)

(1) $\Delta U = \Delta Q_v = nC_v\Delta T = n\frac{f}{2}R\Delta T$

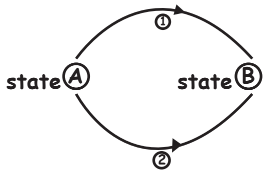
$= \frac{nR\Delta T}{\gamma-1} = \frac{\Delta(PV)}{\gamma-1}$

$= \frac{P_fV_f - P_iV_i}{\gamma-1}$



(Internal Energy is only the function of temperature of the gas)

- First law of T.D $\Longrightarrow$ $Q = \Delta U + W$
- Q, W $\Longrightarrow$ path functions
- ΔU $\Longrightarrow$ state function



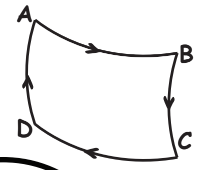
- $W_1 \neq W_2$
- $Q_1 \neq Q_2$
- $\Delta U_1 = \Delta U_2 = U_B - U_A$

Isothermal process $\Rightarrow \Delta T = 0 \longrightarrow \Delta U = 0$

Cyclic process

$A \rightarrow B \rightarrow C \rightarrow D \rightarrow A$

$\Delta U = U_A - U_A = 0$



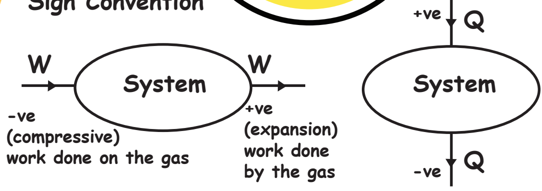
WORK

Work done: path function

$W = F.dx = \int Pdv$

- Unit: Joule(J)

Sign Convention



-ve (compressive) work done on the gas

+ve (expansion) work done by the gas

Work

Heat

HEAT

Heat: path function
$\Rightarrow$ unit:calorie/Joule

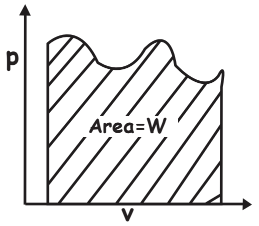
For any process,
$Q = nC\Delta T$
where, C= Specific heat capacity for the process

Adiabatic process $\Longrightarrow \Delta Q = 0$ [No heat transfer]

At constant volume $\Longrightarrow$ $Q_v = \Delta U = nC_v\Delta T$

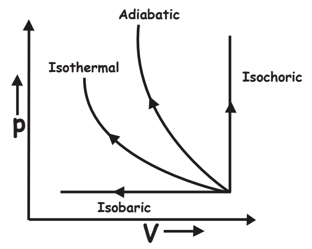
At constant pressure $\Longrightarrow$ $Q_p = \Delta U + W = nC_p\Delta T$

Work done from P-V Graph



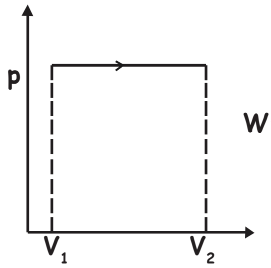
Area under P-V diagram gives work done by the gas

Compression



$|W_{adiabatic}| > |W_{isothermal}| > |W_{isobaric}| > |W_{isochoric}|$

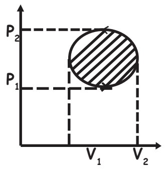
Isobaric process



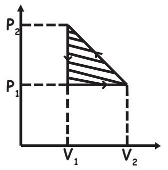
$W = P(V_2 - V_1)$

Cyclic process

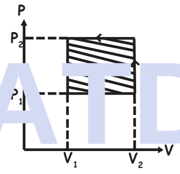
- W=are inside the graph
- For clockwise process, W=-ve
- For anti-clockwise process, W=+ve



$W = \frac{\pi}{4}(P_2-P_1)(V_2-V_1)$

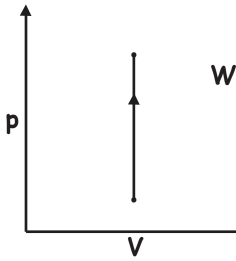


$W = \frac{1}{2}(P_2-P_1)(V_2-V_1)$

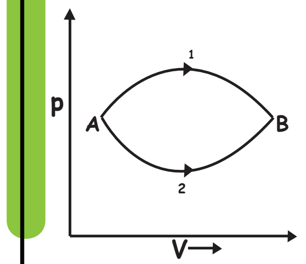


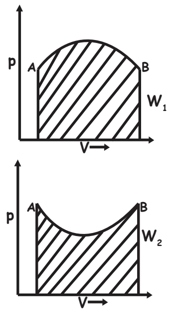
$W = (P_2-P_1)(V_2-V_1)$

Isochoric process



$W = P\Delta V = 0$

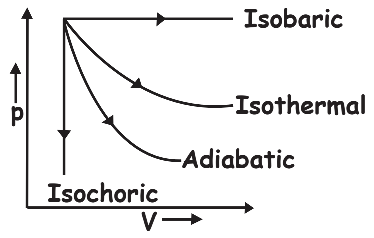




$W_1 \neq W_2$

$W_1 > W_2$

Expansion



$W_{isobaric} > W_{isothermal} > W_{adiabatic} > W_{Isochoric}$

Thermodynamic processes

01 Adiabatic process

- Q=0 [no exchange of heat]
- Rapid or spontaneous process/insulated vessel

$Q = \Delta U + W$

$Q = 0 \quad \Delta U = -W$

Compression

$W = -ve \quad \Delta U = +ve$

$\Delta U\uparrow \Longrightarrow$ Temperature↑

$\Rightarrow$ Pressure↑

Expansion

$W = -ve \quad \Delta U = +ve$

$\Delta U\downarrow \Longrightarrow$ Temperature↓

$\Rightarrow$ Pressure↓

Equation of state

$PV^{\gamma} =$ constant

$TV^{\gamma-1} =$ constant

$PT^{\left[\frac{\gamma-1}{\gamma}\right]} =$ constant

Work done by the gas

$W = -\Delta U = nC_v(T_1 - T_2)$

$= n\frac{f}{2}R(T_i - T_f)$

$W = \frac{nR}{\gamma-1}(T_i - T_f)$

$W = \frac{P_iV_i - P_fV_f}{\gamma-1}$

Slope of adiabatic process
$= \gamma \times$ slope of isothermal process
specific heat of gas $\Rightarrow C = 0$

$C = \frac{Q}{\Delta t} \longrightarrow Q = 0$

$C = 0$

02 Isothermal process

$\Rightarrow \Delta T = 0 \Rightarrow \Delta U = 0$

eg:- perfectly conducting
slow process

$Q = \Delta U + W$

$Q = W$

equation of states $\Rightarrow PV =$ Constant

$P_1V_1 = P_2V_2$

Workdone by the gas

$W = 2.303\, nRT \log\left(\frac{V_2}{V_1}\right)$

$W = 2.303\, nRT \log\left(\frac{P_1}{P_2}\right)$

Slope:

Slope of adiabatic process
$= \gamma \times$ slope of isothermal process

specific heat $C = \infty$

03 Isobaric process

$\Delta P = 0$

$Q = \Delta U + W$

equation of state $\Rightarrow V \propto T$

$\frac{V_1}{V_2} = \frac{T_1}{T_2}$

Work done by the gas

$W = P\Delta V = P(V_2 - V_1) = nR(T_2 - T_1)$

specific heat

$\Rightarrow C_p = \left(1 + \frac{f}{2}\right)R$

$= \frac{\gamma R}{\gamma-1}$

04 Isochoric process

ΔV=0 or V=constant

equation of state $\Rightarrow P \propto T \Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2}$

Work done by the gas

$\Delta V = 0 \Rightarrow W = 0$

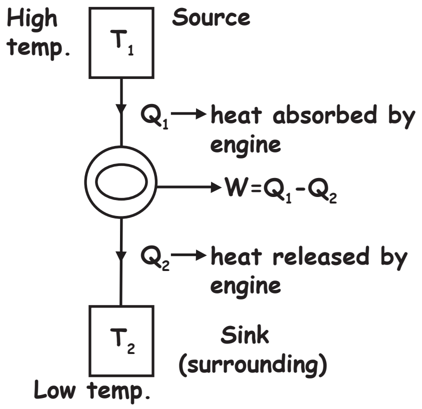
specific heat

$\Rightarrow C_V = \frac{f}{2}R$

$= \frac{R}{\gamma-1}$

Heat Engine

'Device that converts heat into work'



$Q_1 \rightarrow$ heat absorbed by engine

$Q_2 \rightarrow$ heat released by engine

efficiency(η)

$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$

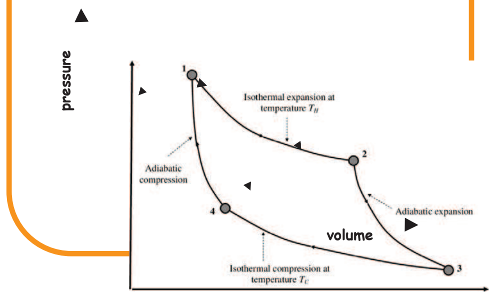
$\eta_{carnot} = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1}$

$\eta_{max} \Longrightarrow$ When $Q_2 = 0$ or $T_2 = 0K$
(not possible)

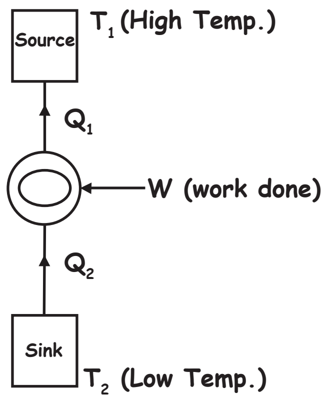
Carnot Engine

→ Ideal engine

→ $\boxed{\eta = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1}}$



Refrigerator and heat pump



Coefficient of performance of refgeration(β)

$\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$ $\qquad \beta = \frac{T_2}{T_1 - T_2}$

Coefficient of performance of heat pump

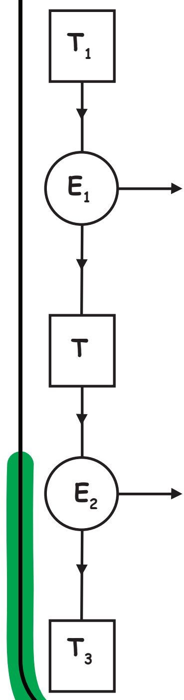
$= \frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$

Relationship between

$\beta = \frac{1-\eta}{\eta}$

$(COP)_{heat\ pump} = 1 + (COP)_{refrigerator}$

Cascaded engine



Same work output

$W_1 = W_2$

$T_1 - T = T - T_3$

$2T = T_1 + T_3$

$T = \frac{T_1 + T_3}{2}$

Same efficiency

$1 - \frac{T}{T_1} = 1 - \frac{T_3}{T}$

$T^2 = T_1T_3$

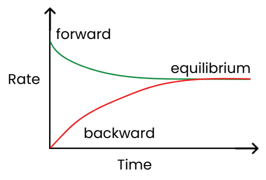
$T = \sqrt{T_1T_3}$

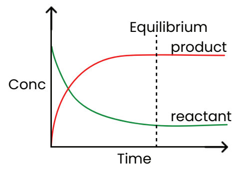
CHEMICAL EQUILIBRIUM

EQUILIBRIUM

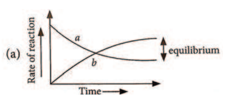
- The chemical reactions which takes place in both directions are called reversible reactions
- Equilibrium is the end state of a reversible reaction.
- Gaseous Equilibrium is established only in a closed container.
- At equilibrium, the rate of forward and backward reactions are equal.
- At equilibrium, the concentration of reactants & products becomes constant.

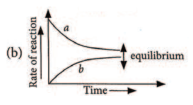
GRAPHICAL REPRESENTATIONS

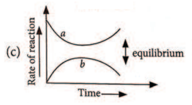


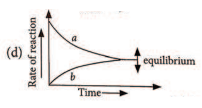


Q. For the equilibrium A $\rightleftharpoons$ B, the variation of the rate of the forward (a) & reverse (b) reaction with time is given by









PHYSICAL EQUILIBRIUM

- Such equilibrium is established in physical reactions.
- It is dynamic in nature.

LIQUID $\rightleftharpoons$ VAPOUR EQUILIBRIUM

- Here vapour pressure is constant at a constant temp for given.

SOLID $\rightleftharpoons$ LIQUID EQUILIBRIUM

- Established only at a constant temparature
- Ice-water equilibrium established at 0°C (at1 atm)

SOLID IN LIQUID EQUILIBRIUM

- Established only in a Saturated solution
- eg: Saturated sugar solution.

Sugar (dissolved) $\rightleftharpoons$ Sugar (undissolved)

GAS IN LIQUID EQUILIBRIUM

- Here solubility depends upon pressure (Henry's law)
- eg: Soda water

CO_2 (dissolved) $\rightleftharpoons$ CO_2 (undissolved)

Q. Which of the given statements does not elucidate the equilibrium state precisely?

(A) The equilibrium can be approached from either direction.
(B) The equilibrium can be attained only if the system is an isolated system.
(C) The free energy change at constant pressure and temperature is zero.
(D) It is dynamic in nature.

CHEMICAL EQUILIBRIUM

- Chemical equilibrium approaches from both forward & backward direction
- Chemical equilibrium is dynamic in nature.

EQUILIBRIUM CONSTANT $[K_c]$

- For a general reversible reaction

aA + bB $\rightleftharpoons$ cC+ dD

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

REACTION QUOTIENT $[Q_c]$

- At any time during the reaction aA+bB $\rightleftharpoons$ cc+dD the ratio $\frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$ is known as concentration quotient, Q_c.
- At equilibrium $Q_c = K_c$

CHARACTERISTICS OF K [eqb. const]

1. Value of K does not depends upon initial concentration of reactants and products.
2. Value of K does not depends upon the direction from which equilibrium is attained.

Q In the given reaction: A+2B $\rightleftharpoons$ 2C, 2 moles each of A & B present in 10 L of solution combine to form 1 mole of C. Calculate K_c for the reaction.

(A) 1.5 (B) 6.67 (C) 0.15 (D) 2.3

Applications of K & Q

- Value of K depends only on temperature.
- If K for the reaction aA + bB $\rightleftharpoons$ cC+dD is K, then K for the reaction cC+dD $\rightleftharpoons$ aA+ bB will be $\frac{1}{K}$
- If K for the reaction aA + bB $\rightleftharpoons$ cC+dD is K, then K for the reaction naA+ nbB $\rightleftharpoons$ ncC + ndD will be $(K)^n$
- During the addition of two reactions having equilibrium constants K_1 & K_2, then the net Constant $K = K_1 \times K_2$
- During the subtraction of a reaction having constant K_2 from a reaction having constant K_1, then the net constant $K = K_1/K_2$
- If Q<K, the reaction will proceed in forward direction
- If Q>K, the reaction will proceed in backward direction
- If Q=K, the system is in equilibrium.
- If $K > 10^3$, the reaction is almost complete in forward direction.
- If $K < 10^{-3}$, the reaction is in backward direction.
- If K is in b/w 10^3 & 10^{-3}, almost same reaction takes place in both forward and backward direction

Q At a given temperature, the equilibrium constants for the reactions,

$NO(g) + \frac{1}{2}O_2(g) \rightleftharpoons NO_2(g)$ & $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$

are K_1 and K_2 respectively. If K_1 is 4×10^{-3} . then K_2 will be

(A) 8×10^{-3} (B) 16×10^{-3} (C) 6.25×10^4 (D) 6.25×10^6

HOMOGENEOUS EQUILIBRIUM

- If they are in solid or liquid phase(or aqueous), K can be represented as Kc.
- If they are in gaseous phase, K can be represented as Kp
- For a general reaction

aA + bB $\rightleftharpoons$ cC + dD

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b} \quad \& \quad K_p = \frac{P_C^{\,c}P_D^{\,d}}{P_A^{\,a}P_B^{\,b}}$$

- $\boxed{K_p = K_c(RT)^{\Delta n_g}}$ $\Delta n_g = n_p - n_R$

UNIT OF EQUILIBRIUM CONSTANT

- Unit of $K_c = (mol/L)^{\Delta n_g}$
- Unit of $K_p = (atm)^{\Delta n_g}$
- If $\Delta n_g = 0$, equilibrium constant has no unit

HETEROGENEOUS EQUILIBRIUM

- In heterogeneous equilibrium, concentration of pure solid & pure liquid is taken as one
- eg : $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

$K_p = P_{CO_2}$

Q For the reaction,

$$Fe_2N_{(s)} + \frac{3}{2}H_{2(g)} \rightleftharpoons 2Fe_{(s)} + NH_{3(g)}$$

(a) $K_c = K_p(RT)$ (b) $K_c = K_P(RT)^{-1/2}$
(c) $K_c = K_P(RT)^{1/2}$ (d) $K_c = K_P(RT)^{3/2}$

LE CHATELIER'S PRINCIPLE

According to Le-chatelier's principle, if a system at equilibrium is subjected to a change in concentration, temperature or pressure, the equilibrium will shifts automatically in one direction which will nullify the effect of the change.

1. Conc. of reactant increases → shift towards forward reaction.
2. Conc. of product decreases → shift towards forward reaction.
3. Conc. of reactant decreases → shift towards backward reaction.
4. Conc. of product increases → shift towards backward reaction.
5. Pressure increases → shift towards lesser number of gaseous moles
6. Pressure decreases → shift towards higher number of gaseous moles
7. No. of gaseous moles of reactants & products are equal, pressure has no effect.
8. If temperature increases → shift towards endothermic
9. If temperature decreases → shift towards exothermic
10. Catalyst helps to attain eqm state easily.
    After the establishment of eqm, catalyst has no effect.
11. Addition of inert gas at constant volume, no effect.
12. Addition of inert gas at constant pressure → shift towards higher number of gaseous moles

Q Which one of the following conditions will favour maximum formation of the product in the reaction $A_2(g) + B_2(g) \rightleftharpoons X_2(g)$. ΔrH = -XkJ/mol?

(A) Low temperature and high pressure (B) High temperature and high pressure
(C) Low temperature and low pressure (D) High temperature and low pressure

QUANTUM NUMBER

PRINCIPLE QUANTUM NUMBER

In n^{th} Shell ,

Number of subshells = n

Number of orbitals = n^2

Max. number of electrons $= 2n^2$

1 It describes shell or orbit
n = 1, 2, 3, 4,........
K, L, M, N,........

2 It describes size & energy of shell.
$r \propto n^2 \quad E \propto \frac{1}{n^2}$

3 It defines the angular momentum
$mvr = \frac{nh}{2\pi}$

AZIMUTHAL QUANTUM NUMBER

1 It describes subshell
value from 0 to n-1
$l=0 \rightarrow s \quad l=2 \rightarrow d$
$l=1 \rightarrow p \quad l=3 \rightarrow f$

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

3 Maximum no. of orbital in a subshell $= 2l + 1$
Maximum no. of electrons in a subshell $= 4l + 2$

MAGNETIC QUANTUM NUMBER

Value of m $= -l \le m \le l$
Total values of m $= 2l + 1$
n = 4
$l = 0 \quad m = 0$
$l = 1 \quad m = -1, 0, +1$
$l = 2 \quad m = -2, -1, 0, +1, +2$
$l = 3 \quad m = -3, -2, -1, 0, +1, +2, +3$

SPIN QUANTUM NUMBER

SPIN
CLOCKWISE (+ 1/2)
ANTICLOCKWISE (- 1/2)

Q. Find angular momentum of
(i) 2s orbital (ii) 3d orbital
(iii) 4p orbital (iv) e^- in 4^{th} orbit

Q. Find maximum no.of e^- having
(i) $n=4, s=-\frac{1}{2}$ (ii) $n=3, l=1, m=0$
(iii) $n=2, l=0$ (iv) $n=3, l=1$

Q. Which of the following set of quantum numbers is correct?

	n	l	m	s
1)	4	0	0	$+\frac{1}{2}$
2)	5	2	3	$-\frac{1}{2}$
3)	2	-1	0	$+\frac{1}{2}$
4)	6	3	0	$-\frac{1}{2}$

If l=2
1) Orbital = d
2) No. of orbitals = 2(2+1)=5
$(d_{xy}, d_{xz}, d_{yz}, d_{x^2-y^2}, d_{z^2})$
3) Total e^-s $= 2(2l+1) = 10$ e^-s
4) Orbital angular momentum =
$= \sqrt{2(2+1)}\,\hbar = \sqrt{6}\,\hbar$

01

UNCERTAINTY PRINCIPLE

$$\Delta x.\Delta p \ge \frac{h}{4\pi}$$

$$\Delta x.m\Delta v \ge \frac{h}{4\pi}$$

Q. According to Heisenberg's uncertainty principle, $\Delta x.\Delta p \ge \frac{h}{4\pi}$ which of the following is correct ?
a) If $\Delta x = 0$ then $\Delta p = \infty$
b) If $\Delta v = 0$ then $\Delta p = 0$
c) If $\Delta p = 0$ then $\Delta x = \infty$
d) All are correct

Q. Find uncertainty in velocity, if uncertainty position is equal to uncertalnty in momentum.
a) $\frac{h}{2\sqrt{\pi m}}$ b) $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$ c) $\frac{1}{m}\sqrt{\frac{h}{\pi}}$ d) $\frac{1}{2}\sqrt{\frac{h}{m\pi}}$

Q. The uncertainty involved in the measurement of velocity within a distance of $0.1A^0$ is:
a) 5.79×10^6 m/s b) 5.79×10^7 m/s
c) 5.79×10^8 m/s d) 5.79×10^5 m/s

Angular momentum in n^{th} orbital
$= mvr = n\hbar$

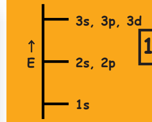
Orbital angular momentum
$= \sqrt{l(l+1)}\,\hbar$

Spin angular momentum
$= \sqrt{s(s+1)}\,\hbar$

STRUCTURE OF ATOM

ENERGY OF ORBITALS

1) Mono electronic species
Energy defined upon n



$\boxed{1s < 2s = 2p < 3s = 3p = 3d}$

2) Multi electronic species
$\boxed{3s < 3p < 4s < 3d}$

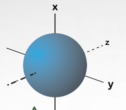
(n+l) rule

→ As (n + l) ↑, E ↑

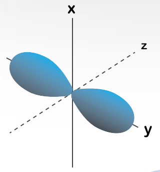
→ If (n + l) is same, then n ↑ E ↑

Orbital	2s	3d
(n+l) value	n = 2 l = 0 n+l = 2	n = 3 l = 2 n+l = 5

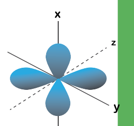
SHAPE OF ORBITALS



1) s orbital - Spherical shape



2) p orbital - dumb bell shape

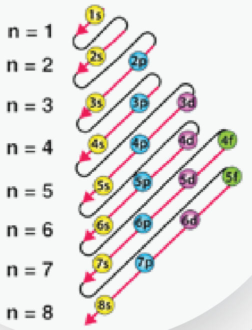


3) d orbital - double dumb bell shape

NODES

$\Psi \rightarrow$ e^- wave function
$\Psi^2 \rightarrow$ probability of finding the electrons
* Node → Probability of finding the electron is zero.
* Node plane → Plane; where $\Psi^2 = 0$
* Radial nodes → n-l-1
* Angular nodes = l
* Total nodes = n-1

FILLING OF ATOMIC ORBITAL



1 **Aufbau principle**
Electrons are filled in the increasing order of energy
1s < 2s < 2p < 3s < 3p < 4s < 3d ....

2 **Pauli's exclusion principle**
No two electrons can have same four quantum numbers
$1s^3$- against Pauli's exclusion principle

3 **Hund's rule**
Pairing is only takes place after each orbital is singly occupied.
[↑↓ | ↑ | ↑] →Against Hund's rule

PHYSICS WALLAH

SOLUTIONS

Types

Gaseous
Gas-Gas → Mixture of O_2 and N_2
Liquid-Gas → Chloroform with N_2
Solid-Gas → Camphor in N_2

Liquid
Gas-Liquid → O_2 dissolved in water
Liquid-Liquid → Ethanol dissolved in water
Solid-Liquid → Glucose dissolved in water

Solid
Gas-Solid → O_2 in Pd
Liquid-Solid → Amalgam of Hg with Na
Solid-Solid → Cu dissolved in gold

Expressing Concentration of solutions

Mass by volume percentage (w/v)

$$\frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

Volume percentage (v/v)

$$\frac{\text{Volume of component}}{\text{Total volume of solution}} \times 100$$

Mass percentage (w/w)

$$\frac{\text{Mass of component in solution}}{\text{Total mass of solution}} \times 100$$

Parts per million : For trace quantities

$$\frac{\text{No. of parts of components} \times 10^6}{\text{Total no. parts of components of solution}}$$

Mole fraction

$$\frac{\text{No. of moles of component}}{\text{Total No.of moles of all components}}$$

Normality:
Number of gram equivalents of the solute dissolved in one litre of solution

$$\frac{\text{No. of gram equivalent of solute} \times 100}{\text{Volume of solution (in L)}}$$

Gram Equivalents of solute

$$= \frac{\text{Mass of solute}}{\text{Equivalent weight}}$$

$$\text{Equivalent weight} = \frac{\text{Molecular mass}}{\text{valency}}$$

Molality:
Number of moles of solute per kilogram of the solvent

$$\frac{\text{No. of moles of solute} \times 1000}{\text{Mass of solvent (in g)}}$$

Molarity :
Number of moles of solute in 1L solution

$$\frac{\text{No. of moles of solute} \times 100}{\text{Volume of solution (in L)}}$$

Solubility

Solid in liquid

Effect of temperature
- Endothermic $\Delta_{sol}H > 0$, Solubility Increases at high temp.
- Exothermic $\Delta_{sol}H < 0$, Solubility decreases at high temp.

Effect of Pressure
- Not significant

Gas in liquid

Effect of temperature
- Increases with decrease in temperature

Effect of Pressure
- Increases with increase in Pressure

Henry's Law
Partial pressure of gas in vapour phase is proportional to the mole fraction of gas in the solution.

$$p = K_H x$$

Colligative properties

Osmotic pressure → $\pi = CRT$

Depression in freezing point → $\Delta T_f = \dfrac{K_f \times W_2 \times 1000}{M_2 \times W_1}$

Elevation of boiling point → $\Delta T_b = \dfrac{K_b \times 1000 \times W_2}{M_2 \times W_1}$

Relative lowering of vapour pressure (for dilute solutions) → $\dfrac{W_2 \times M_1}{M_2 \times W_1} = \dfrac{P^o_1 - P_1}{P^o_1}$

Abnormal molecular mass

Molecular mass different from expected value

$$\text{Van't Hoff factor (i)} = \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}}$$

Raoult's Law
For any solution, the partial vapour pressure of each volatile component is directly proportional to its mole fraction in solution phase

Obey raoult's law
Ideal solution → $\Delta H_{mix} = \Delta V_{mix} = 0$
eg: n-hexane and n-heptane
Ethyl bromide + Ethyl chloride,
Chlorobenzene + Bromobenzene, etc.

Do not Obey raoult's law
Non-Ideal solution → ΔH_{mix} or $\Delta V_{mix} \neq 0$

Positive Deviation
$\Delta H_{mix} > 0$
$\Delta V_{mix} > 0$

eg: Acetone + Ethyl alcohol,
Water + Ethyl alcohol,
Carbon tetrachloride + Chloroform,
Chloroform + Ethanol,
Acetone + Carbon disulphide,
Acetone + Benzene, etc.

Negative Deviation
$\Delta H_{mix} < 0$
$\Delta V_{mix} < 0$

eg: Acetone + Aniline,
HCl + H_2O, HNO_3 + H_2O,
H_2SO_4 + H_2O,
Acetone + Chloroform,
HNO_3 + Chloroform,
Benzene + Chloroform,
Pyridine + Glacial acetic acid, etc.

Azeotropes:
The mixtures of liquids which boil at constant temperature like a pure liquid and possess same composition of components in liquid as well as vapour phase are called constant boiling mixtures or azeotropic mixtures.

Minimum boiling azeotropes:
They are formed by those liquid pairs which show positive deviations from ideal behaviour. eg: ethanol-water mixture.

Maximum boiling azeotropes:
They are formed by those liquid pairs which show negative deviations from ideal behaviour e.g nitric acid-water mixture.

PHYSICS WALLAH