



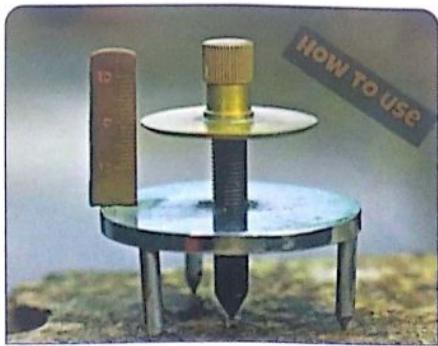
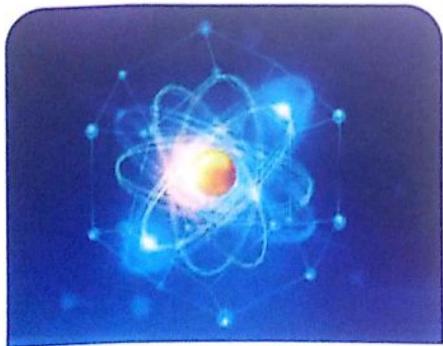
**NARAYANA**  
JUNIOR COLLEGES

**40**  
YEARS  
OF EXCELLENCE

## Jr. Intermediate - MPC



# CDF



# Jr. INTERMEDIATE INDEX

NAME OF THE SUBJECT	Page No.
MATHEMATICS-IA	1 - 16
MATHEMATICS-IB	17 - 33
PHYSICS	34 - 63
CHEMISTRY	64 - 106

# NARAYANA

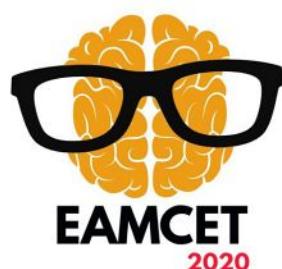
## JUNIOR COLLEGES

2019-20 | MPC | CDF

ANDHRA PRADESH

&

TELANGANA



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## FUNCTIONS

1. SET: : A well defined collection of objects is called a set.
2. FUNCTION : A and B are two non-empty sets. Then a relation ' $f$ ' from A to B, which associates every element of A to a unique element of B is called a Function.
3. DOMAIN, CO-DOMAIN :  $f : A \rightarrow B$  is a function. Then A = Domain and B = Co-domain
4. IMAGE , PRE-IMAGE :  $f : A \rightarrow B$  is a function if  $f(a) = b$  for  $a \in A, b \in B$ , then ' $b$ ' is image of ' $a$ ' and ' $a$ ' is pre-image of ' $b$ '.
5. RANGE : The set of all images of the elements of A in B is called a Range.  
Range of  $f \subseteq$  codomain of  $f$ .
6. INJECTION (OR)  
ONE ONE FUNCTION :  $f : A \rightarrow B$  is one - one  $\Leftrightarrow$   
 $a_1, a_2 \in A, f(a_1) = f(a_2) \Rightarrow a_1 = a_2$
7. SURJECTION (OR)  
ONTO FUNCTION :  $f : A \rightarrow B$  is onto if  $\forall b \in B \exists a \in A \ni f(a) = b$  or  
 $f : A \rightarrow B$  is onto  $\Leftrightarrow$  Range of  $f =$  codomain of  $f$  ( Mar-2017 )  
( May-2016 )  
( TS Mar-2016 )  
( TS Mar-2017 )
8. BIJECTION (OR)  
ONE-ONE ONTO  
FUNCTION : If  $f : A \rightarrow B$  is both one-one and onto, then  $f$  is called a Bijection.
9. IDENTITY  
FUNCTION : A function  $f : A \rightarrow A$  is defined by  $f(x) = x, \forall x \in A$  is called Identity function and is denoted by  $I_A$
10. INVERSE FUNCTION : If  $f : A \rightarrow B$  is a bijection, then  $f^{-1} : B \rightarrow A$  defined as  $f^{-1}(b) = a \Leftrightarrow f(a) = b, \forall b \in B$  is called inverse function.
11. CONSTANT FUNCTION : A function  $f : A \rightarrow B$  is said to be constant if  $f(x) = c$  ( a constant )  
 $\forall x \in A$
12. EVEN AND ODD FUNCTIONS : Let  $f : A \rightarrow R$  be a function
  - If  $f(-x) = f(x), \forall x \in A$  then f is called an even function
  - If  $f(-x) = -f(x), \forall x \in A$  then f is called an odd function
13. GREATEST INTEGER FUNCTION : For any real number x, we denote by  $[x]$  the greatest integer less than or equal to x  
ie,  $[x] = n$ , if  $n \leq x < n+1$ , where n is integer.  
The function  $f : R \rightarrow Z$  defined by  $f(x) = [x], \forall x \in R$  is called greatest

integer function.(Eamcet-2006)

**14. Composition function :**

- i) Let  $f: A \rightarrow B, g: B \rightarrow C$  be functions then  $(gof): A \rightarrow C$  is a function and  $(gof)(a) = g(f(a))$  for all  $a \in A$ .

15. If  $f: A \rightarrow B, g: B \rightarrow C$  are bijections so is  $(gof): A \rightarrow C$  and  $(gof)^{-1} = f^{-1}og^{-1}$

**16. ALGEBRA OF REAL VALUED FUNCTIONS :**

**PROPERTIES :** If  $f$  and  $g$  are real valued functions with domain  $A$  &  $B$  respectively. Then both  $f$  and  $g$  are defined on  $A \cap B$  when  $A \cap B \neq \emptyset$ .

- i) Let  $f: A \rightarrow R$  and  $g: B \rightarrow R$  then  $f+g, f-g$  and  $fg$  are defined on  $A \cap B$  as  $(f \pm g)(x) = f(x) \pm g(x)$  and  $(fg)(x) = f(x)g(x)$

- ii) Let  $f: A \rightarrow R$  be a function and  $k$  be a constant then from the above definition

$(f+k)(x) = f(x) + k$  and  $(kf)(x) = k f(x)$  for all  $x \in A$ . The function  $(-1)f$  is defined by  $-f$

- iii) Let  $f: A \rightarrow R, g: B \rightarrow R, c = \{x \in A \cap B / g(x) \neq 0\} \neq \emptyset$ , then  $\frac{f}{g}$  defined on  $c$  as

$$\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)} \quad \forall x \in c$$

Note :- If  $g(x) = 0$ , then  $\frac{f(x)}{g(x)}$  is not defined.

- iv) Let  $f: A \rightarrow R$  and  $n \in N$  then  $|f|, f^n$  are defined on  $A$  as  $|f|(x) = |f(x)|$  and

$$f^n(x) = (f(x))^n \text{ for all } x \in A$$

- v) Let  $f: A \rightarrow R, c = \{x \in A / f(x) \geq 0\} \neq \emptyset$ , then  $\sqrt{f}$  defined on  $c$  as

$$\sqrt{f}(x) = \sqrt{f(x)} \quad \forall x \in c$$

(Mar 2017)

## MATHEMATICAL INDUCTION

1. Steps to prove a statement using the principle of mathematical induction

(i) Basis of induction : show that  $P(1)$  is true

(ii) Inductive hypothesis : For  $k \geq 1$  assume that  $P(k)$  is true

(iii) Inductive step : show that  $P(k+1)$  is true on the basis of the inductive hypothesis

2.  $\sum_{n=1}^{\infty} 1+2+3+\dots+n = \frac{n(n+1)}{2}$

3.  $\sum n^2 = 1^2 + 2^2 + 3^2 + \dots + n^2 = \frac{n(n+1)(2n+1)}{6}$  (IPE March-09,12, May-09)

4.  $\sum n^3 = 1^3 + 2^3 + 3^3 + \dots + n^3 = \frac{n^2(n+1)^2}{4}$  (IPE March-05,07)

5.  $1 + 3 + 5 + \dots + (2n-1) = n^2$

6.  $2 + 4 + 6 + \dots + (2n) = n(n+1)$

7. A.P. series :  $a + (a+d) + (a+2d) + \dots$

i)  $n^{\text{th}}$  term =  $a + (n-1)d$

$t_n = s_n - s_{n-1}$

ii) sum of first n terms of an A.P

$$= s_n = \sum t_n = \frac{n}{2} [2a + (n-1)d] \text{ where "a" is the first term, "d" is common difference of an A.P.}$$

8. G.P. series :  $a + ar + ar^2 + ar^3 + \dots$

i)  $n^{\text{th}}$  term =  $t_n = a \cdot r^{n-1}$

ii) sum of first n terms =  $s_n = \frac{a(r^n - 1)}{r - 1}$  if  $r > 1$

iii) sum of infinite terms =  $S_\infty = \frac{a}{1-r}$  ( $|r| < 1$ )

### MATRICES & DETERMINANTS

#### 1. Order:

(i) A matrix having 'm' rows and 'n' columns then its order is  $m \times n$  (Eamcet-94)

(ii) A general  $3 \times 3$  matrix is  $A_{3 \times 3} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}_{3 \times 3}$

#### 2. Trace:

The sum of the principal diagonal elements of a square matrix is called the trace of a matrix denoted by  $Tr(A)$ . (Eamcet-92)

NOTE: Trace of the above matrix is  $Tr(A) = a_{11} + a_{22} + a_{33}$

#### 3. Different types of matrices:

(i) A square matrix A is said to be a **diagonal matrix** if every non diagonal element is zero.

eg:  $A_{3 \times 3} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}_{3 \times 3}$

(ii) A square matrix A is said to be a **scalar matrix** if every non diagonal element is zero and every

diagonal element is equal.

$$\text{eg: } A_{3 \times 3} = \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix}_{3 \times 3}$$

(iii) A square matrix A is said to be an unit matrix or identity matrix if every non diagonal element is zero and every diagonal element is unity. It is denoted by I.

$$\text{eg: } I_{3 \times 3} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}_{3 \times 3}$$

#### 4. Transpose of a matrix ( $A^T$ ):

In a square matrix interchanging of elements of rows and columns is known as transpose of a matrix.

**A is symmetric matrix if  $A^T = A$**  (IPE March-05 Jun-05, May-07)

**A is skew-symmetric matrix if  $A^T = -A$**  (IPE March-05,09, Jun-05, May-07,11)

NOTE: In a skew-symmetric matrix, every principal diagonal element is zero.

#### 5. Determinants:

(i)  $|A| = 0 \Leftrightarrow A$  is singular (Eamcet-95,07)

$|A| \neq 0 \Leftrightarrow A$  is non-singular

(ii)  $|kA| = k^3 |A|$  if A is a matrix of order  $3 \times 3$

#### 6. Properties of determinants:

(i) The sign of the determinant changes sign when any two rows (or columns) are interchanged

(ii) Two rows (or columns) are identical or proportional the value of the determinant is zero

(iii) If each element of a row (or column) is the sum of two terms then its determinant can be expressed as the sum of two determinants of the same order.

(iv) The sum of the products of the elements of any row (or column) with the cofactors of the corresponding elements of any other row (or column) is zero.

#### 7. Adjoint of a matrix:

The transpose of square matrix obtained by replacing the elements by their corresponding cofactors. It is denoted by  $\text{Adj } A$ . (IPE March-2009, 2013)

**8. Inverse of a Matrix:** For the matrix A and identity matrix I if  $AB = BA = I$  then that matrix B is inverse matrix and A is invertable.

(i)  $(AB)^{-1} = B^{-1}A^{-1}$

(ii)  $A^{-1} = \frac{\text{adj } A}{|A|}$  where  $|A| \neq 0$  (Eamcet-90) (IPE March-2013, May-11,12,Mar-17)

#### 9. Rank of a matrix: (Eamcet-04) (IPE March-08,12, Jun-10)

Let A be a non zero matrix. The rank of A is defined as the maximum of the orders of the non singular square sub matrices of A.

NOTE: 1. If A is a non zero matrix of order  $3 \times 3$ ,

- (i) The rank of A is 3, if A is non - singular.
- (ii) The rank of A is 2, if A is singular and at least one of the  $2 \times 2$  sub matrix is non singular.
- (iii) The rank of A is 1, if every  $2 \times 2$  sub matrices are singular.

2. The rank of null matrix is zero.

**10. Triangular matrix :** In a square matrix  $A = [a_{ij}]$  (TS Mar 2016)

- (i) If  $i > j$  and  $a_{ij} = 0$  then that matrix A is an upper triangular matrix
- (ii) If  $i < j$  and  $a_{ij} = 0$  then that matrix A is a lower triangular matrix

**11. Consistent and Inconsistent systems:** (IPE March-05, May-02,11) (Eamcet-94,03)

A system of linear equations is said to be consistent if it has a solution. Otherwise the system is said to be inconsistent.

NOTE: 1. A non homogenous system of 3 equations in three unknowns  $AX = D$  has

- (i) unique solution if  $\text{Rank}(A) = \text{Rank}(AD) = 3$
- (ii) infinitely many solutions if  $\text{Rank}(A) = \text{Rank}(AD) < 3$
- (iii) no solution if  $\text{Rank}(A) \neq \text{Rank}(AD)$

2. A homogenous system of 3 equations with 3 unknowns  $AX=O$  has

- (i) unique solution (trivial solution) if  $\text{Rank}(A) = 3$  or  $\det A \neq 0$
- (ii) infinitely many solutions if  $\text{Rank } A < 3$  or  $\det A = 0$

**12. (i) Matrix Inversion method:** (IPE March-2013, May-11,12)

$$AX = D \Leftrightarrow X = A^{-1}D$$

(ii) Cramer's Rule: (IPE March-12)

$$x = \frac{\Delta_1}{\Delta}, \quad y = \frac{\Delta_2}{\Delta}, \quad z = \frac{\Delta_3}{\Delta} \quad \text{where } \Delta \neq 0,$$

$$\text{Where, } \Delta = \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}, \quad \Delta_1 = \begin{vmatrix} d_1 & b_1 & c_1 \\ d_2 & b_2 & c_2 \\ d_3 & b_3 & c_3 \end{vmatrix}, \quad \Delta_2 = \begin{vmatrix} a_1 & d_1 & c_1 \\ a_2 & d_2 & c_2 \\ a_3 & d_3 & c_3 \end{vmatrix}, \quad \Delta_3 = \begin{vmatrix} a_1 & b_1 & d_1 \\ a_2 & b_2 & d_2 \\ a_3 & b_3 & d_3 \end{vmatrix}$$

(iii) Gauss - Jordan method: (IPE March-09,10, May-10)

Transform the augmented matrix

$$\left[ \begin{array}{cccc} a_1 & b_1 & c_1 & d_1 \\ a_2 & b_2 & c_2 & d_2 \\ a_3 & b_3 & c_3 & d_3 \end{array} \right] \text{ to the form } \left[ \begin{array}{cccc} 1 & 0 & 0 & \alpha \\ 0 & 1 & 0 & \beta \\ 0 & 0 & 1 & \gamma \end{array} \right] \text{ then } x = \alpha, y = \beta, z = \gamma$$

v **Gauss Jordan Method working rule:**

- i) Write Augmented matrix [AD]

ii) To bring unit matrix  $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$  in [AD]

- iii) By using first row we have to bring two zeros in first column
- iv) By using second row we have to bring two zeros in second column
- v) By using third row we have to bring two zeros in third column

vi) Augmented matrix we get  $\begin{bmatrix} 1 & 0 & 0 & x \\ 0 & 1 & 0 & y \\ 0 & 0 & 1 & z \end{bmatrix}$

### ADDITION OF VECTORS

1. a) Vectors  $\bar{a}, \bar{b}$  are collinear (linearly dependent)  $\Leftrightarrow \bar{a} = t\bar{b}$ ,  $t$  is scalar. (Eamcet-07)
- b) Vectors  $\bar{a} = a_1\bar{i} + a_2\bar{j} + a_3\bar{k}$  and  $\bar{b} = b_1\bar{i} + b_2\bar{j} + b_3\bar{k}$  are collinear  $\Leftrightarrow \frac{a_1}{b_1} = \frac{a_2}{b_2} = \frac{a_3}{b_3}$  (TS Mar-17), (May-16)
- c)  $A, B, C$  are collinear  $\Leftrightarrow \overline{AB} = t(\overline{AC})$ ,  $t$  is scalar
2. If  $\bar{r} = x\bar{i} + y\bar{j} + z\bar{k}$  and  $\alpha, \beta, \gamma$  are the angles made by  $\bar{r}$  with  $\overline{OX}, \overline{OY}, \overline{OZ}$  respectively, then Modulus of  $\bar{r}$  is  $|\bar{r}|$  and  $|\bar{r}| = \sqrt{x^2 + y^2 + z^2}$
3. Unit vector i) along  $\bar{r} = \frac{\bar{r}}{|\bar{r}|}$  ii) opposite to  $\bar{r} = -\frac{\bar{r}}{|\bar{r}|}$  iii) parallel to  $\bar{r} = \pm \frac{\bar{r}}{|\bar{r}|}$  (TS Mar-2016)
4. The vector equation of the line passing through the point whose position vector is  $\bar{a}$  and parallel to the vector  $\bar{b}$  is  $\bar{r} = \bar{a} + t\bar{b}$ ,  $t \in R$
5. The vector equation of the line joining points whose position vectors are  $\overline{OA}$  and  $\overline{OB}$  is  $\bar{r} = (1-t)\bar{a} + t\bar{b}$  where  $t \in R$ . ( $\because \overline{OA} = \bar{a}, \overline{OB} = \bar{b}$ )
6. The vector equation of the plane passing through the points whose position vectors  $\overline{OA}, \overline{OB}, \overline{OC}$  is  $\bar{r} = (1-s-t)\bar{a} + s\bar{b} + t\bar{c}$  where  $s, t \in R$   $\because \overline{OA} = \bar{a}, \overline{OB} = \bar{b}, \overline{OC} = \bar{c}$  (Mar 2017)
7. The vector equation of the plane passing through the point  $A(\bar{a})$  and parallel to the vector  $\bar{b}$  and  $\bar{c}$  is  $\bar{r} = \bar{a} + t\bar{b} + s\bar{c}$ ,  $t, s \in R$
8. The equation of the plane passing through the points  $A(\bar{a}), B(\bar{b})$  and parallel to the vector  $\bar{c}$  is  $\bar{r} = (1-t)\bar{a} + t\bar{b} + s\bar{c}$ ,  $t, s \in R$

### PRODUCT OF VECTORS

1.  $\bar{a}, \bar{b}$  are two vectors, then
  - a) If  $\bar{a} = a_1\bar{i} + a_2\bar{j} + a_3\bar{k}$  and  $\bar{b} = b_1\bar{i} + b_2\bar{j} + b_3\bar{k}$  then  $\bar{a} \cdot \bar{b} = a_1b_1 + a_2b_2 + a_3b_3$

b)  $\bar{a} \cdot \bar{b} = 0 \Leftrightarrow \bar{a} = \bar{0}$  (or)  $\bar{b} = \bar{0}$  (or)  $\bar{a} \perp \bar{b}$ .

c)  $\text{Cos}(\bar{a}, \bar{b}) = \frac{\bar{a} \cdot \bar{b}}{|\bar{a}| |\bar{b}|}$  (TS Mar 2017)

2.  $\bar{i} \cdot \bar{i} = \bar{j} \cdot \bar{j} = \bar{k} \cdot \bar{k} = 1; \quad \bar{i} \cdot \bar{j} = \bar{j} \cdot \bar{k} = \bar{k} \cdot \bar{i} = 0$

3. If  $\bar{a} = a_1 \bar{i} + a_2 \bar{j} + a_3 \bar{k}$ ,  $\bar{b} = b_1 \bar{i} + b_2 \bar{j} + b_3 \bar{k}$ , then  $\bar{a} \times \bar{b} = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}$  (IPE Mar-13)

4. (i)  $\bar{i} \times \bar{i} = \bar{j} \times \bar{j} = \bar{k} \times \bar{k} = \bar{0}$

(ii)  $\bar{i} \times \bar{j} = \bar{k}$ ,  $\bar{j} \times \bar{k} = \bar{i}$ ,  $\bar{k} \times \bar{i} = \bar{j}$

(iii)  $\bar{i} \times \bar{k} = -\bar{j}$ ,  $\bar{k} \times \bar{j} = -\bar{i}$ ,  $\bar{j} \times \bar{i} = -\bar{k}$  ( $\because \bar{i}, \bar{j}, \bar{k}$  are in right handed system)

5. a)  $\bar{a} = a_1 \bar{i} + a_2 \bar{j} + a_3 \bar{k}$ ,  $\bar{b} = b_1 \bar{i} + b_2 \bar{j} + b_3 \bar{k}$ ,  $\bar{c} = c_1 \bar{i} + c_2 \bar{j} + c_3 \bar{k}$  then

$$\begin{bmatrix} \bar{a} & \bar{b} & \bar{c} \end{bmatrix} = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} \quad (\text{Mar 2017})$$

b)  $[\bar{AB} \bar{AC} \bar{AD}] = 0 \Leftrightarrow$  the points A, B, C, D are coplanar (TS Mar 2016)

6. The shortest distance between two skew lines  $\bar{r} = \bar{a} + t\bar{b}$  and  $\bar{r} = \bar{c} + s\bar{d}$  is  $\frac{|\bar{a} - \bar{c} \cdot \bar{b} \cdot \bar{d}|}{|\bar{b} \times \bar{d}|}$  (May-16)

### VECTOR PRODUCT OF THREE VECTORS:

7. i)  $(\bar{a} \times \bar{b}) \times \bar{c} = (\bar{c} \cdot \bar{a}) \bar{b} - (\bar{c} \cdot \bar{b}) \bar{a}$  ii)  $\bar{a} \times (\bar{b} \times \bar{c}) = (\bar{a} \cdot \bar{c}) \bar{b} - (\bar{a} \cdot \bar{b}) \bar{c}$

8.  $\bar{a}$  is perpendicular to both  $\bar{b}$  and  $\bar{c}$  then  $\bar{a}$  is parallel to  $\bar{b} \times \bar{c}$  i.e.,  $(\bar{a}, \bar{b} \times \bar{c}) = 0^\circ$  or  $180^\circ$

9. Unit vector perpendicular to the plane determined by the points P, Q and R is  $\pm \frac{\overrightarrow{PQ} \times \overrightarrow{PR}}{|\overrightarrow{PQ} \times \overrightarrow{PR}|}$  (Mar-17)

10. Volume of parallelopiped having co-terminous edges  $\bar{a}, \bar{b}$  and  $\bar{c}$  is  $V = |\begin{bmatrix} \bar{a} & \bar{b} & \bar{c} \end{bmatrix}|$

11. a) Volume of the tetrahedron having co-terminous edges  $\bar{a}, \bar{b}, \bar{c}$  is  $V = \frac{1}{6} |\begin{bmatrix} \bar{a} & \bar{b} & \bar{c} \end{bmatrix}|$  (Mar-16)

b) Volume of the tetrahedron having vertices A, B, C, D is  $V = \frac{1}{6} |\begin{bmatrix} \bar{AB} & \bar{AC} & \bar{AD} \end{bmatrix}|$

12..  $|\bar{a} \times \bar{b}| = |\bar{a}| |\bar{b}| \sin \theta$

13. The vector area of  $\Delta ABC$  is  $\frac{1}{2}(\overrightarrow{AB} \times \overrightarrow{AC}) = \frac{1}{2}(\overrightarrow{BC} \times \overrightarrow{BA}) = \frac{1}{2}(\overrightarrow{CA} \times \overrightarrow{CB})$

14. Area of  $\Delta ABC$  is  $\frac{1}{2}|\overrightarrow{AB} \times \overrightarrow{AC}| = \frac{1}{2}|\overrightarrow{BC} \times \overrightarrow{BA}| = \frac{1}{2}|\overrightarrow{CA} \times \overrightarrow{CB}|$

15. The vector area of any plane quadrilateral

i) ABCD interms of the diagonals AC and BD is  $\frac{1}{2}(\overrightarrow{AC} \times \overrightarrow{BD})$

ii) The area of the quadrilateral ABCD is  $\frac{1}{2}|\overrightarrow{AC} \times \overrightarrow{BD}|$

iii) The vector area of a parallelogram with  $\vec{a}$  and  $\vec{b}$  as adjacentsides is  $\vec{a} \times \vec{b}$  and the area is  $|\vec{a} \times \vec{b}|$

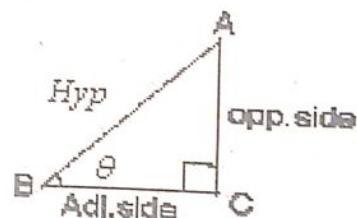
( TS May-2016)

16. The vector equation of plane passing through the intersectio of the planes  $r.n_1 = d_1$  and  $r.n_2 = d_2$  is  $r.(n_1 + \lambda n_2) = d_1 + \lambda d_2$ ,  $\lambda$  is scalar

17. The equation of plane passing through the points A,B and C is  $[\overrightarrow{AP} \overrightarrow{AB} \overrightarrow{AC}] = 0$ , here  $P = (x, y, z)$

### TRIGONOMETRIC RATIOS UPTO TRANSFORMATIONS

1. a.  $\sin \theta = \frac{\text{opp side to } \theta}{\text{Hyp}} = \frac{AC}{AB}$



b.  $\cos \theta = \frac{\text{Adj side to } \theta}{\text{Hyp}} = \frac{BC}{AB}$

c.  $\tan \theta = \frac{\text{Opp to } \theta}{\text{Adj to } \theta} = \frac{AC}{BC}$

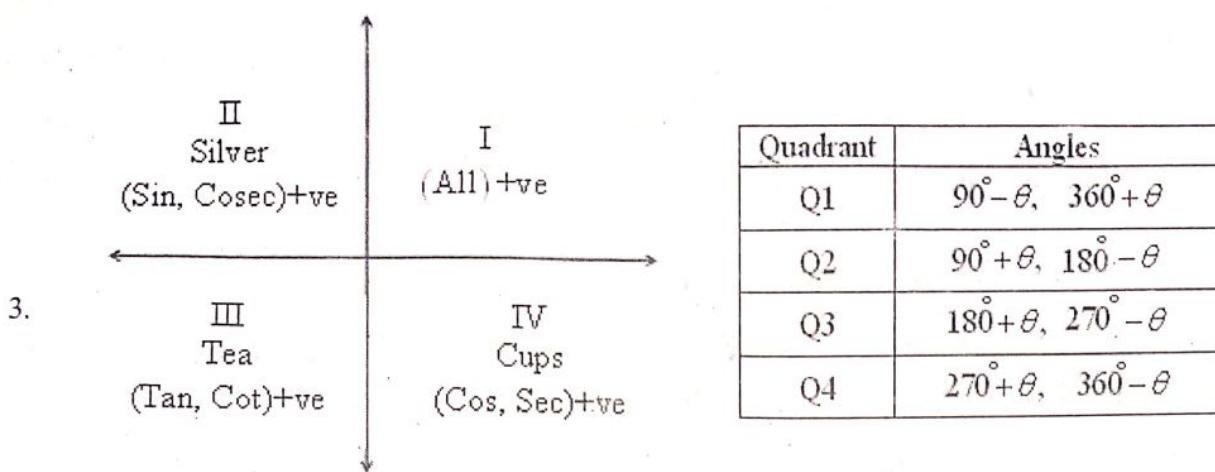
2. a.  $\tan \theta = \frac{\sin \theta}{\cos \theta}$

b.  $\cot \theta = \frac{\cos \theta}{\sin \theta}$

c.  $\cosec \theta = \frac{1}{\sin \theta} \Rightarrow \sin \theta \cosec \theta = 1$

d.  $\sec \theta = \frac{1}{\cos \theta} \Rightarrow \cos \theta \sec \theta = 1$

e.  $\tan \theta = \frac{1}{\cot \theta} \Rightarrow \cot \theta \tan \theta = 1$



3. a. For  $90^\circ \pm \theta, 270^\circ \pm \theta$ , Trigonometric functions Changes as  
 $\sin \leftrightarrow \cos, \tan \leftrightarrow \cot, \sec \leftrightarrow \cosec$
- b. For  $180^\circ \pm \theta, 360^\circ \pm \theta$  no changes
4. a.  $\sin(-\theta) = -\sin \theta$       b.  $\cosec(-\theta) = -\cosec \theta$   
 c.  $\cos(-\theta) = +\cos \theta$       d.  $\sec(-\theta) = +\sec \theta$   
 e.  $\tan(-\theta) = -\tan \theta$       f.  $\cot(-\theta) = -\cot \theta$
5. a.  $\sin^2 \theta + \cos^2 \theta = 1 \Rightarrow \sin^2 \theta = 1 - \cos^2 \theta \Rightarrow \cos^2 \theta = 1 - \sin^2 \theta$   
 b.  $\sec^2 \theta - \tan^2 \theta = 1 \Rightarrow \sec^2 \theta = 1 + \tan^2 \theta \Rightarrow \tan^2 \theta = \sec^2 \theta - 1$   
 $\Rightarrow (\sec \theta + \tan \theta)(\sec \theta - \tan \theta) = 1 \Rightarrow \sec \theta - \tan \theta = \frac{1}{\sec \theta + \tan \theta}$   
 c.  $\cosec^2 \theta - \cot^2 \theta = 1 \Rightarrow \cosec^2 \theta = 1 + \cot^2 \theta \Rightarrow \cot^2 \theta = \cosec^2 \theta - 1$   
 $\Rightarrow (\cosec \theta + \cot \theta)(\cosec \theta - \cot \theta) = 1 \Rightarrow \cosec \theta - \cot \theta = \frac{1}{\cosec \theta + \cot \theta}$

Angle	$0^\circ$	$30^\circ$	$45^\circ$	$60^\circ$	$90^\circ$	$180^\circ$	$270^\circ$	$360^\circ$
sin	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1	0	-1	0
cos	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0	-1	0	1
tan	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	$\infty$	0	$\infty$	0

### PERIODICITY AND EXTREME VALUES

8. If  $f(x+k) = f(x)$  then  $f(x)$  is called a periodic function with period k . (where k is the least +ve real value)

**JR MATHS-IA**

9. a. (i) The period of  $\sin ax, \cos ax, \sec ax, \cosec ax$  is  $2\pi/|a|$  (Mar 2016)  
(ii) The period of  $\sin x, \cos x, \sec x, \cosec x$  is  $2\pi$  (IPE March-2013)
- b. (i) The period of  $\tan ax, \cot ax$  is  $\pi/|a|$  (Eamcet-97) (May -2016)  
(ii) The period of  $\tan x, \cot x$  is  $\pi$
10. a. The period of  $a \cos^n x + b \sin^n x$  is  $\frac{\pi}{2}$  if  $a = b$  and  $n$  is +ve even  
b. The period of  $a \cos^n x + b \sin^n x$  is  $\pi$  is  $a \neq b$  and  $n$  is +ve even  
c. The period of  $a \cos^n x + b \sin^n x$  is  $2\pi$  if  $n$  is odd
11. The period of  $f(x) \pm g(x), \frac{f(x)}{g(x)}$  is the L.C.M. of the periods of  $f(x)$  and  $g(x)$  (Eamcet-03)
12. a. Maximum value of  $a \cos \alpha + b \sin \alpha + c$  is  $c + \sqrt{a^2 + b^2}$  (Eamcet-06) (Mar-2017)  
b. Minimum value of  $a \cos \alpha + b \sin \alpha + c$  is  $c - \sqrt{a^2 + b^2}$

**COMPOUND ANGLES**

13. a.  $\sin(A+B) = \sin A \cos B + \cos A \sin B$       b.  $\sin(A-B) = \sin A \cos B - \cos A \sin B$   
c.  $\cos(A+B) = \cos A \cos B - \sin A \sin B$       d.  $\cos(A-B) = \cos A \cos B + \sin A \sin B$   
e.  $\tan(A+B) = \frac{\tan A + \tan B}{1 - \tan A \tan B}$       f.  $\tan(A-B) = \frac{\tan A - \tan B}{1 + \tan A \tan B}$   
g.  $\cot(A+B) = \frac{\cot B \cdot \cot A - 1}{\cot B + \cot A}$       h.  $\cot(A-B) = \frac{\cot B \cdot \cot A + 1}{\cot B - \cot A}$   
i.  $\tan\left(\frac{\pi}{4} + A\right) = \frac{1 + \tan A}{1 - \tan A} = \frac{\cos A + \sin A}{\cos A - \sin A}$       j.  $\cot\left(\frac{\pi}{4} + A\right) = \frac{\cot A - 1}{\cot A + 1} = \frac{\cos A - \sin A}{\cos A + \sin A}$
14. a.  $\sin(A+B) \sin(A-B) = \sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A$   
b.  $\cos(A+B) \cos(A-B) = \cos^2 A - \sin^2 B = \cos^2 B - \sin^2 A$

Angle	$15^\circ$	$75^\circ$
sin	$\frac{\sqrt{3}-1}{2\sqrt{2}}$	$\frac{\sqrt{3}+1}{2\sqrt{2}}$
cos	$\frac{\sqrt{3}+1}{2\sqrt{2}}$	$\frac{\sqrt{3}-1}{2\sqrt{2}}$
Tan	$2-\sqrt{3}$	$2+\sqrt{3}$
cot	$2+\sqrt{3}$	$2-\sqrt{3}$

MULTIPLE & SUB MULTIPLE ANGLES

16. a.  $\sin 2A = 2 \sin A \cos A = \frac{2 \tan A}{1 + \tan^2 A}$

b.  $\cos 2A = \cos^2 A - \sin^2 A = 2 \cos^2 A - 1 = 1 - 2 \sin^2 A = \frac{1 - \tan^2 A}{1 + \tan^2 A}$

c.  $\tan 2A = \frac{2 \tan A}{1 - \tan^2 A}$

d.  $\cot 2A = \frac{\cot^2 A - 1}{2 \cot A}$

17. a.  $\sin A = 2 \sin \frac{A}{2} \cos \frac{A}{2} = \frac{2 \tan \frac{A}{2}}{1 + \tan^2 \frac{A}{2}}$

b.  $\cos A = \cos^2 \frac{A}{2} - \sin^2 \frac{A}{2} = 2 \cos^2 \frac{A}{2} - 1 = 1 - 2 \sin^2 \frac{A}{2} = \frac{1 - \tan^2 \frac{A}{2}}{1 + \tan^2 \frac{A}{2}}$

c.  $\tan A = \frac{2 \tan \frac{A}{2}}{1 - \tan^2 \frac{A}{2}}$

d.  $\cot A = \frac{\cot^2 \frac{A}{2} - 1}{2 \cot \frac{A}{2}}$

18. a.  $1 + \cos 2A = 2 \cos^2 A$

b.  $1 + \cos A = 2 \cos^2 \frac{A}{2}$

c.  $1 - \cos 2A = 2 \sin^2 A$

d.  $1 - \cos A = 2 \sin^2 \frac{A}{2}$

19. For any  $A \in R$ ,

a.  $\sin A = \pm \sqrt{\frac{1 - \cos 2A}{2}}$

b.  $\cos A = \pm \sqrt{\frac{1 + \cos 2A}{2}}$

c.  $\tan A = \pm \sqrt{\frac{1 - \cos 2A}{1 + \cos 2A}}$

20. a.  $\sin \frac{A}{2} = \pm \sqrt{\frac{1 - \cos A}{2}}$

b.  $\cos \frac{A}{2} = \pm \sqrt{\frac{1 + \cos A}{2}}$

c.  $\tan \frac{A}{2} = \pm \sqrt{\frac{1 - \cos A}{1 + \cos A}}$

21. a.  $\sin 3A = 3 \sin A - 4 \sin^3 A$

b.  $\cos 3A = 4 \cos^3 A - 3 \cos A$

c.  $\tan 3A = \frac{3 \tan A - \tan^3 A}{1 - 3 \tan^2 A}$

d.  $\sin A = 3 \sin A / 3 - 4 \sin^3 A / 3$

e.  $\cos A = 4 \cos^3 A / 3 - 3 \cos A / 3$

f.  $\tan A = \frac{3 \tan A / 3 - \tan^3 A / 3}{1 - 3 \tan^2 A / 3}$

g.  $\cot A = \frac{3 \cot A / 3 - \cot^3 A / 3}{1 - 3 \cot^2 A / 3}$

22. **Compodendo - Dividendo Rule :** If  $\frac{a}{b} = \frac{c}{d} \Leftrightarrow \frac{a+b}{a-b} = \frac{c+d}{c-d}$  then this principle is called compodendo

- dividendo rule when  $b \neq 0, d \neq 0$

<i>Agnle</i>	$18^0$	$36^0$	$54^0$	$72^0$
$\sin$	$\frac{\sqrt{5}-1}{4}$	$\frac{\sqrt{10-2\sqrt{5}}}{4}$	$\frac{\sqrt{5}+1}{4}$	$\frac{\sqrt{10+2\sqrt{5}}}{4}$
$\cos$	$\frac{\sqrt{10+2\sqrt{5}}}{4}$	$\frac{\sqrt{5}+1}{4}$	$\frac{\sqrt{10-2\sqrt{5}}}{4}$	$\frac{\sqrt{5}-1}{4}$

## TRANSFORMATIONS

24. a.  $\sin(A+B) + \sin(A-B) = 2 \sin A \cos B$   
      b.  $\sin(A+B) - \sin(A-B) = 2 \cos A \sin B$   
      c.  $\cos(A+B) + \cos(A-B) = 2 \cos A \cos B$  (Eamcet-95,02)  
      d.  $\cos(A+B) - \cos(A-B) = -2 \sin A \sin B$   
      e.  $\cos(A-B) - \cos(A+B) = 2 \sin A \sin B$

25. a.  $\sin C + \sin D = 2 \sin\left(\frac{C+D}{2}\right) \cdot \cos\left(\frac{C-D}{2}\right)$   
      b.  $\sin C - \sin D = 2 \cos\left(\frac{C+D}{2}\right) \cdot \sin\left(\frac{C-D}{2}\right)$   
      c.  $\cos C + \cos D = 2 \cos\left(\frac{C+D}{2}\right) \cdot \cos\left(\frac{C-D}{2}\right)$  (Eamcet-95,03)  
      d.  $\cos C - \cos D = -2 \sin\left(\frac{C+D}{2}\right) \cdot \sin\left(\frac{C-D}{2}\right) = 2 \sin\left(\frac{C+D}{2}\right) \cdot \sin\left(\frac{D-C}{2}\right)$

## TRIGONOMETRIC EQUATIONS

1. a. The general solution of  $\sin \theta = 0$ ,  $\tan \theta = 0$  is  $\theta = n\pi$ ,  $\forall n \in Z$  (Eamcet-89,90,97)

b.  $\cos \theta = 0$  then G.S. is  $\theta = (2n+1)\frac{\pi}{2}$ ,  $\forall n \in Z$  (Eamcet-83,03)

2. a. If  $\sin \theta = \sin \alpha$  then G.S.  $\theta = n\pi + (-1)^n \alpha$ ,  $\forall n \in Z$ ,  $\frac{-\pi}{2} \leq \alpha \leq \frac{\pi}{2}$

b. If  $\cos \theta = \cos \alpha$  then G.S.  $\theta = 2n\pi \pm \alpha$ ,  $\forall n \in Z$ ,  $0 \leq \alpha \leq \pi$  (Eamcet-86)

c. If  $\tan \theta = \tan \alpha$  then G.S. of  $\theta = n\pi + \alpha$ ,  $\forall n \in Z$ ,  $\frac{-\pi}{2} < \alpha < \frac{\pi}{2}$  (Eamcet-81,99)

3. If  $\sin^2 \theta = \sin^2 \alpha$ ,  $\cos^2 \theta = \cos^2 \alpha$ ,  $\tan^2 \theta = \tan^2 \alpha$  then G.S. is  $\theta = n\pi \pm \alpha$ ,  $\forall n \in Z$  (EAM-87)

4. Common Solution (or) G. S. of Two trigonometric equations is  $\theta = 2n\pi + \alpha$ ,  $0 \leq \alpha < 2\pi$ ,  $\forall n \in Z$  (Eamcet-96)

## INVERSE TRIGONOMETRIC FUNCTIONS

1. a)  $\sin^{-1}(-x) = -\sin^{-1}(x)$  b)  $\cos^{-1}(-x) = \pi - \cos^{-1}(x)$   
c)  $\tan^{-1}(-x) = -\tan^{-1}(x)$
2. a)  $\sin^{-1}(\sin \theta) = \theta, \theta \in \left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$  b)  $\cos^{-1}(\cos \theta) = \theta, \theta \in [0, \pi]$   
c)  $\tan^{-1}(\tan \theta) = \theta, \theta \in \left(-\frac{\pi}{2}, \frac{\pi}{2}\right)$
3. a.  $\sin^{-1} x + \cos^{-1} x = \frac{\pi}{2}, \forall x \in [-1, 1]$  b.  $\tan^{-1} x + \cot^{-1} x = \frac{\pi}{2}, \forall x \in \mathbb{R}$
4. a.  $\sin^{-1} x \pm \sin^{-1} y = \sin^{-1} \left[ x\sqrt{1-y^2} \pm y\sqrt{1-x^2} \right]$  (Eamcet-83,01,08) (AIEEE-07)  
b.  $\cos^{-1} x \pm \cos^{-1} y = \cos^{-1} \left[ xy \mp \sqrt{1-x^2} \sqrt{1-y^2} \right]$   
c.  $\tan^{-1} x + \tan^{-1} y = \tan^{-1} \left[ \frac{x+y}{1-xy} \right], \text{ if } x>0, y>0 \text{ and } xy<1$  (EAM-98,99)  
d.  $\tan^{-1} x + \tan^{-1} y = \pi + \tan^{-1} \left[ \frac{x+y}{1-xy} \right], \text{ if } x>0, y>0 \text{ and } xy>1$   
e.  $\tan^{-1} x + \tan^{-1} y = \frac{\pi}{2}, \text{ if } xy=1$   
f.  $\tan^{-1} x - \tan^{-1} y = \tan^{-1} \left[ \frac{x-y}{1+xy} \right]$  (Eamcet-92)  
g.  $\tan^{-1}(x) + \tan^{-1}(y) + \tan^{-1}(z) = \tan^{-1} \left( \frac{x+y+z-xyz}{1-xy-yz-zx} \right)$
5.  $2 \tan^{-1} x = \tan^{-1} \left( \frac{2x}{1-x^2} \right) = \sin^{-1} \left( \frac{2x}{1+x^2} \right) = \cos^{-1} \left( \frac{1-x^2}{1+x^2} \right)$  (Eamcet-83)

## HYPERBOLIC FUNCTIONS

1. a)  $e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$  b)  $e^{-x} = 1 - \frac{x}{1!} + \frac{x^2}{2!} - \frac{x^3}{3!} + \dots$
2. a)  $\sinh x = \frac{e^x - e^{-x}}{2}$  b)  $\cosh x = \frac{e^x + e^{-x}}{2}$   
c)  $\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$  d)  $\coth x = \frac{\cosh x}{\sinh x} = \frac{e^x + e^{-x}}{e^x - e^{-x}}$
3.  $\cosh^2 x - \sinh^2 x = 1$

4. a)  $\sinh(x+y) = \sinh x \cosh y + \cosh x \sinh y$   
     b)  $\sinh(x-y) = \sinh x \cosh y - \cosh x \sinh y$   
     c)  $\cosh(x+y) = \cosh x \cosh y + \sinh x \sinh y$   
     d)  $\cosh(x-y) = \cosh x \cosh y - \sinh x \sinh y$  (IPE March-06,07)

e)  $\sinh 2x = 2 \sinh x \cosh x = \frac{2 \tanh x}{1 - \tanh^2 x}$  (IPE March-12, May-09, Mar-17)

f)  $\cosh 2x = \cosh^2 x + \sinh^2 x = 2 \cosh^2 x - 1 = 1 + 2 \sinh^2 x = \frac{1 + \tanh^2 x}{1 - \tanh^2 x}$  (IPE March-10,11, May-06,11)

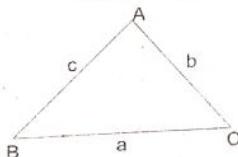
5. a.  $\tanh(x+y) = \frac{\tanh x + \tanh y}{1 + \tanh x \cdot \tanh y}$  b.  $\tanh(x-y) = \frac{\tanh x - \tanh y}{1 - \tanh x \cdot \tanh y}$

c.  $\sinh 3x = 3 \sinh x + 4 \sinh^3 x$

6. a.  $\sinh^{-1} x = \log_e \left( x + \sqrt{x^2 + 1} \right)$  (TS Mar-2016) (May-2016)  
     b.  $\tanh^{-1} x = \frac{1}{2} \log_e \left( \frac{1+x}{1-x} \right)$  (Eam-05), IPE Mar.-05,07,17, May- 05,07

7.  $\tanh^2 \frac{x}{2} = \frac{\cosh x - 1}{\cosh x + 1}$ .

## PROPERTIES OF TRIANGLES



In  $\triangle ABC$ ,

- B              a              C

  - Let  $BC=a$ ,  $CA=b$ ,  $AB=c$  then the perimeter  $2S=a+b+c \Rightarrow S = \frac{a+b+c}{2}$
  - Sine Rule :**  $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = 2R$  (Eamcet-89,90)  
 $\Rightarrow a = 2R \sin A, b = 2R \sin B, c = 2R \sin C$   
 $\Rightarrow \sin A = \frac{a}{2R}, \sin B = \frac{b}{2R}, \sin C = \frac{c}{2R}$ ; Where 'R' is the circum radius
  - Cosine Rule:**
    - $a^2 = b^2 + c^2 - 2bc \cos A \Rightarrow \cos A = \frac{b^2 + c^2 - a^2}{2bc}$   
 (Eamcet-85,87,97,01) (AIEEE-02)
    - $b^2 = c^2 + a^2 - 2ac \cos B \Rightarrow \cos B = \frac{c^2 + a^2 - b^2}{2ac}$
    - $c^2 = a^2 + b^2 - 2ab \cos C \Rightarrow \cos C = \frac{a^2 + b^2 - c^2}{2ab}$

4. **Tangent Rule :** a.  $\tan\left(\frac{A-B}{2}\right) = \left(\frac{a-b}{a+b}\right) \cot\frac{C}{2}$

b.  $\tan\left(\frac{B-C}{2}\right) = \left(\frac{b-c}{b+c}\right) \cot\frac{A}{2}$

c.  $\tan\left(\frac{C-A}{2}\right) = \left(\frac{c-a}{c+a}\right) \cot\frac{B}{2}$

4. **Projection Rule:** (i)  $a = b \cos C + c \cos B$  (ii)  $b = c \cos A + a \cos C$   
 (iii)  $c = a \cos B + b \cos A$  (Eamcet-01,05)

5. **Area of triangle:** (Eamcet-86,88,90,02)

a.  $\Delta = \frac{1}{2}bc \sin A = \frac{1}{2}ca \sin B = \frac{1}{2}ab \sin C = 2R^2 \sin A \cdot \sin B \cdot \sin C$

b.  $\Delta = \sqrt{s(s-a)(s-b)(s-c)}$

c.  $\Delta = \frac{abc}{4R} \Rightarrow R = \frac{abc}{4\Delta} \Rightarrow abc = 4R\Delta$

d. Area of triangle ABC ( $\Delta$ ) =  $\frac{1}{2} \times \text{base} \times \text{height}$

6. **Half-Angle formulae.** (Eamcet-94,2000, 03,04)

a.  $\sin \frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{bc}}; \cos \frac{A}{2} = \sqrt{\frac{s(s-a)}{bc}}$

$$\sin^2 \frac{A}{2} = \frac{(s-b)(s-c)}{bc}; \quad \cos^2 \frac{A}{2} = \frac{s(s-a)}{bc}$$

b.  $\sin \frac{B}{2} = \sqrt{\frac{(s-c)(s-a)}{ca}}; \cos \frac{B}{2} = \sqrt{\frac{s(s-b)}{ca}}$

$$\sin^2 \frac{B}{2} = \frac{(s-c)(s-a)}{ca}; \quad \cos^2 \frac{B}{2} = \frac{s(s-b)}{ca}$$

c.  $\sin \frac{C}{2} = \sqrt{\frac{(s-a)(s-b)}{ab}}; \cos \frac{C}{2} = \sqrt{\frac{s(s-c)}{ab}}$

$$\sin^2 \frac{C}{2} = \frac{(s-a)(s-b)}{ab}; \quad \cos^2 \frac{C}{2} = \frac{s(s-c)}{ab}$$

d.  $\tan\left(\frac{A}{2}\right) = \frac{(s-b)(s-c)}{\Delta}; \quad \tan\left(\frac{B}{2}\right) = \frac{(s-c)(s-a)}{\Delta}; \quad \tan\left(\frac{C}{2}\right) = \frac{(s-a)(s-b)}{\Delta}$

e.  $\cot\frac{A}{2} = \frac{s(s-a)}{\Delta}, \cot\frac{B}{2} = \frac{s(s-b)}{\Delta}, \cot\frac{C}{2} = \frac{s(s-c)}{\Delta}$

**7. In-radius and Ex-radii :**

$$\text{a. } r = \frac{\Delta}{s} = 4R \sin \frac{A}{2} \sin \frac{B}{2} \sin \frac{C}{2}$$

$$\text{b. (i) } r_1 = \frac{\Delta}{s-a} = s \tan \frac{A}{2} = 4R \sin \frac{A}{2} \cos \frac{B}{2} \cos \frac{C}{2}$$

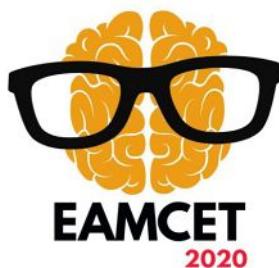
$$\text{(ii) } r_2 = \frac{\Delta}{s-b} = 4R \cos \frac{A}{2} \sin \frac{B}{2} \cos \frac{C}{2}$$

$$\text{(iii) } r_3 = \frac{\Delta}{s-c} = 4R \cos \frac{A}{2} \cos \frac{B}{2} \sin \frac{C}{2}$$

$$\text{c. (i) } r \cdot r_1 \cdot r_2 \cdot r_3 = \Delta^2$$

$$\text{(ii) } \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} = \frac{1}{r}$$

\* \* \*



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## CO-ORDINATE SYSTEM

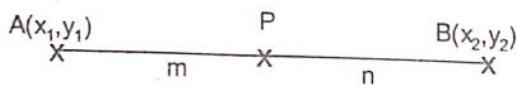
1. i) The distance between the two points  $A(x_1, y_1)$  and  $B(x_2, y_2)$  is

$$AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

ii) The distance from the origin to the point  $P(x, y)$  is  $OP = \sqrt{x^2 + y^2}$

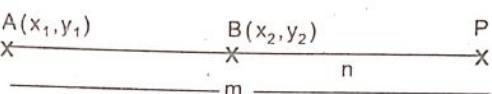
2. The coordinates of the point 'P' which divides  $A(x_1, y_1)$  and  $B(x_2, y_2)$  in the ratio  $m : n$

i) Internally is  $P = \left( \frac{mx_2 + nx_1}{m+n}, \frac{my_2 + ny_1}{m+n} \right); m+n \neq 0$



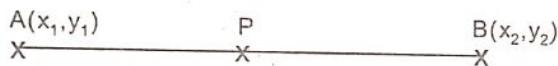
ii) Externally is

$$P = \left( \frac{mx_2 - nx_1}{m-n}, \frac{my_2 - ny_1}{m-n} \right); m \neq n$$



- iii) The coordinates of the mid point P of the line joining  $A(x_1, y_1)$  and  $B(x_2, y_2)$  is

$$P = \left( \frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$



3. The points P and Q which divides the line segment AB in the ratio 1:2 and 2:1 are called the points of trisection.

4. i) The area of triangle formed by the vertices  $A(x_1, y_1)$ ,  $B(x_2, y_2)$  and  $C(x_3, y_3)$  is

$$\frac{1}{2} |x_1(y_2 - y_3) + x_2(y_3 - y_1) + x_3(y_1 - y_2)| \text{ Sq. Units. or } \frac{1}{2} \begin{vmatrix} x_1 - x_2 & x_1 - x_3 \\ y_1 - y_2 & y_1 - y_3 \end{vmatrix} \text{ sq.units.}$$

ii) The area of the traingle O(0,0),  $A(x_1, y_1)$  and  $B(x_2, y_2)$  is  $\frac{1}{2} |x_1y_2 - x_2y_1| \text{ Sq. Units}$

- iii) The area of the quadrilateral with vertices  $A(x_1, y_1)$ ,  $B(x_2, y_2)$ ,  $C(x_3, y_3)$  and  $D(x_4, y_4)$  is

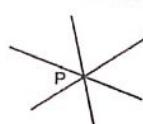
$$\frac{1}{2} |x_1y_2 - x_2y_1 + x_2y_3 - x_3y_2 + x_3y_4 - x_4y_3 + x_4y_1 - x_1y_4| \text{ Sq. Units}$$

(or)  $\frac{1}{2} \begin{vmatrix} x_1 - x_3 & x_2 - x_4 \\ y_1 - y_3 & y_2 - y_4 \end{vmatrix} \text{ sq.units.}$

- iv) If the area of triangle with the points A,B and C is equal to zero , then the points A,B,C are collinear.

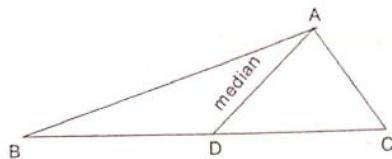
5. i) Concurrent lines : If three or more lines passing through the same point 'P' then the lines are called

concurrent lines and the point 'P' is called point of concurrency.

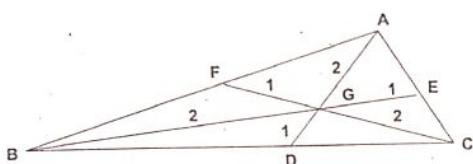


**JR MATHS-IB**

- ii) Median :** A line drawn from the vertex and which is passing through the mid point of the side opposite to that vertex is called the median.



- iii) Centroid :** The point of concurrency of the medians of a triangle is called the centroid, and is denoted by 'G'. G divides every median in the ratio  $2 : 1$ .

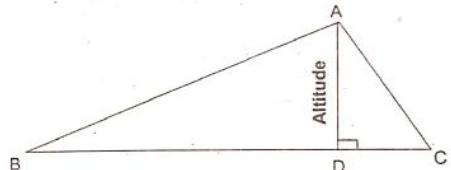


- iv)** The centroid of the triangle having vertices  $A(x_1, y_1)$ ,  $B(x_2, y_2)$  and  $C(x_3, y_3)$  is

$$G = \left( \frac{x_1 + x_2 + x_3}{3}, \frac{y_1 + y_2 + y_3}{3} \right)$$

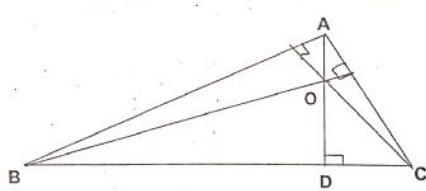
- 6. i) Altitude :** A line drawn from the vertex and which is perpendicular to the side opposite to that

vertex is called an altitude.

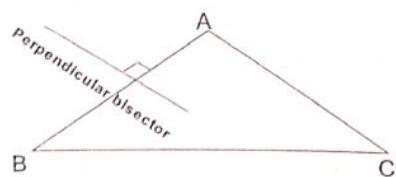


- ii) Orthocentre:** The point of concurrency of the altitudes of a triangle is called orthocentre, and is denoted by 'O'.

(IIT-93) (EAMCET-99)

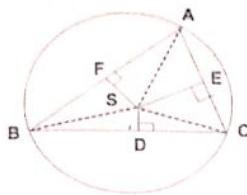


- 7. i) Perpendicular bisector:** A line drawn through the mid point of the side and is perpendicular to that side is called a perpendicular bisector.

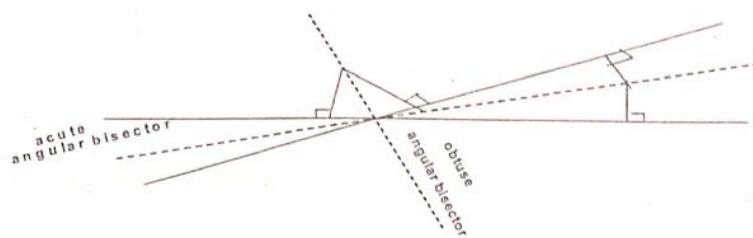


- ii) Circumcentre:** The point of concurrency of the perpendicular bisectors of the sides of a triangle is called circumcentre and is denoted by 'S'.

- iii) Circumcentre** which is equidistant from the vertices of the triangle ABC i.e  $SA = SB = SC$



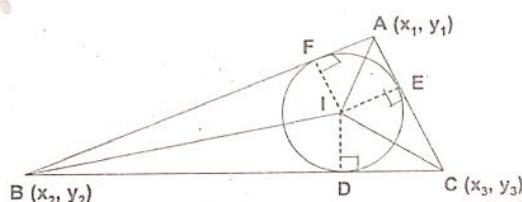
8. i) **Angular bisector** : The set of points joining which are equidistant from any two intersecting lines is called an angular bisector.



ii) **Incentre** : The point of concurrency of the internal angular bisectors of a triangle is called incentre and is denoted by 'I' (EAMCET-01)

iii) If  $A(x_1, y_1)$ ,  $B(x_2, y_2)$  and  $C(x_3, y_3)$  are the vertices of the triangle ABC then the incentre

$$I = \left( \frac{ax_1 + bx_2 + cx_3}{a+b+c}, \frac{ay_1 + by_2 + cy_3}{a+b+c} \right)$$



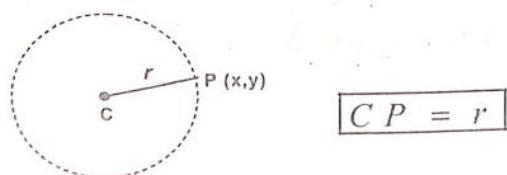
(where  $AB = c$ ,  $BC = a$ ,  $CA = b$ )

iv) Incentre is equidistant from the sides of the triangle i.e  $ID = IE = IF$ .

### LOCUS

**Definition :** A variable point moves under given geometrical conditions. The path traced by the point is called the locus of the point.

**Ex :** The locus of a point which moves such that its distance from a given point is constant is a circle whose centre is the given point and radius the given constant.



### TRANSFORMATION OF AXES

1. **Translation of axes** : Shifting the origin to another point  $(h, k)$  without changing the direction of the axes is called Translation of axes. The transformed equations are  $x = X + h$ ,  $y = Y + k$

$$\Rightarrow X = x - h, Y = y - k$$

2. If the axes are translated to the point  $(h, k)$  then the equation  $f(x, y) = 0$  of a curve is transformed to  $f(X + h, Y + k) = 0$ .
3. If  $f(X, Y) = 0$  is the transformed equation of a curve when the axes are translated to the point  $(h, k)$  then the original equation of the curve is  $f(x - h, y - k) = 0$ .
4. To remove the first degree terms from the equation  $ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$  ( $h^2 \neq ab$ ) the origin should be shifted to the point  $\left( \frac{hf - bg}{ab - h^2}, \frac{gh - af}{ab - h^2} \right)$ .

5. Rotation of axes : If the axes are rotated through an angle ' $\theta$ ' without changing the position of the origin, then the transformation is called Rotation of axes. The transformed equations are

$$x = X\cos\theta - Y\sin\theta, y = X\sin\theta + Y\cos\theta$$

$\theta$	$x$	$y$
$x$	$\cos\theta$	$-\sin\theta$
$y$	$\sin\theta$	$\cos\theta$

$$X = x\cos\theta + y\sin\theta, Y = -x\sin\theta + y\cos\theta$$

6. To remove 'xy' term from the equation  $ax^2 + 2hxy + by^2 = 0$  the axes should be rotated through an angle of  $\frac{1}{2}\tan^{-1}\left(\frac{2h}{a-b}\right)$  when  $(a \neq b)$ . and through an angle  $\frac{\pi}{4}$ , if  $a = b$ .

7. If the axes are rotated through an angle ' $\theta$ ', then the equation  $f(x, y) = 0$  of a curve is transformed to  $f(X\cos\theta - Y\sin\theta, X\sin\theta + Y\cos\theta) = 0$ . (EAMCET-97,08)
8. If  $f(X, Y) = 0$  is the transformed equation of a curve when the axes are rotated through an angle ' $\theta$ ', then the original equation of the curve is  $f(x\cos\theta + y\sin\theta, -x\sin\theta + y\cos\theta) = 0$ .

### STRAIGHT LINES

1. Inclination and slope : If a line L makes an angle  $\theta$  ( $0^\circ \leq \theta < 180^\circ$ ) with the positive direction of the X - axis then  $\theta$  is called inclination of L and  $\tan\theta$  is called the slope of the line L.

Slope is generally denoted by m i.e  $m = \tan\theta$ .

2. i) The slope of a horizontal line is zero      ii) The slope of a vertical line is not defined  
 3. i) The equation of x-axis is  $y = 0$       ii) The equation of y-axis is  $x = 0$   
 iii) Equation of line parallel to x-axis is  $y = k$       iv) Equation of line parallel to y-axis is  $x = k$

4. a) If  $A(x_1, y_1)$  and  $B(x_2, y_2)$  are two points, then slope of  $\overline{AB} = \frac{y_2 - y_1}{x_2 - x_1}$

b) The slope of the line  $ax + by + c = 0$  is  $-\frac{a}{b}$

5. a) If  $m_1, m_2$  are slopes of two parallel lines then  $m_1 = m_2$

b) If  $m_1, m_2$  are slopes of two perpendicular lines then  $m_1 m_2 = -1 \Rightarrow m_2 = -\frac{1}{m_1}$

6. Slope point form :- i) The equation of a line passing through  $(x_1, y_1)$  and having slope 'm' is

$$y - y_1 = m(x - x_1)$$

ii) The equation of a line passing through origin and having slope 'm' is  $y = mx$

7. Two points form :- The equation of a line passing through the points  $(x_1, y_1)$  and

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

8. Slope intercept form :- i) The equation of the line with slope 'm' and y - intercept 'c' is

$$y = mx + c$$

ii) The equation of the line with slope 'm' and x - intercept 'a' is  $y = m(x - a)$

9. Intercept form :- The equation of a line having 'a', 'b' as intercepts is  $\frac{x}{a} + \frac{y}{b} = 1$

10. Normal form :- The equation of a line in the normal form is  $x \cos \alpha + y \sin \alpha = p$

11. Symmetric form :- The equation of a line passing through  $(x_1, y_1)$  and having inclination ' $\theta$ ' is

$$\frac{x - x_1}{\cos \theta} = \frac{y - y_1}{\sin \theta} \text{ where } \theta \in \left(0, \frac{\pi}{2}\right) \cup \left(\frac{\pi}{2}, \pi\right)$$

12. Parametric form :- The parametric equations of the line are  $x = x_1 \pm r \cos \theta$

$$y = y_1 \pm r \sin \theta$$

13. a) The perpendicular distance from origin to the line  $ax + by + c = 0$  is  $\frac{|c|}{\sqrt{a^2 + b^2}}$

b) The perpendicular distance from  $P(x_1, y_1)$  to the line  $ax + by + c = 0$  is  $\frac{|ax_1 + by_1 + c|}{\sqrt{a^2 + b^2}}$

14. The distance between the parallel lines  $ax + by + c_1 = 0$  and  $ax + by + c_2 = 0$  is  $\frac{|c_1 - c_2|}{\sqrt{a^2 + b^2}}$

15. a) Area of the triangle formed by the line  $\frac{x}{a} + \frac{y}{b} = 1$  with co-ordinate axes is  $\frac{1}{2}|ab|$

b) The area of triangle formed by the line  $ax + by + c = 0$  with co-ordinate axes is  $\frac{c^2}{2|ab|}$

16. a) The x-axis divides  $\overline{AB}$  in the ratio  $-y_1 : y_2$

b) The y-axis divides  $\overline{AB}$  in the ratio  $-x_1 : x_2$

17. i) The ratio in which the line  $L \equiv ax + by + c = 0$  divides the line segment joining  $A(x_1, y_1), B(x_2, y_2)$  is  $-L_{11} : L_{22}$  where  $L_{11} = ax_1 + by_1 + c, L_{22} = ax_2 + by_2 + c$

ii) The points A, B lie in the same side or opposite side of the line  $L = 0$  according as  $L_{11}, L_{22}$  have the same sign or opposite signs.

18. If  $m_1, m_2$  are slopes of two lines and angle between two lines is  $\theta$ , then  $\tan \theta = \left| \frac{m_1 - m_2}{1 + m_1 m_2} \right|$

19. If ' $\theta$ ' is the acute angle between the lines  $a_1 x + b_1 y + c_1 = 0$  and  $a_2 x + b_2 y + c_2 = 0$

$$\text{then } \cos \theta = \frac{|a_1 a_2 + b_1 b_2|}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}}$$

or

$$\sin \theta = \frac{|a_1 b_2 - a_2 b_1|}{\sqrt{a_1^2 + b_1^2} \sqrt{a_2^2 + b_2^2}}$$

or

$$\tan \theta = \left| \frac{a_1 b_2 - a_2 b_1}{a_1 a_2 + b_1 b_2} \right|$$

20. a) The equation of the line parallel to  $ax + by + c = 0$  is  $ax + by + k = 0$

b) The equation of the line passing through  $(x_1, y_1)$  and parallel to  $ax + by + c = 0$  is

$$a(x - x_1) + b(y - y_1) = 0$$

c) The equation of the line perpendicular to  $ax + by + c = 0$  is  $bx - ay + k = 0$

d) The equation of the line passing through  $(x_1, y_1)$  and perpendicular to  $ax + by + c = 0$  is

$$b(x - x_1) - a(y - y_1) = 0$$

21. i) The lines  $a_1 x + b_1 y + c_1 = 0, a_2 x + b_2 y + c_2 = 0$  are parallel iff  $\frac{a_1}{a_2} = \frac{b_1}{b_2}$

ii) The lines  $a_1 x + b_1 y + c_1 = 0, a_2 x + b_2 y + c_2 = 0$  are perpendicular iff  $a_1 a_2 + b_1 b_2 = 0$

iii)  $a_1 x + b_1 y + c_1 = 0, a_2 x + b_2 y + c_2 = 0$  represent the same line  $\Leftrightarrow \frac{a_1}{a_2} = \frac{b_1}{b_2} = \frac{c_1}{c_2}$

22. If  $(h, k)$  is the image of  $(x_1, y_1)$  w.r.t the line  $ax + by + c = 0$

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

23. If  $(h, k)$  is the foot of the perpendicular from  $P(x_1, y_1)$  w.r.t the line  $ax + by + c = 0$

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

24. The equation of family of lines passing through the point of intersection of  $L_1 = 0$  and  $L_2 = 0$  is  $L_1 + \lambda L_2 = 0$ , where  $\lambda$  is a parameter

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

25. If three lines  $a_1 x + b_1 y + c_1 = 0, a_2 x + b_2 y + c_2 = 0$  and  $a_3 x + b_3 y + c_3 = 0$  are concurrent then

26. In the square  $ABCD$ , mid point of  $AC$  = mid point of  $BD$  and  $AC \perp BD$   
 27. If  $A, B, C$  are collinear then slope of  $AB$  = slope of  $BC$

### PAIR OF STRAIGHT LINES

1. If  $h^2 \geq ab$ , then  $ax^2 + 2hxy + by^2 = 0$  (second degree homogenous equation in  $x$  and  $y$ ) represents a pair of lines passing through the origin, which are  $ax + \left(h + \sqrt{h^2 - ab}\right)y = 0$  and  $ax + \left(h - \sqrt{h^2 - ab}\right)y = 0$
2. If  $m_1$  and  $m_2$  are the slopes of the lines represented by  $ax^2 + 2hxy + by^2 = 0$  then
  - i) Sum of the slopes :  $m_1 + m_2 = \frac{-2h}{b}$
  - ii) Product of the slopes :  $m_1 m_2 = \frac{a}{b}$
3.  $ax^2 + 2hxy + by^2 = (y - m_1 x)(y - m_2 x)$  Comparing the coefficients of like terms on either side  
 $m_1 + m_2 = \frac{-2h}{b}$ ,  $m_1 m_2 = \frac{a}{b}$
4.  $ax^2 + 2hxy + by^2 = (l_1 x + m_1 y)(l_2 x + m_2 y)$  Comparing the coefficients of like terms on either side  $\Rightarrow l_1 l_2 = a$ ,  $m_1 m_2 = b$ ,  $l_1 m_2 + l_2 m_1 = 2h$
5. i) If ' $\theta$ ' is angle between the lines represented by  $ax^2 + 2hxy + by^2 = 0$  then  $\cos \theta = \pm \frac{a+b}{\sqrt{(a-b)^2 + 4h^2}}$   
 ii) If ' $\theta$ ' is acute then  $\cos \theta = \frac{|a+b|}{\sqrt{(a-b)^2 + 4h^2}}$ ,  $\tan \theta = \frac{2\sqrt{h^2 - ab}}{|a+b|}$ ,  $\sin \theta = \frac{2\sqrt{h^2 - ab}}{\sqrt{(a-b)^2 + 4h^2}}$
6. The angle between the pair of lines represented by the equation  $ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$  is  
 $\cos \theta = \pm \frac{a+b}{\sqrt{(a-b)^2 + 4h^2}}$ ,  $\tan \theta = \pm \frac{2\sqrt{h^2 - ab}}{a+b}$ ,  $\sin \theta = \pm \frac{2\sqrt{h^2 - ab}}{\sqrt{(a-b)^2 + 4h^2}}$  (EAMCET-99)
7. The pair of lines  $ax^2 + 2hxy + by^2 = 0$  represents a pair of perpendicular lines  
 then coefficient of  $x^2$  + coefficient of  $y^2 = 0$  (i.e.,  $a+b=0$ )
8. If the pair of lines  $ax^2 + 2hxy + by^2 = 0$  represents coincident lines then  $h^2 = ab$
9. The equation of bisectors of angle between the lines  $a_1 x + b_1 y + c_1 = 0$ ,  $a_2 x + b_2 y + c_2 = 0$  is  

$$\frac{a_1 x + b_1 y + c_1}{\sqrt{a_1^2 + b_1^2}} = \pm \frac{a_2 x + b_2 y + c_2}{\sqrt{a_2^2 + b_2^2}}$$
10. If the equation  $ax^2 + 2hxy + by^2 = 0$  represents a pair of distinct (i.e., intersecting) lines then the combined equation of the pair of bisectors of the angles between the lines is  $h(x^2 - y^2) = (a-b)xy$
11. The equation of the pair of lines passing through  $(x_0, y_0)$  and parallel to  $ax^2 + 2hxy + by^2 = 0$  is  $a(x - x_0)^2 + 2h(x - x_0)(y - y_0) + b(y - y_0)^2 = 0$

12. The equation of the pair of lines passing through  $(x_0, y_0)$  and perpendicular to  $ax^2 + 2hxy + by^2 = 0$  is  $b(x - x_0)^2 - 2h(x - x_0)(y - y_0) + a(y - y_0)^2 = 0$
13.  $ax^2 + 2hxy + by^2 + 2gx + 2fy + c = (l_1x + m_1y + n_1)(l_2x + m_2y + n_2)$   
Comparing the coefficients of like terms on either side  
 $l_1l_2 = a$  ;  $m_1m_2 = b$  ;  $n_1n_2 = c$  ;  $l_1m_2 + l_2m_1 = 2h$  ;  
 $l_1n_2 + l_2n_1 = 2g$  ;  $m_1n_2 + m_2n_1 = 2f$
14.  $ax^2 + 2hxy + by^2 + 2gx + 2fy + c = (lx + my + n_1)(lx + my + n_2)$   
Comparing the coefficients of like terms on either side  
 $l^2 = a, m^2 = b, n_1n_2 = c, 2lm = 2h, l(n_1 + n_2) = 2g, m(n_1 + n_2) = 2f$
15. If the second degree equation  $S \equiv ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$  in two variables x and y represents a pair of straight lines then  
i)  $\Delta \equiv abc + 2fgh - af^2 - bg^2 - ch^2 = 0$  (EAMCET-82,93,96,2000, 08)  
and ii)  $h^2 \geq ab, g^2 \geq ac$  and  $f^2 \geq bc$
16. If  $ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$  represents a pair of intersecting lines, then their point of intersection is  $\left( \frac{h-fg}{ab-h^2}, \frac{gh-af}{ab-h^2} \right)$ . (EAMCET-97,2000, 02)

## DIRECTION COSINES AND DIRECTION RATIOS

1. If a given directed line makes angles  $\alpha, \beta, \gamma$  with positive direction of the axes of x, y and z respectively then  $\cos \alpha, \cos \beta, \cos \gamma$  are called direction cosines (d.c's) of the line and these are usually denoted by  $l, m, n$ .
2. If the direction cosines of a directed line  $\overrightarrow{AB}$  are  $l, m, n$  then the direction cosines of the directed line  $\overrightarrow{BA}$  are  $-l, -m, -n$ .
3. Direction cosines of i) x-axis are  $(1, 0, 0)$       ii) y-axis are  $(0, 1, 0)$       iii) z-axis are  $(0, 0, 1)$ .
4. If  $(l, m, n)$  are the direction cosines of a line then  $l^2 + m^2 + n^2 = 1$ , i.e  $\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = 1$ . (EAMCET-2001)
5. If  $\alpha, \beta, \gamma$  are the angle made by a directed line with the positive direction of the coordinate axes, then  $\sin^2 \alpha + \sin^2 \beta + \sin^2 \gamma = 2$ .
6. Direction ratios of the line joining the points  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  are  $(x_2 - x_1, y_2 - y_1, z_2 - z_1)$ .
7. If  $(a, b, c)$  are direction ratios of a line then  $\left( \frac{\pm a}{\sqrt{a^2 + b^2 + c^2}}, \frac{\pm b}{\sqrt{a^2 + b^2 + c^2}}, \frac{\pm c}{\sqrt{a^2 + b^2 + c^2}} \right)$  are direction cosines of the line.
8. If  $(l_1, m_1, n_1)$  and  $(l_2, m_2, n_2)$  are direction cosines of two lines and ' $\theta$ ' is an angle between them, then

$$\cos\theta = \pm(l_1l_2 + m_1m_2 + n_1n_2).$$

(EAMCET- 01, 02, 03)

9. Let  $(l_1, m_1, n_1)$  and  $(l_2, m_2, n_2)$  be d.c's of two lines. Then

i) The lines are parallel  $\Leftrightarrow \frac{l_1}{l_2} = \frac{m_1}{m_2} = \frac{n_1}{n_2}$

ii) The lines are perpendicular  $\Leftrightarrow l_1l_2 + m_1m_2 + n_1n_2 = 0$ .

10. If ' $\theta$ ' is an angle between two lines whose d.r.'s are  $(a_1, b_1, c_1)$  and  $(a_2, b_2, c_2)$  then

i)  $\cos\theta = \pm \frac{a_1a_2 + b_1b_2 + c_1c_2}{\sqrt{a_1^2 + b_1^2 + c_1^2} \sqrt{a_2^2 + b_2^2 + c_2^2}}$

ii) The lines are parallel  $\Leftrightarrow \frac{a_1}{a_2} = \frac{b_1}{b_2} = \frac{c_1}{c_2}$

iii) The lines are perpendicular  $\Leftrightarrow a_1a_2 + b_1b_2 + c_1c_2 = 0$ .

11. If  $A(x_1, y_1, z_1)$ ,  $B(x_2, y_2, z_2)$  then the projection of  $\overline{AB}$  on

a) i) x-axis is  $|x_2 - x_1|$  ii) y-axis is  $|y_2 - y_1|$  iii) z-axis is  $|z_2 - z_1|$

b) i) xy plane is  $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$  ii) yz plane is  $\sqrt{(y_2 - y_1)^2 + (z_2 - z_1)^2}$

iii) zx plane is  $\sqrt{(z_2 - z_1)^2 + (x_2 - x_1)^2}$

### 3D-GEOMETRY

1. The distance between two points  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  is  $AB = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$  units
2. Midpoint of  $A(x_1, y_1, z_1)$  &  $B(x_2, y_2, z_2)$  is  $\left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}, \frac{z_1 + z_2}{2}\right)$
3. If 'P' divides the line segment joining  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  in the ratio  $l:m$  internally then
- $$P = \left(\frac{lx_2 + mx_1}{l+m}, \frac{ly_2 + my_1}{l+m}, \frac{lz_2 + mz_1}{l+m}\right)$$
4. If P divides the line segment joining  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  in the ratio  $l:m$  externally then
- $$P = \left(\frac{lx_2 - mx_1}{l-m}, \frac{ly_2 - my_1}{l-m}, \frac{lz_2 - mz_1}{l-m}\right)$$
5. YZ-plane divides the line joining  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  in the ratio  $-x_1 : x_2$
6. XY-plane divides the line joining  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  in the ratio  $-z_1 : z_2$
7. ZX-plane divides the line joining  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  in the ratio  $-y_1 : y_2$
8.  $P(x, y, z)$  divides the line segment  $A(x_1, y_1, z_1), B(x_2, y_2, z_2)$  in the ratio  $x_1 - x : x - x_2$

9. The centroid of a triangle whose vertices are  $A(x_1, y_1, z_1), B(x_2, y_2, z_2), C(x_3, y_3, z_3)$   
is  $G\left(\frac{x_1 + x_2 + x_3}{3}, \frac{y_1 + y_2 + y_3}{3}, \frac{z_1 + z_2 + z_3}{3}\right)$
10. If three consecutive vertices of a parallelogram are  $A(x_1, y_1, z_1), B(x_2, y_2, z_2), C(x_3, y_3, z_3)$  then  
fourth vertex  $D = (x_1 + x_3 - x_2, y_1 + y_3 - y_2, z_1 + z_3 - z_2)$
11. The Centroid of the tetrahedron whose vertices are  $A(x_1, y_1, z_1), B(x_2, y_2, z_2), C(x_3, y_3, z_3), D(x_4, y_4, z_4)$   
is  $G\left(\frac{x_1 + x_2 + x_3 + x_4}{4}, \frac{y_1 + y_2 + y_3 + y_4}{4}, \frac{z_1 + z_2 + z_3 + z_4}{4}\right)$
12. When origin is shifted to  $O'(h, k, l)$  by translation of axes the co-ordinates of  $(x, y, z)$  changed to  
 $(X, Y, Z)$  then  $x = X + h, y = Y + k, z = Z + l$
13. If  $A, B, C$  are collinear iff  $AB + BC = CA$  or  $BC + CA = AB$  or  $CA + AB = BC$

## THE PLANE

1. The equation to
  - i) xy-plane is  $z = 0$
  - ii) yz-plane is  $x = 0$
  - iii) zx-plane is  $y = 0$
2. The equation to the plane parallel to
  - i) xy-plane is  $z = k$
  - ii) yz-plane is  $x = k$
  - iii) zx-plane is  $y = k$
3. Equation of the plane parallel to  $ax + by + cz + d = 0$  is of the form  $ax + by + cz + k = 0$ , where  $k$  is constant.
4. The equation of the plane passing through  $(x_1, y_1, z_1)$  and parallel to  $ax + by + cz + d = 0$  is  
 $a(x - x_1) + b(y - y_1) + c(z - z_1) = 0$
5. Equation of a plane passing through  $(x_1, y_1, z_1)$  and perpendicular to the line whose d.r's are  $a, b, c$  is  
 $a(x - x_1) + b(y - y_1) + c(z - z_1) = 0$  (EAMCET-02)
6. The equation of the plane having x - intercept 'a', y - intercept 'b' and z - intercept 'c' is  

$$\frac{x}{a} + \frac{y}{b} + \frac{z}{c} = 1$$
7. i) The equation of a plane in the normal form which is at a distance of 'p' units from the origin and whose normal has the direction cosines  $(l, m, n)$  is  $lx + my + nz = p$ .  
 ii) Equation of a plane through the origin is  $lx + my + nz = 0$ .
8. Distance from origin to the plane  $ax + by + cz + d = 0$  is  $\frac{|d|}{\sqrt{a^2 + b^2 + c^2}}$
9. The length of the perpendicular from  $(x_1, y_1, z_1)$  to the plane  $ax + by + cz + d = 0$  is  

$$\frac{|ax_1 + by_1 + cz_1 + d|}{\sqrt{a^2 + b^2 + c^2}}$$

10. The distance between parallel planes  $ax + by + cz + d_1 = 0$ ,  $ax + by + cz + d_2 = 0$  is  $\frac{|d_1 - d_2|}{\sqrt{a^2 + b^2 + c^2}}$

11. i) The angle between any two intersecting planes is the angle between their normals  
ii) Angle between the planes  $a_1x + b_1y + c_1z + d_1 = 0$  and  $a_2x + b_2y + c_2z + d_2 = 0$  is

$$\cos \theta = \pm \frac{a_1a_2 + b_1b_2 + c_1c_2}{\sqrt{a_1^2 + b_1^2 + c_1^2} \sqrt{a_2^2 + b_2^2 + c_2^2}}$$

12. i) The equations  $a_1x + b_1y + c_1z + d_1 = 0$  and  $a_2x + b_2y + c_2z + d_2 = 0$  represent the same plane iff  
 $a_1 : b_1 : c_1 : d_1 = a_2 : b_2 : c_2 : d_2$ .  
ii) parallel  $\Leftrightarrow a_1 : b_1 : c_1 = a_2 : b_2 : c_2$   
iii) perpendicular  $\Leftrightarrow a_1a_2 + b_1b_2 + c_1c_2 = 0$ .

### LIMITS & CONTINUITY

1.  $\lim_{x \rightarrow a} \frac{x^n - a^n}{x - a} = n.a^{n-1}$

2.  $\lim_{x \rightarrow a} \frac{x^m - a^m}{x^n - a^n} = \frac{m}{n} a^{m-n}$

3.  $\lim_{x \rightarrow 0} \frac{\sin x}{x} = 1$

4.  $\lim_{x \rightarrow 0} \frac{\sin ax}{x} = a$

5.  $\lim_{x \rightarrow 0} \frac{\tan x}{x} = 1$

6.  $\lim_{x \rightarrow 0} \frac{\tan ax}{x} = a$

7.  $\lim_{x \rightarrow 0} \frac{e^x - 1}{x} = 1$

8.  $\lim_{x \rightarrow 0} \frac{a^x - 1}{x} = \log_e a$

9.  $\lim_{x \rightarrow 0} (1+x)^{\frac{1}{x}} = e$

10.  $\lim_{x \rightarrow \infty} \left(1 + \frac{1}{x}\right)^x = e$

11.  $\lim_{x \rightarrow 0} \frac{\log_e(1+x)}{x} = 1$

12. Continuity of a function f(x) :

A function  $f(x)$  is said to be continuous at  $x = a$  if  $\lim_{x \rightarrow a} f(x)$  exists and is equal to  $f(a)$

$$\Rightarrow \lim_{x \rightarrow a} f(x) = f(a) = \lim_{x \rightarrow a^+} f(x)$$

### DIFFERENTIATION

First principle : If 'f' is differentiable at 'x' then  $f'(x) = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$

1. The derivative of a function 'f' at  $x = a$  is defined by

$$f'(a) = \lim_{h \rightarrow 0} \frac{f(a+h) - f(a)}{h} = \lim_{x \rightarrow a} \frac{f(x) - f(a)}{x - a}$$

2.  $\frac{d}{dx}(k) = 0$  (  $k$  is constant)

3. i)  $\frac{d}{dx}(x^n) = nx^{n-1}$  ii)  $\frac{d}{dx}(x) = 1$  iii)  $\frac{d}{dx}\left(\frac{1}{x}\right) = \frac{-1}{x^2}$

iv)  $\frac{d}{dx}(\sqrt{x}) = \frac{1}{2\sqrt{x}}$  v)  $\frac{d}{dx}|x| = \frac{|x|}{x}$

4.  $\frac{d}{dx}(kx) = k \frac{d(x)}{dx} = k \cdot 1 = k$  (  $k$  is constant)

5.  $\frac{d}{dx}(e^x) = e^x$

6.  $\frac{d}{dx}(\log_e x) = \frac{1}{x}$

7.  $\frac{d}{dx}(a^x) = a^x \log_e a$

Derivatives of trigonometric functions :

8.  $\frac{d}{dx}(\sin x) = \cos x$

9.  $\frac{d}{dx}(\cos x) = -\sin x$

10.  $\frac{d}{dx}(\tan x) = \sec^2 x$

11.  $\frac{d}{dx}(\cot x) = -\operatorname{cosec}^2 x$

12.  $\frac{d}{dx}(\sec x) = \sec x \tan x$

13.  $\frac{d}{dx}(\operatorname{cosec} x) = -\operatorname{cosec} x \cot x$

Derivatives of inverse trigonometric functions:

14.  $\frac{d}{dx}(\operatorname{Sin}^{-1} x) = \frac{1}{\sqrt{1-x^2}}$

15.  $\frac{d}{dx}(\operatorname{Cos}^{-1} x) = \frac{-1}{\sqrt{1-x^2}}$  (EAMCET-99)

16.  $\frac{d}{dx}(\operatorname{Tan}^{-1} x) = \frac{1}{1+x^2}$

17.  $\frac{d}{dx}(\operatorname{Cot}^{-1} x) = \frac{-1}{1+x^2}$

18. 
$$\frac{d}{dx}(\text{Sec}^{-1}x) = \frac{1}{|x|\sqrt{x^2-1}}$$

19. 
$$\frac{d}{dx}(\text{Cosec}^{-1}x) = \frac{-1}{|x|\sqrt{x^2-1}}$$

Derivatives of hyperbolic functions :

20. 
$$\frac{d}{dx}(\sinhx) = \cosh x$$

21. 
$$\frac{d}{dx}(\cosh x) = \sinh x$$

22. 
$$\frac{d}{dx}(\tanh x) = \operatorname{sech}^2 x$$

23. 
$$\frac{d}{dx}(\operatorname{sech} x) = -\operatorname{sech} x \tanh x$$

24. 
$$\frac{d}{dx}(\operatorname{cosech} x) = -\operatorname{cosech} x \coth x$$

25. 
$$\frac{d}{dx}(\coth x) = -\operatorname{cosech}^2 x$$

Derivatives of inverse hyperbolic functions :

26. 
$$\frac{d}{dx}(\operatorname{Sinh}^{-1}x) = \frac{1}{\sqrt{1+x^2}}$$

27. 
$$\frac{d}{dx}(\operatorname{Cosh}^{-1}x) = \frac{1}{\sqrt{x^2-1}}$$

28. 
$$\frac{d}{dx}(\operatorname{Tanh}^{-1}x) = \frac{1}{1-x^2}$$

29. 
$$\frac{d}{dx}(\operatorname{Sech}^{-1}x) = \frac{-1}{x\sqrt{1-x^2}}$$

30. 
$$\frac{d}{dx}(\operatorname{Cosech}^{-1}x) = \frac{-1}{|x|\sqrt{1+x^2}}$$

31. 
$$\frac{d}{dx}(\operatorname{Coth}^{-1}x) = \frac{1}{1-x^2}$$

Let  $u, v, w$  be the functions of  $x$  and whose derivatives exists :

32. 
$$\frac{d}{dx}(u \pm v) = \frac{d}{dx}(u) \pm \frac{d}{dx}(v)$$

33. 
$$\frac{d}{dx}(u.v) = u \frac{d(v)}{dx} + v \frac{d(u)}{dx} \quad (\text{or}) \quad (u.v)' = u.v' + v.u'$$

34.  $\frac{d}{dx} \left( \frac{u}{v} \right) = \frac{v \frac{d}{dx}(u) - u \frac{d}{dx}(v)}{v^2}$  (or)  $\left( \frac{u}{v} \right)' = \frac{v.u' - u.v'}{v^2}$

35.  $\frac{d}{dx}(uvw) = uv \frac{d(w)}{dx} + vw \frac{d(u)}{dx} + wu \frac{d(v)}{dx}$  (or)  $(u.v.w)' = u.v.w' + v.w.u' + w.u.v'$

36. If  $x = f(t)$ ,  $y = g(t)$  then  $\frac{dy}{dx} = \frac{\frac{dy}{dt}}{\frac{dx}{dt}}$

### ERRORS AND APPROXIMATIONS

1. If  $y = f(x)$  be a function then

i) change (error) in  $y = \Delta y$

$$\therefore \Delta y = f(x + \Delta x) - f(x)$$

ii) Differential of  $y = dy$

$$\therefore dy = f'(x) \Delta x$$

iii) Relative error in  $y = \frac{\Delta y}{y}$  iv) Percentage error in  $y = \frac{\Delta y}{y} \times 100$

v) Approximation formula  $f(x + \Delta x) \approx f(x) + f'(x) \Delta x$

2. i) Area of the square  $= x^2$ , where 'x' is side of a square

ii) volume of the cube  $= x^3$ , where 'x' is side of a cube

iii) Surface area of the sphere  $= 4\pi r^2$ , where 'r' is radius of a sphere

iv) Volume of the sphere  $= \frac{4}{3}\pi r^3$ , where 'r' is radius of a sphere

v) Volume of the cone  $= \frac{1}{3}\pi r^2 h$ , where 'r' is the radius, 'h' is the height of cone

vi) Volume of cylinder  $= \pi r^2 h$ , where 'r' is base radius, 'h' is the height of cylinder

vii) Surface area of cylinder  $= 2\pi r h$ , where 'r' is base radius, 'h' is the height of cylinder

### TANGENTS AND NORMALS

Equations of the tangent and normal to the curve  $y = f(x)$ :

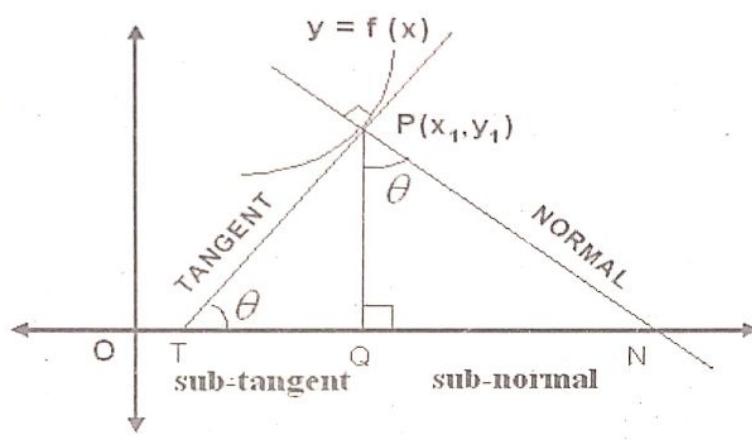
1. The slope of the tangent to the curve  $y = f(x)$  at a point  $P(x_1, y_1)$  is  $m = \left( \frac{dy}{dx} \right)_{P(x_1, y_1)}$
2. The equation of the tangent at  $P(x_1, y_1)$  is  $y - y_1 = m(x - x_1)$
3. The equation of the normal at  $P(x_1, y_1)$  is  $y - y_1 = -\frac{1}{m}(x - x_1)$

Angle between the two curves :

4. Let  $y = f(x)$ ,  $y = g(x)$  be two curves intersecting at a point 'P' and let  $m_1, m_2$  be the slopes of the tangents to the two curves at 'P' respectively. If ' $\theta$ ' is the acute angle between the curves at 'P' then

$$\tan \theta = \left| \frac{m_1 - m_2}{1 + m_1 m_2} \right|$$

- i) If  $m_1 = m_2$  then the two curves touch each other at P  
ii) If  $m_1 m_2 = -1$  then the two curves cuts orthogonally at 'P'



5. Let  $P(x_1, y_1)$  be the any point on the curve  $y = f(x)$ . Let the tangent and normal at 'P' meets the x-axis at M and N respectively. Draw PQ perpendicular to the x-axis Then

i) The length of the tangent  $PT = \left| \frac{y_1 \sqrt{1+m^2}}{m} \right|$

ii) The length of the normal  $PN = \left| y_1 \sqrt{1+m^2} \right|$

iii) The length of the sub tangent  $TQ = \left| \frac{y_1}{m} \right|$

iv) The length of the sub normal  $QN = \left| y_1 \cdot m \right|$  Where  $m = \left( \frac{dy}{dx} \right)_{at P(x_1, y_1)}$

RATE MEASURE

1. The approximate value of  $\frac{\Delta y}{\Delta x}$ , as  $\Delta x$  tends to zero, it is called the rate of change of  $y$  with respect to  $x$ .

When  $Lt_{\Delta x \rightarrow 0} \frac{\Delta y}{\Delta x}$  exists it is denoted by  $\frac{dy}{dx}$  is the rate of change of  $y$  with respect to  $x$  i.e.  $\frac{dy}{dx} = Lt_{\Delta x \rightarrow 0} \frac{\Delta y}{\Delta x}$ .

2. **Velocity :** Consider a particle moving along a straight line OX. Let  $OP = s$  be the distance travelled by the particle in time 't' measured from a fixed point 'O' along OX. Let the particle further travel a small

distance  $PQ = \Delta s$  in a small interval of time  $\Delta t$ .

The average speed in the interval  $\Delta t$  is  $\frac{\Delta s}{\Delta t}$ .

The velocity at time 't' is the limit of  $\frac{\Delta s}{\Delta t}$  as  $\Delta t \rightarrow 0$  and is denoted by v.

$$\therefore v = \text{velocity at time } t = \lim_{\Delta t \rightarrow 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt} \text{ unit/sec}$$

$$3. \quad \underline{\text{Acceleration}} : a = \frac{dv}{dt} = \frac{d^2s}{dt^2} \text{ unit/sec}^2$$

$$4. \quad \underline{\text{Angular acceleration}} : \frac{d}{dt} \left( \frac{d\theta}{dt} \right) = \frac{d^2\theta}{dt^2} \text{ radians/sec}^2$$

### ROLLE'S THEOREM AND LAGRANGE'S MEAN VALUE THEOREM

1. **ROLLE'S THEOREM**: If  $f : [a, b] \rightarrow R$  be a function satisfying the following conditions
  - i)  $f$  is continuous on  $[a, b]$
  - ii)  $f$  is differentiable on  $(a, b)$
  - iii)  $f(a) = f(b)$  then there exists atleast one  $c \in (a, b)$  such that  $f'(c) = 0$

2. **LAGRANGE'S MEAN VALUE THEOREM**:

If  $f : [a, b] \rightarrow R$  be a function satisfying the following conditions

- i)  $f$  is continuous on  $[a, b]$
- ii)  $f$  is differentiable on  $(a, b)$  then there exists atleast one point  $c \in (a, b)$  such that

$$f'(c) = \frac{f(b) - f(a)}{b - a}$$

### MAXIMA AND MINIMA

1. Let I be an open interval contained in the domain of the real valued function  $y = f(x)$ . Then  $f(x)$  is said to be
  - i) increasing on I if  $x_1 < x_2 \Rightarrow f(x_1) \leq f(x_2)$  for  $x_1, x_2 \in I$
  - ii) strictly increasing on I if  $x_1 < x_2 \Rightarrow f(x_1) < f(x_2)$  for all  $x_1, x_2 \in I$
  - iii) decreasing on I if  $x_1 < x_2 \Rightarrow f(x_1) \geq f(x_2)$  for all  $x_1, x_2 \in I$
  - iv) strictly decreasing on I if  $x_1 < x_2 \Rightarrow f(x_1) > f(x_2)$  for all  $x_1, x_2 \in I$
  - v) If  $f'(x) > 0$  then 'f' is said to be an increasing function
  - vi) If  $f'(x) < 0$  then 'f' is said to be a decreasing function

2. Stationary point :- If  $f'(a) = 0$  then  $y = f(x)$  is said to be stationary at  $x = a$ ;  $f(a)$  is called the stationary value of  $f$  at  $x = a$  then  $(a, f(a))$  is called a stationary point or turning point of 'f'.
3. For maxima or minima,  $f'(x) = 0$
4. i) If  $f'(a) = 0, f''(a) < 0$  then 'f' has a maximum at  $x = a$   
ii) If  $f'(a) = 0, f''(a) > 0$  then 'f' has a minimum at  $x = a$

\* \* \*

## JUNIOR INTER PHYSICS

### PHYSICAL WORLD

1. **Physics:** Physics is the branch of science which deals with the physical properties of matter and their energies.
2. Gravitational force, Electromagnetic force, Strong nuclear force, and weak nuclear force are the fundamental forces in nature
3. Acceleration due to gravity has no symmetry but Law of gravitation has symmetry.
4. The gravitational force is the force of mutual attraction between any two objects by virtue of their masses. It is a universal force.
5. Electromagnetic force is the force between charged particles.
6. The electric force between two protons, is  $10^{36}$  times the gravitational force between them, for any fixed distance.
7. The strong nuclear force binds protons and neutrons in a nucleus.
8. The strong nuclear force is the strongest of all fundamental forces, about 100 times the electromagnetic force in strength.
9. The radius of a nucleus is of the order of  $10^{-15}$  m and that of the atom is nearly  $10^{-10}$  m thus nucleus is 5 order of magnitude greater than the radius of atom.
10. The weak nuclear force appears only in certain nuclear processes such as the  $\beta$  – decay of a nucleus.
11. The range of weak nuclear force is exceedingly small, of the order of  $10^{-16}$  m
12. According to Einstein's theory, as m is equivalent to energy E given by the relation  $E = mc^2$ , where c is speed of light in vacuum. C = 3 \times 10^8 m/s
13. **The discovery of C.V.Raman is Raman Effect.** The Raman Effect deals with

scattering of light by molecules of a medium when they are excited to vibrational energy levels. (Mar - 14)

14. Chandra sekhar limit, structure and evolution of stars is the contribution of S.Chandra Sekhar to Physics.(Mar-13,15)

### UNITS & MEASUREMENTS

1. **Fundamental Physical quantities:**  
The physical quantity which does not depend upon other physical quantities.
2. **Derived Physical quantities:**  
The physical quantities which can be derived from the fundamental quantities are called as derived quantities.
3. **Fundamental units :** The units of fundamental physical quantities are called the fundamental units.  
Ex : Kg, m, sec etc.
4. **Derived units :** The units of derived physical quantity are called the derived units  
Ex : m/s ,  $m / s^2$  , J etc.
5. **Dimensional formula:** The expression in which a physical quantity is represented as mathematical powers of fundamental physical quantity is known as dimensional formula.
6. **Dimensions:**  
The dimensions of a physical quantities are the powers to which the fundamental quantities to be raised to represent that physical quantity
7. **Dimensional constant:**  
Constants having dimensional formula are called dimensional constants.  
Ex:- Planck's constant, universal gravitational constant
8. **Dimensionless quantities:-**  
Physical quantities having no dimensional formula are called dimension less quantity  
Ex: Angle,strain
9. **Principle of homogeneity,** (Eamcet-2012)  
Only physical quantities having same dimensions can be added, subtracted or can be equated.

**10. Uses of dimensional formula :**

- Dimensional formulae can be used
- to check the correctness of an equation.
  - to convert one system of units to another system.
  - to derive relationship among different physical quantities.

**11. Limitations of dimensional analysis :**

- This method does not give information about dimensionless constants.
- This method is limited to physical relations which are power functions only
- This method is not suitable to derive relations involving exponential and logarithmic, trigonometric functions.
- This method is not suitable to derive relation when a physical quantity depends on more than three other physical quantities

**12. In a physical quantity the numerical value is inversely proportional to its units.**

$$N \propto \frac{1}{U} \Rightarrow N_1 U = N_2 U_2$$

**13. Error:** The difference between true value and measured value is called Error.**14. Different types of Errors** are systematic errors, random errors and gross errors.**15. True Value :**

The arithmetic mean of a large number of repeated measurements is taken as the true value or actual value.

**16. Accuracy :**

(Mar-13,15)  
Accuracy is a measure of the closeness of the measured value to the true value.

**17. Precision :**

Precision tells us to what resolution or limit the quantity is measured by an instrument.

**18. Significant digits :** The digits of a number that are definitely known plus one more digit i.e estimated are called the significant digits**19. The value of unified atomic mass unit(1amu) =  $1.66 \times 10^{-27}$  kg .****20. Systematic errors can be minimised by improving**

experimental techniques, selecting better instruments and removing personal bias as far as possible.

(Mar. - 14)

**MOTION IN A STRAIGHT LINE****1. Distance :**

- The total length of the path is known as distance.

- Distance is a scalar.

**2. Displacement:**

- The shortest distance between two points with specific direction is known as displacement.

- Displacement is a vector quantity.

- Both distance and displacement have same units and dimensions.

- Units: metre

- Dimensional formula:  $M^0 L^1 T^0$

**3. Speed :** The rate of change of distance is known as speed.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \Rightarrow V = \frac{S}{t}$$

Speed is a scalar quantity.

**4. Velocity :** The rate of change of displacement is known as velocity.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} \Rightarrow V = \frac{S}{t}$$

Units : m/s

- Dimensional formula:  $M^0 L^1 T^{-1}$

Velocity is a vector quantity.

Both speed and velocity have same units and dimensions.

**5. Average speed :**

$$= \frac{\text{Total distance travelled}}{\text{Total time}}$$

Distance travelled = Average speed x time

$$S = V_{avg} \times t$$

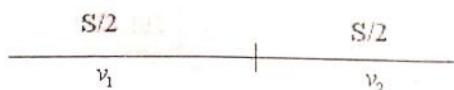
**6. Resultant displacement =**

(Average velocity) X (time);  $S = V \times t$

If a body cover first half of the total displacement with a velocity  $v_1$  and

**second half with velocity  $v_2$ , then the average velocity is given by**

$$V_{\text{avg}} = \frac{2v_1 v_2}{v_1 + v_2}$$



8. **Average velocity** (Mar-2013)

**The ratio of total displacement to the total time interval in which the displacement occurs**

$$V_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

9. **Instantaneous velocity** : The velocity of a body at any particular instant in its journey is known as instantaneous velocity. (Mar:2013)

$$V_{\text{inst}} = \frac{ds}{dt}$$

**Units:** m/s

**Dimensional formula:**  $M^0 L^1 T^{-1}$

10. **Average velocity and Instantaneous velocity are equal, if the particle is in uniform motion along a straight line.**

11. **Acceleration** : The rate of change of velocity of a body is called acceleration. Acceleration( a )

$$= \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$$

$$a = \frac{v-u}{t}$$

The direction of acceleration lies along the direction of change in velocity.

12. **Retardation** : The negative acceleration is known as retardation.

Any body travelling with decreasing velocity possess retardation or deceleration.

**Units:**  $m/s^2$

**Dimensional formula:**  $M^0 L^1 T^{-2}$

13. Acceleration is maximum at the extreme

points of simple harmonic motion.

14. **Equations of motion ( moving with uniform acceleration)**

$u$  = initial velocity,  $v$  = final velocity

$a$  = acceleration,  $s$  = displacement,

$t$  = time of travel

$$1) v = u + at \quad 2) S = ut + \frac{1}{2}at^2$$

$$3) v^2 - u^2 = 2as \quad 4) S_n = u + a\left(n - \frac{1}{2}\right)$$

Where  $S_n$  is the distance travelled in  $n^{\text{th}}$  second of its journey.

15. **Equations of motion of a freely falling body** (take  $u = 0$  and  $a = g$ )

$$1) v = gt \quad 2) S = \frac{1}{2}gt^2$$

$$3) v^2 = 2gs \quad 4) S_n = g\left(n - \frac{1}{2}\right)$$

16. **Equations of motion for a body thrown vertically up** ( $a = -g$ ,  $s = h$ )

$$1) v = u - gt$$

$$2) h = ut - \frac{1}{2}gt^2$$

$$3) v^2 = u^2 - 2gh$$

$$4) h_n = u - g\left(n - \frac{1}{2}\right)$$

17. For a body thrown up vertically from the top of a tower (or) a body dropped from a balloon moving vertically up

$$1) v = u - gt \quad 2) h = -ut + \frac{1}{2}gt^2$$

$$3) v^2 = u^2 + 2gh$$

$$4) h_n = -u + g\left(n - \frac{1}{2}\right)$$

18. **For a body thrown vertically up with an initial velocity 'u'**

a. **Maximum height** : Maximum vertical distance travelled is known as maximum

$$\text{height } h = \frac{u^2}{2g} \Rightarrow h \propto u^2$$

**b. Time of ascent :** The time taken by a body to reach the maximum height is known

$$\text{as time of ascent. } t_a = \frac{u}{g} \quad (\text{Mar-12})$$

**c. Time of descent :** The time in which body comes down from maximum height is known as time of descent.

$$t_d = \frac{u}{g} \quad (\text{Mar:12})$$

**d. Time of flight :** The total time for which a body remains in air before reaching the ground is known as time of flight.

$$T = t_a + t_d = \frac{u}{g} + \frac{u}{g} = \frac{2u}{g}$$

19. Time of ascent is equal to time of descent, if air resistance is neglected.
20. If a body is thrown vertically up with a velocity 'u', it returns to ground with velocity 'v' which is equal to magnitude of 'u' but opposite in direction i.e.,  $\vec{v} = -\vec{u}$ .
21. For a body falling freely through a height 'h'

$$\text{The time of descent } t = \sqrt{\frac{2h}{g}}$$

$$\text{The velocity gained } V = \sqrt{2gh}.$$

22. If a body is allowed to fall freely from the top of a tower of height 'h' and another is projected simultaneously from the foot of tower in the upward direction with velocity

$$u \text{ then, they meet after time } t = \frac{h}{u}.$$

23. **Relative velocity :** Velocity of one body with respect to that of another body is called relative velocity. The velocity of 'A' with respect to that of 'B' is given by

$$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$$

If 'A' and 'B' are moving at an angle  $\theta$

with one another, then, velocity of 'A' with respect to that of 'B' is given by

$$|\vec{V}_{AB}| = \sqrt{V_A^2 + V_B^2 - 2V_A V_B \cos\theta}.$$

## MOTION IN A PLANE

1. The physical quantities having both magnitude and direction and also obeying laws of vector addition are known as vectors.

### Different types of vectors

#### i) Like vectors or Parallel vectors:

Two vectors (representing same physical quantity) are called like vectors, if they are parallel to each other, however their magnitudes may be different.

#### ii) Equal vectors:

Two or more vectors (representing same physical quantity) are called equal vectors if their magnitudes and directions are same.

#### iii) Negative vector:

A vector having the same magnitude and opposite direction of a given vector is called negative vector of the given vector.

#### iv) Null vector: (Mar:2008, May-97, Sep-2000)

A vector whose magnitude is zero and whose direction is indetermined is called as Null vector (or) zero vector.

#### v) Unit vector: (Mar:2008, May-97, Sep-2000)

A vector whose magnitude is equal to

$$\hat{A} = \frac{\vec{A}}{|\vec{A}|}$$

one is called as Unit vector.

Ex:-  $\hat{i}$ ,  $\hat{j}$  and  $\hat{k}$  are unit vectors along X, Y and Z axes respectively.

#### vi) Position vector:

The vector used to specify the position of a point with respect to some fixed point (say origin 'O') is called position vector. (Mar:08, May-97, Sep-2000)

a) If P(x, y, z) is a point in 3D space, then the position vector of P is given by

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

## JR PHYSICS

b) If  $(A_x, A_y, A_z)$  is a point 3D space, then the position vector of this point is given by

$$\vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$$

c) Magnitude of  $\vec{A}$  is  $|\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$

d) If  $\alpha, \beta, \gamma$  are the angles made by  $\vec{A}$  with X, Y and Z axes respectively, then

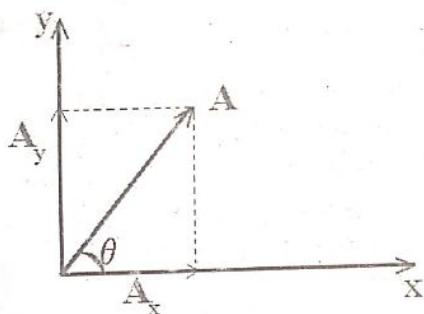
$$\cos \alpha = \frac{A_x}{|\vec{A}|}; \cos \beta = \frac{A_y}{|\vec{A}|}; \cos \gamma = \frac{A_z}{|\vec{A}|}$$

where  $\cos \alpha, \cos \beta$  and  $\cos \gamma$  are called as direction cosines.

e) The relation between direction cosines is  $\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = 1$

### 3. Resolution of Vectors

The process of dividing a vector into its components is called resolution of vector



i) Horizontal component  $A_x = A \cos \theta$

ii) Vertical component  $A_y = A \sin \theta$

iii) Resultant  $A = \sqrt{A_x^2 + A_y^2}$

iv) If the horizontal component of a vector is equal to its vertical component, then the angle made by the vector with X-axis is  $\theta = 45^\circ$

### 4. Parallelogram law of vectors:

(Mar:05,09,10,13,14 May-05,06,09, Jun-10.)

If two vectors are represented in magnitude and direction by the adjacent

sides of a parallelogram drawn from a point, the diagonal passing through that point represents their resultant both in magnitude and direction.

Magnitude of resultant of given two

$$\text{vectors} = R = \sqrt{A^2 + B^2 + 2AB \cos \theta}$$

where  $\theta$  is the angle between the vectors.

Direction of resultant vectors  $\bar{R}$ .

$$\tan \alpha = \frac{B \sin \theta}{A + B \cos \theta}$$

where  $\alpha$  is angle made by the  $\bar{R}$  with  $\vec{A}$ .

5. Projectile : A body projected in to air with some velocity at an angle (other than  $90^\circ$ ) with the horizontal is called a projectile.

6. The path of a projectile is a parabola.

i) If a body is projected at an angle ' $\theta$ ' to the horizontal with an initial velocity 'u' its horizontal and vertical components of initial velocities are

$$u_x = u \cos \theta \text{ and } u_y = u \sin \theta.$$

ii) After a time 't' the horizontal displacement  $= x = (u \cos \theta) t$

vertical displacement =

$$y = (u \sin \theta) t - \frac{1}{2} g t^2.$$

iii) Equation for the trajectory of the body

$$y = x \tan \theta - \left( \frac{g}{2u^2 \cos^2 \theta} \right) x^2$$

7. The velocity of projectile is not zero at any point. Its value is minimum ( $u \cos \theta$ ) at the highest point of its path. At this point only vertical component of velocity is zero.

At any instant of time 't' the horizontal component of velocity is  $v_x = u \cos \theta$ .

The vertical component of velocity is  $v_y = u \sin \theta - gt$ .

The resultant velocity is  $v = \sqrt{v_x^2 + v_y^2}$ .

The direction 'v' makes an angle  $\alpha$  with horizontal

$$\text{where } \tan \alpha = \frac{v_y}{v_x}.$$

9. Time of ascent ( $t_a$ ) =  $\frac{u \sin \theta}{g}$

10. Time of descent ( $t_d$ ) =  $\frac{u \sin \theta}{g}$

11. Time of flight  $T = t_a + t_d = \frac{2u \sin \theta}{g}$

12. Maximum height reached

$$= H_{\max} = \frac{u^2 \sin^2 \theta}{2g} \quad (\text{Mar:2012})$$

13. Horizontal range  $(\text{Mar:2012})$

$$R = \frac{2u_x u_y}{g} = \frac{2(u \sin \theta)(u \cos \theta)}{g}$$

$$= \frac{u^2 \sin(2\theta)}{g}$$

14. Angle of projection for maximum range is  $\theta = 45^\circ$

15. Two angles of projection for same range are ' $\theta$ ' and  $(90 - \theta)$  and  $(45 + \theta)$  and  $(45 - \theta)$  also.

16. If the range and maximum height of a projectile are equal, the angle of projection  $\theta = \tan^{-1}(4)$

17. The relation between range and maximum height is  $\frac{R}{H} = \frac{4}{\tan \theta}$

$$\text{when } \theta = 45^\circ \text{ then } H = \frac{R}{4}$$

18. The path of a body projected horizontally from the top of a tower of height 'h' is a parabola  
The equation of the trajectory is given by

$$y = \left( \frac{g}{2u^2} \right) x^2$$

a) The time of descent  $t = \sqrt{\frac{2h}{g}}$

b) The horizontal range  $R = u \times t = u \sqrt{\frac{2h}{g}}$

c) At any instant 't' horizontal velocity is  $v_x = u$ , vertical velocity  $v_y = gt$

d) The resultant velocity  $v = \sqrt{v_x^2 + v_y^2}$

e) The angle made by V with horizontal is

$$\text{given by } \tan \alpha = \frac{v_y}{v_x}.$$

19. Suppose a bomb is dropped from a plane moving horizontally with uniform velocity 'u'. the path of bomb as observed by a man stationary on ground is parabola and as observed by the pilot of the plane is a vertical straight line.

## LAWS OF MOTION

Newton First law defines inertia and force.

Inertia : The inability of a body to change its state of rest or of uniform motion along a straight line by itself is called inertia. Mass is a measure of inertia.

(Mar - 14)

1. The inability of a body to change its state of rest by itself is called inertia of rest.
2. The inability of a body to change its state of motion by itself is inertia of motion.
3. The inability of a body to change its direction of motion by itself is inertia of direction.
4. Newton's second law: The rate of change of momentum of a body is directly proportional to the net external force acting on the body and takes place in the direction in which the force acts.

Newton second law measures the force

$$F \propto \frac{\Delta p}{\Delta t}$$

The product of mass and velocity of a

body is called linear momentum.  $p = mv$

$$F = ma = \frac{mv - mu}{t}$$

1 newton =  $10^5$  dyne

1 kg wt = g newton

6. Apparent weight in a lift =  $m(g \pm a)$ ,  
a) Use + sign when acceleration is upwards.  
b) Use - sign when acceleration is downwards.
7. When a lift moves downwards with a uniform acceleration or moves upwards with uniform retardation (a) the apparent weight of a person mass (m) is  $R = m(g - a)$ . Apparent weight decreases
8. When the lift falls down freely, apparent weight of a person is zero since  $a = g$ .
9. When a lift moves upward or downwards with constant velocity, the apparent weight of a person is  $mg$ ; since  $a = 0$ . (EAM-2007)
10. The apparent weight of a person in a lift depends on the direction of acceleration.
11. A large force acting on a body for a short time interval is an impulsive force.
12. Impulse is equal to change of linear momentum of the body and given by  $I = (mv - mu) = \text{change in momentum}$ .  
Impulse =  $F \times t$
13. The area under force-time graph gives impulse
14. To decrease an impulsive force, time of impulse is increased
15. **Newton third law :** "To every action there is always an equal and opposite reaction". i.e., Action = - (reaction)
16. Action and reaction never act on the same body, but act on two different bodies
17. **Law of conservation of linear momentum :**  
"The total momentum of an isolated system of interacting particles is conserved".
18. For translatory equilibrium of a body, net External force acting on it is zero.
19. **Friction:** The property which opposes the relative motion of one body over the surface of another body is called friction.

20. **Advantages of friction :** (Mar-15)  
i) While walking, friction between the ground and shoes prevent us from slipping

ii) Without friction, motion cannot be conveyed by belts from motor to machine

21. **Disadvantages of friction :**

i) Friction causes wear and tear of moving parts of the machinery.  
ii) Friction generates heat in machine parts which damages the machinery.

22. **Methods of reducing friction :**

- i) By Polishing
  - ii) By using Lubricants
  - iii) By using Ball bearings
  - iv) Stream lining
- (Mar-14)

23. **Types of friction :**

There are three types of frictional forces

- i) Static friction
- ii) Dynamic friction
- iii) Rolling friction

24. **Laws of friction :**

i) Friction opposes relative motion between two surfaces in contact and is always tangential to the surfaces of contact.

ii) Friction depends on the nature of the two surfaces in contact i.e., nature of materials, surface finishing etc..

iii) Frictional force is independent of the area of contact between the two surfaces

iv) Frictional force is directly proportional to the normal reaction acting on the body.

$$v) f \propto R \Rightarrow f = \mu R$$

Where  $\mu$  = coefficient of friction

$$vi) \text{Coefficient of static friction } (\mu_s) = \frac{f_{ms}}{R}$$

$$vii) \text{Coefficient of kinetic friction } (\mu_k) = \frac{f_k}{R}$$

viii) Coefficient of rolling friction ( $\mu_r$ ) =  $\frac{f_r}{R}$

ix)  $\mu_s > \mu_k > \mu_r$

25. **Normal reaction (R):**

a) When the body lies on a horizontal surface

$$R = W = mg$$

b) When the body lies on an inclined surface

$$R = W \cos \theta = mg \cos \theta$$

26. The angle between the normal reaction R and the resultant of f and R is called angle of friction

27. If  $\theta$  is angle of friction and  $\mu$  is the coefficient of friction then  $\mu = \tan \theta$

28. **Angle of repose ( $\alpha$ ):**

Angle of repose is the minimum angle of the rough inclined plane for which body placed on it may just start sliding down.

a) If  $\theta < \alpha$ , the body is at rest on the plane.

Frictional force =  $mg \sin \theta$  (Self adjusting force)

b) If  $\theta = \alpha$ , the body just tends to slide down the plane

Frictional force =  $mg \sin \alpha = \mu_s mg \cos \alpha$

c) If  $\theta > \alpha$ , the body slides down with acceleration

Frictional force =  $\mu_k mg \cos \theta$

29. **Pulling with inclined force is easier than pushing.**

a) In case of a pulling a lawn roller

$$N = mg - F \sin \theta$$

b) In case of a pushing a lawn roller

$$N = mg + F \sin \theta$$

## WORK-ENERGY-POWER

1. **Dot Product or scalar product**

**Definition of dot product:**

The dot product of two non zero vectors is defined as the product of their magnitudes

and cosine of the angle between them.

$$\vec{A} \cdot \vec{B} = AB \cos \theta$$

Dot product of two vectors is a scalar.

**Properties of scalar product:**

i) Dot product obeys commutative law

$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$$

ii) Dot product obeys distributive law

$$\vec{A} \cdot (\vec{B} + \vec{C}) = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{C}$$

iii) Dot product can be -Ve, +Ve, or 0

iv) Dot product of unit vectors

$$\hat{i} \cdot \hat{i} = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k} = 1$$

$$\hat{i} \cdot \hat{j} = \hat{j} \cdot \hat{k} = \hat{k} \cdot \hat{i} = 0$$

v) If  $\vec{A} = A_1 \hat{i} + A_2 \hat{j} + A_3 \hat{k}$  and

$$\vec{B} = B_1 \hat{i} + B_2 \hat{j} + B_3 \hat{k}$$
, then,

$$\vec{A} \cdot \vec{B} = A_1 B_1 + A_2 B_2 + A_3 B_3$$

2. **Work :** Work is said to be done by a force when a body undergoes displacement parallel to the line of action of the force.

Units: S.I. - joule

C.G.S - erg

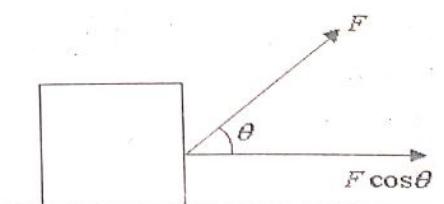
$$1 \text{ Joule} = 10^7 \text{ ergs}$$

3. If a force F acts on a body at an angle  $\theta$  and displaces the body through a distance 'S' then workdone,

$$W = (F \cos \theta) S = \vec{F} \cdot \vec{S}$$

Work done is a scalar quantity

4.



i) When  $\theta = 90^\circ$ ,  $W = 0$

ii) when  $0 < \theta < 90^\circ$  workdone is positive

**JR PHYSICS**

- iii) when  $90^\circ < \theta < 180^\circ$  workdone is negative
- 5. **Conditions for zero work**
  1. when force is zero
  2. when displacement is zero
  3. when angle between force and displacement is  $90^\circ$
- 6. **Power :** The rate of doing work is called power. (Eamcet-2012)

$$\text{Power}(P) = \frac{\text{Work}}{\text{time}} = \frac{Fs}{t} = \frac{W}{t}$$

$$P = \frac{\bar{F} \cdot \bar{S}}{t} = \bar{F} \cdot \bar{V}$$

Power is a scalar.

**Units :** SI - watt or J/sec

1 Horse Power (H.P) = 746 watt

- 7. The power of a machine gun firing 'n' bullets, each of mass 'm' in "t" second with velocity 'v' is  $P = \frac{mnv^2}{2t}$

- 8. **Energy :** The capacity of doing work is called energy.
- a) It is a scalar, its unit is same as that of work.
- b) **Units :** SI - Joule  
C. G. S - erg

$$c) 1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

- 9. Energy possessed by a body by virtue of its position or configuration is known as potential energy.
- i) The P. E. of a body at a height h

$$P. E. = mgh$$

Where  $h \ll R$ , where R is the radius of the earth.

**Ex :** Energy possessed by

- 1) Bird sitting on a branch of a tree
- 2) Water stored in the dam.
- ii) The elastic P.E. stored in a compressed

$$\text{spring is } P.E. = \frac{1}{2} kx^2 = \frac{1}{2} Fx = \frac{1}{2} \cdot \frac{F^2}{K}$$

Where K is spring constant

- 10. The energy possessed by a body by virtue of its motion is called kinetic energy.  $K.E = \frac{1}{2} mv^2$   
**Ex:** Energy possessed by
  - (1) A vehicle in motion.
  - (2) Water flowing along a river.
  - (3) A bullet fired from a gun.
  - (4) A satellite going around the earth.
- 11. A flying bird, moving aeroplane, freely falling body, a body moving on an inclined plane and oscillating pendulum posses both P. E. and K. E.
- 12. The relation between K.E. and momentum is  $KE = \frac{P^2}{2m}$   
 $KE \propto P^2$  for a given body.
- 13. **Work - Energy theorem:-** The work done on a particle by the net force is equal to the change in its kinetic energy.  

$$W = \frac{1}{2} mv^2 - \frac{1}{2} mu^2 = K_f - K_i$$
- 14. **Conservative force :**
  - 1) A force is conservative if the work done by the force on a body along any closed path is zero.
  - 2) The work done by the conservative force on a body depends only on the initial and final positions and does not depend on the path followed.  
**Ex:** gravitational force

**Non-conservative force :**

  - 1) A force is Non-conservative if the work done by the force on a body along a closed path is not zero
  - 2) The work done by the non-conservative force on a body depends on the path followed.  
**Ex:** frictional force.
- 15. **Law of Conservation of Energy :** The total mechanical energy of a system is

**constant if the internal forces doing work on it are conservative and the external forces do no work.**

**16. Law of conservation of momentum :**

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

Total momentum before collision = Total momentum after collision. This is valid in the absence of external force and in a given direction.

**17. In elastic collision both momentum and kinetic energy are conserved.**

**18. In inelastic collision only momentum is conserved; kinetic energy is not conserved**

19. When two bodies of masses  $m_1$  and  $m_2$  moving with velocities  $u_1$  and  $u_2$  undergo head on elastic collision, both momentum and kinetic energy are conserved. If  $v_1$  and  $v_2$  are their respective velocities after collision, then

$$\text{i) } m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$\text{ii) } \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

$$\text{iii) } v_2 - v_1 = u_1 - u_2$$

$$\text{iv) } v_1 = \left( \frac{m_1 - m_2}{m_1 + m_2} \right) u_1 + \left( \frac{2m_2}{m_1 + m_2} \right) u_2$$

(Eamcet-2009)

$$\text{v) } v_2 = \left( \frac{2m_1}{m_1 + m_2} \right) u_1 + \left( \frac{m_2 - m_1}{m_1 + m_2} \right) u_2$$

20. A bullet of mass  $m$  is fired from a rifle of mass  $M$  with velocity  $u$ . The velocity of

$$\text{recoil of the rifle is } v = \frac{mu}{M}$$

**21. Coefficient of restitution**

$$e = \frac{\text{Relative velocity of separation after collision}}{\text{Relative velocity of approach before collision}}$$

$$= \frac{(v_2 - v_1)}{(u_1 - u_2)}$$

The value of coefficient of restitution ( $e$ ) is

independent of the masses and velocities of the colliding bodies. It depends on the nature of colliding bodies.

**22. a) For perfectly elastic collisions  $e = 1$**

**b) For perfectly inelastic collisions  $e = 0$**

**c) For other collisions (inelastic collision) 'e' lies between 0 and 1**

23. A body freely falls from a height  $h_1$  on to a hard floor and rebounds to a height  $h_2$ . Then the coefficient of restitution

$$e = \sqrt{\frac{h_2}{h_1}}$$

24. A body freely falls on the ground from a height "h" and rebounces. The total distance travelled by the body before ceases the

$$\text{rebounce is } d = h \left( \frac{1+e^2}{1-e^2} \right)$$

## SYSTEM OF PARTICLES AND ROTATIONAL MOTION

**1. Centre of mass:**

Centre of mass of a body is a point, where the entire mass is supposed to be concentrated.

**2. Characteristics of centre of mass :**

i) Centre of mass of system of particles depend on mass of particles and their relative positions.

ii) For continuous distribution of mass, centre of mass depends on mass distribution and shape of the body.

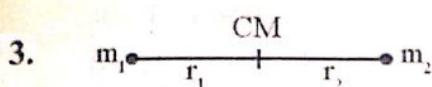
iii) It is not necessary that a mass should be present at the centre of mass of any system. Ex : uniform ring, bangle.

iv) It does not depend on acceleration due to gravity

v) Internal forces cannot change the path followed by CM of a system.

vi) In absence of external force,

$$a_{CM} = 0 \quad (\text{or}) \quad V_{CM} = \text{constant}$$



When two particles of masses  $m_1$  and  $m_2$  are located on a straight line, their centre of mass lies on the line joining the two particles. Let  $r_1$  and  $r_2$  be the distances of the particles from their centre of mass respectively, then

$$m_1 r_1 = m_2 r_2$$

#### Coordinates of centre of mass

Let us consider a system of  $n$  particles of masses  $m_1, m_2, \dots, m_n$  whose co-ordinates are  $(x_1, y_1, z_1), (x_2, y_2, z_2), \dots, (x_n, y_n, z_n)$  respectively. Then co-ordinates of their centre of mass are

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 + \dots + m_n x_n}{m_1 + m_2 + \dots + m_n}$$

$$y_{cm} = \frac{m_1 y_1 + m_2 y_2 + \dots + m_n y_n}{m_1 + m_2 + \dots + m_n}$$

and

$$z_{cm} = \frac{m_1 z_1 + m_2 z_2 + \dots + m_n z_n}{m_1 + m_2 + \dots + m_n}$$

#### Position vector of centre of mass

Consider two particles of mass  $m_1$  and  $m_2$  whose position are represented by position

vectors  $\vec{r}_1$  and  $\vec{r}_2$  respectively at an instant,

$$\text{then, } \vec{r}_{cm} = \frac{\vec{m}_1 \vec{r}_1 + \vec{m}_2 \vec{r}_2}{m_1 + m_2}$$

#### Velocity of centre of mass:

$$\vec{V}_{cm} = \frac{\vec{m}_1 \vec{V}_1 + \vec{m}_2 \vec{V}_2 + \dots + \vec{m}_n \vec{V}_n}{m_1 + m_2 + \dots + m_n}$$

$$\vec{V}_{cm} = \frac{1}{M} \cdot \sum_{i=1}^n m_i \cdot \vec{V}_i$$

#### Momentum of centre of mass :

$$M \vec{V}_{cm} = m_1 \vec{V}_1 + m_2 \vec{V}_2 + \dots + m_n \vec{V}_n$$

$$M \vec{V}_{cm} = \vec{P}_1 + \vec{P}_2 + \dots + \vec{P}_n$$

$$\vec{P}_{cm} = M \vec{V}_{cm} = \sum_{i=1}^n \vec{P}_i$$

#### Acceleration of centre of mass :

$$\vec{a}_{cm} = \frac{\vec{m}_1 \vec{a}_1 + \vec{m}_2 \vec{a}_2 + \dots + \vec{m}_n \vec{a}_n}{m_1 + m_2 + \dots + m_n}$$

$$\vec{a}_{cm} = \frac{1}{M} \sum_{i=1}^n m_i \vec{a}_i$$

**Centre of gravity:** Centre of gravity of the body is a point, through which weight of the body always acts.

i) Centre of mass and centre of gravity coincide for small bodies and they do not coincide for large bodies like planets

ii) It depends on acceleration due to gravity.

**Linear momentum of a system of particles:** The total momentum of a system of particles is equal to the product of the total mass of the system and the velocity of its centre of mass, i.e.  $P = MV$

According to Newton's second law,

$$\vec{F}_{ext} = \frac{d\vec{P}}{dt}$$

$$\text{If, } \vec{F}_{ext} = 0, \text{ then } \frac{d\vec{P}}{dt} = 0,$$

So,  $\vec{P} = \text{constant.}$

#### Vector Product:

The vector product of any two vectors is equal to the product of the magnitude of the two vectors and the sine of the angle between them and the resultant direction is always perpendicular to plane formed by the two vectors.

$$\vec{P} \times \vec{Q} = PQ \sin \theta \hat{n} = \vec{R}$$

where  $\hat{n}$  is a unit vector normal to the plane formed by  $\vec{P}$  and  $\vec{Q}$

The magnitude of  $\vec{R}$  is given by

$$R = PQ \sin \theta$$

#### Properties of Vector Product:

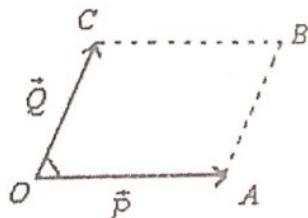
i) Cross product of vectors does not obey commutative law

$$\vec{P} \times \vec{Q} \neq \vec{Q} \times \vec{P} \text{ but } \vec{P} \times \vec{Q} = -(\vec{Q} \times \vec{P})$$

ii) Cross product obeys distributive law of multiplication.

$$\vec{P} \times (\vec{Q} + \vec{R}) = (\vec{P} \times \vec{Q}) + (\vec{P} \times \vec{R})$$

iii) The magnitude of cross product of two vectors is equal to the area of parallelogram with the two vectors as adjacent sides.



If  $\vec{P}, \vec{Q}$  are the adjacent sides of the parallelogram OABC, then the

$$\text{area of } OABC = |\vec{P} \times \vec{Q}|$$

iv) The cross product between two parallel vectors gives a null vector.

$$\vec{P} \times \vec{Q} = PQ \sin \theta \hat{n}.$$

When  $\theta = 0^\circ$  (or)  $180^\circ$ ,

$$\text{then } \vec{P} \times \vec{Q} = \vec{0} \Rightarrow |\vec{P} \times \vec{Q}| = 0$$

v) The cross product between two mutually perpendicular vectors is maximum.

$$\vec{P} \times \vec{Q} = PQ \sin \theta \hat{n}$$

when  $\theta = 90^\circ$ , then,  $|\vec{P} \times \vec{Q}| = PQ$  is the vector with maximum magnitude.

$$\begin{array}{ll} \text{vi)} & \hat{i} \times \hat{i} = 0 \quad \hat{i} \times \hat{j} = \hat{k} \\ & \hat{j} \times \hat{j} = 0 \quad \hat{j} \times \hat{k} = \hat{i} \\ & \hat{k} \times \hat{k} = 0 \quad \hat{k} \times \hat{i} = \hat{j} \end{array}$$

12. If the magnitude of dot product of two vectors is equal to magnitude of cross product of those two vectors then angle between the vectors is  $45^\circ$

$$\left| \vec{A} \cdot \vec{B} \right| = \left| \vec{A} \times \vec{B} \right| \Rightarrow AB \cos \theta = AB \sin \theta$$

$$\Rightarrow \tan \theta = 1 \Rightarrow \theta = 45^\circ$$

#### Examples of cross product:

1) Angular momentum  $\vec{L} = \vec{r} \times \vec{p}$

2) Torque  $\vec{\tau} = \vec{r} \times \vec{F}$ .

14. Angular velocity: The rate of change of angular displacement is called angular

$$\text{velocity } \omega = \frac{d\theta}{dt}$$

S.I. unit : rad / sec

Dimensional Formula:  $[M^0 L^0 T^{-1}]$

15. Relation between angular velocity and linear velocity is  $v = \omega r$

In vector form,  $\vec{v} = \vec{\omega} \times \vec{r}$

16. Centripetal acceleration

$$a_c = \frac{v^2}{R} = \frac{\omega^2 R^2}{R} = \omega^2 R$$

17. Angular acceleration: The rate of change of angular velocity is called angular

acceleration i.e.  $\alpha = \frac{d\omega}{dt}$

S.I. Unit : rad / sec<sup>2</sup>

Dimensional Formula:  $[M^0 L^0 T^{-2}]$

18. Kinematical Equations of rotatory motion:

$$1. \omega = \omega_0 + \alpha t$$

## JR PHYSICS

$$2. \theta = \omega_0 t + \frac{1}{2} \alpha t^2$$

$$3. \omega^2 - \omega_0^2 = 2\alpha\theta$$

$$4. \omega_n = \omega_0 + \frac{\alpha}{2}(2n-1)$$

$$5. \theta = \left[ \frac{\omega + \omega_0}{2} \right] t$$

Where  $\omega_0$  : Initial angular velocity

$\omega$  : Final angular velocity after a time 't'

$\alpha$  : Uniform angular acceleration

$\theta$  : Angular displacement

### 19. Torque:

i) The rate of change of angular momentum

is called Torque i.e.  $\tau = \frac{dL}{dt}$

ii) The turning effect of a force about the axis of rotation is called moment of force or torque.

iii) Torque = Force  $\times$  Perpendicular distance of line of action of force from axis of rotation. i.e.  $\vec{\tau} = \vec{r} \times \vec{F}$

$$|\vec{\tau}| = rF \sin \theta$$

### 20. Angular momentum (L):

Moment of linear momentum of a particle about axis of rotation is known as Angular momentum

Angular momentum = linear momentum  $\times$  Perpendicular distance from the axis of rotation.

Angular momentum is an axial vector.

$$\text{In vector form } \vec{L} = \vec{r} \times \vec{P}$$

$$L = rp \sin \theta$$

$\vec{r}$  = Position vector

$r \sin \theta$  = Perpendicular distance.

i) Relation between L & I  $\Rightarrow L = I\omega$ .

ii) The rate of change of angular momentum

$$\text{is torque .i.e. } \vec{\tau} = \frac{d\vec{L}}{dt}$$

iii) Relation between torque and angular acceleration  $\tau = \frac{d}{dt}(I\omega) = I\left(\frac{d\omega}{dt}\right)$

iv) Relation between angular momentum and rotational K.E. is  $KE = \frac{L^2}{2I}$

Here, I = moment of inertia

### 21. Law of conservation of angular momentum:

If there is no resultant external torque on a rotating system, the angular momentum of the system remains constant both in magnitude and direction.

From Newton's second law,  $\vec{\tau} = \frac{d\vec{L}}{dt}$

If  $\vec{\tau} = 0$ , then,  $\frac{d\vec{L}}{dt} = 0 \Rightarrow L = \text{constant.}$

$\Rightarrow I\omega = \text{constant.} (\because L = I\omega)$

$\Rightarrow I_1\omega_1 = I_2\omega_2$

### 22. Couple:

Two non collinear forces of equal magnitude but opposite in direction acting at two different points on a body constitute couple

### 23. Moment of Couple:

It is the product of magnitude of one of two forces of couple and perpendicular distance between the lines of action of two forces.

### 24. Moment of Inertia:

It is a measure of rotational inertia.

Moment of inertia of a rigid body about a given axis of rotation is the sum of products of the masses of various particles and square of their perpendicular distance from the axis of rotation

$$I = m_1 r_1^2 + m_2 r_2^2 + \dots + m_n r_n^2 \quad \text{or}$$

$$I = \sum_{i=1}^n m_i \cdot r_i^2$$

Units: kg.m<sup>2</sup>

Dimensional formula : [ML<sup>2</sup>T<sup>0</sup>]

### 25. Theorems of moment of inertia

#### a) Perpendicular axes theorem:

The moment of inertia of a plane lamina about an axis passing through a point

perpendicular to its plane is equal to the sum of the moments of inertia about two mutually perpendicular axes in its plane passing through the same point

$$I_z = I_x + I_y$$

**b) Parallel axes theorem:**

Moment of inertia of a rigid body about any axis is equal to the sum of its moment of inertia about a parallel axis passing through its centre of mass and the product of the mass of the body and square of the perpendicular distance between the two axes.

$$I_z = I_{cm} + Mr^2$$

**26. Moment of Inertia of some regular shaped bodies about specific axes**

i) Moment of Inertia of thin circular ring of radius R axis perpendicular to its plane is

$$I = MR^2$$

ii) Moment of Inertia of thin circular ring of radius R about its Diameter is

$$I = MR^2 / 2$$

iii) Moment of Inertia of thin rod of length L, its axis perpendicular to rod, passing through its mid point  $I = ML^2 / 12$

iv) Moment of Inertia of Circular disc of radius R, an axis passing through perpendicular to disc at centre is

$$I = MR^2 / 2$$

v) Moment of Inertia of circular disc of radius R, about an axis passing through any Diameter is  $I = MR^2 / 4$

vi) Moment of Inertia of Hollow cylinder of radius R, an axis passing through Geometrical axis is  $I = MR^2$

vii) Moment of Inertia of Solid cylinder of radius R, an axis passing through Geometrical axis is  $I = MR^2 / 2$

viii) Moment of Inertia of solid sphere of radius R, an axis passing through its Diameter  $I = 2MR^2 / 5$

ix) Moment of Inertia of Hollow sphere of radius R, an axis passing through its Diameter  $I = 2MR^2 / 3$

x) **Power:** The rate of work done by torque is called power. Instantaneous power is given by

$$P = \frac{dW}{dt} = \frac{d}{dt}(\tau\theta) = \tau \frac{d\theta}{dt} = \tau\omega$$

**27. Rolling of a body on an inclined plane without slipping :**

When a body is rolling down on an inclined plane, velocity of the body when it reaches the bottom is given by

$$v = \sqrt{\frac{2gh}{1 + \frac{k^2}{r^2}}} = \sqrt{\frac{2g\sin\theta}{1 + \frac{k^2}{r^2}}} \quad (\text{since } h = r\sin\theta)$$

## OSCILLATIONS

**1. Periodic motion:** The motion repeated in equal interval of time is called periodic motion

**2. Characteristics of simple harmonic motions:**

- i) The motion is periodic
- ii) Particle executes to and fro motion
- iii) Acceleration is directed towards the mean point
- iv) The acceleration is always directly proportional to displacement and which is opposite in direction to the displacement  $a \propto (-y)$

3. Every simple harmonic motion is a periodic motion, but every periodic motion need not be a simple harmonic motion.

4. Revolution of electrons around the nucleus and revolution of planet around the sun are periodic but not oscillatory.

**5. Amplitude:**

The maximum displacement of the vibrating particle is called amplitude, represented by 'A' (or) a

**6. Time period:**

The time taken for one oscillation is called time period

$$T = \frac{2\pi}{\omega}, \quad \text{Where } \omega \text{ angular velocity}$$

**JR PHYSICS****7. Frequency:**

The number of oscillations completed by a particle in one second is called frequency.

$$\text{Frequency } f = \frac{1}{T} \text{ cycles/sec.}$$

$$\text{i) 1 hertz} = 1 \text{ Hz} = 1 \text{ oscillation per second} \\ = 1 \text{ s}^{-1}$$

$$\text{ii) The beat frequency of heart} = 75/(1 \text{ min}) \\ = 75/(60 \text{ s}) = 1.25 \text{ s}^{-1}$$

**8. Phase:**

Phase is that which denotes the state of vibration with respect to mean position.

**9. Displacement, velocity and acceleration of a particle executing simple harmonic motion.**

a) Displacement of a particle executing simple harmonic motion is given by

$$y = A \sin(\omega t \pm \phi)$$

where,  $\phi \rightarrow$  is initial phase

$\omega \rightarrow$  angular frequency

$A \rightarrow$  amplitude

b) Velocity of the particle executing simple harmonic motion is given by

$$V = A\omega \cos \omega t \text{ (or)} V = \omega \sqrt{A^2 - y^2}$$

c) Acceleration of a particle executing simple harmonic motion is given by

$$a = -A\omega^2 \sin(\omega t \pm \phi)$$

$$a = -\omega^2 y$$

**Case(i)** When particle at mean position

Displacement  $y = 0$

Acceleration  $a = 0$

Velocity  $V = \omega A$  (maximum)

**Case(ii)** When particle at extreme position

Displacement  $y = A$

Acceleration  $a = -\omega^2 A$  (maximum)

Velocity  $V = 0$

**10. Time period of a particle executing simple harmonic motion is given by**

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

Where  $y =$  displacement and

$a =$  acceleration

**Simple pendulum**

Time period of simple pendulum executing simple harmonic motion is

$$\text{given by } T = 2\pi \sqrt{\frac{l}{g}}$$

where  $l \rightarrow$  length of the simple pendulum  
 $g \rightarrow$  acceleration due to gravity

**12. Laws of simple pendulum**

Time period of a simple pendulum is directly proportional to square root of its length  $T \propto \sqrt{l}$

Time period of simple pendulum is inversely proportional to square root of

$$\text{the acceleration due to gravity } T \propto \frac{1}{\sqrt{g}}$$

a) Time period of simple pendulum is independent of mass and shape of the body so wooden bob is replaced by identical aluminium bob there will be no change in its time period.

b) When pendulum is taken to the top of a mountain, acceleration due to gravity 'g' decreases, time period increases.

$$\left( T \propto \frac{1}{\sqrt{g}} \right). \text{ So the number of oscillations}$$

decreases per day. Hence it loses time. When a pendulum clock showing correct time at the equator is taken to poles, then it will gain time. because acceleration due to gravity at poles is maximum,

$$\text{time period } \left( T \propto \frac{1}{\sqrt{g}} \right)$$

decreases. So number of oscillations made in the given time increases. Hence clock gains time.

If girl stands in a swing, centre of mass goes up. Then length of the oscillation of the swing decreases, the time period also decreases as  $T \propto \sqrt{l}$ . When time period decreases frequency of oscillation increases as  $T = \frac{1}{f}$ .

**JR PHYSICS**

- e). As water begins to drain out from the hollow sphere, the centre of mass of (sphere + water) system goes down. So the effective length of pendulum increases. As  $T \propto \sqrt{l}$ , the time period (T) also increases.

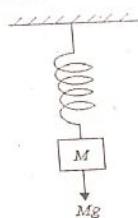
When water is completely drained out the centre of mass comes to its original position (i.e. centre of the sphere). So the pendulum will have its original period.

13. Seconds pendulum:

The pendulum whose time period is 2 seconds is called seconds pendulum. Its length on earth is 100 cm. ( $l = 100\text{cm}$ )

$$(T = 2 \text{ sec})$$

14. Loaded spring:



- i) If a mass M is suspended vertically from a spring and if the spring elongates 'x' then spring constant (K) is

$$K = \frac{F}{x} \Rightarrow K = \frac{Mg}{x}$$

ii) Time period of this loaded spring is:

$$T = 2\pi \sqrt{\frac{M}{K}} = 2\pi \sqrt{\frac{M}{Mg/x}} \Rightarrow T = 2\pi \sqrt{\frac{x}{g}}$$

15. Energy of a particle executing simple harmonic motion:

Let us consider a particle executing simple harmonic motion. It possesses both P. E. and K. E.

$$P.E. = \frac{1}{2} m \omega^2 y^2 \dots\dots\dots(1)$$

$$K.E. = \frac{1}{2} m \omega^2 (A^2 - y^2) \dots\dots\dots(2)$$

Total energy of the particle = PE + KE

$$TE = \frac{1}{2} m \omega^2 A^2 \dots\dots\dots(3)$$

Where A = amplitude, Y = displacement.

If amplitude is doubled its energy is increased by four times

a) Simple pendulum moves from extreme to mean position its PE decreases and KE increases.

b) When it moves from mean to extreme position, KE decreases and PE increases. But total energy remains constant.

16. Forced oscillations. The oscillations in which a body oscillates under the influence of an external periodic force are known as forced oscillations.

17. Damped oscillations.

The oscillations in which the amplitude of the body decreases with time are known as damped oscillations.

**GRAVITATION**

1) Geocentric theory: All the celestial objects, stars, sun and the planets all revolved around the earth is called geocentric theory

2) Heliocentric theory: Sun was the centre of the universe around which the planets revolved is called heliocentric theory.

3) Kepler's laws:

i) Law of orbits: All planets revolve around sun in elliptical orbits with the sun at one of the foci of the ellipse.

ii) Law of areas: The line joining the planet to the sun sweeps out equal areas in equal intervals of time.

$$\frac{dA}{dt} = \text{Constant}$$

iii) Law of periods: The square of the time period of revolution of a planet is directly proportional to the cube of the length of semi major axis of the elliptical path. i.e.,  $T^2 \propto a^3$ .

Where T is time period of revolution of planet, 'a' is the length of the semi major axis or average distance between sun and planet.

4) Relation between acceleration due to gravity (g) at the surface of a planet and gravitational constant (G) is  $g = \frac{GM}{R^2}$

5) Variation of g with altitude (height):

$$g_h = g \left[ 1 + \frac{h}{R} \right]^{-2}$$

if  $h \ll R$ , above equation can be written as

$$g_h = g \left[ 1 - \frac{2h}{R} \right]$$

6) Variation of 'g' with depth:

$$g_d = g \left( 1 - \frac{d}{R} \right)$$

7) Variation of 'g' with latitude:

$$g_\phi = g - r\omega^2 \cos^2 \phi$$

8) Orbital velocity ( $v_o$ ): The speed of a satellite in the orbit is called orbital velocity (or)

Velocity required for a body in order that it revolve round the earth in circular orbit is known as orbital velocity.

$$v_o = \sqrt{\frac{GM}{(R+h)}}$$

If 'h' is very much less than R then

$$v_o = \sqrt{\frac{GM}{R}}$$

$$\text{Therefore } v_o = \sqrt{gR} \quad \left( \because \frac{GM}{R} = gR \right)$$

9) Escape velocity ( $v_e$ ): The minimum velocity with which a body is projected, so that it escapes from the gravitational field of earth is called escape velocity.

$$\Rightarrow V_e = \sqrt{\frac{2GM}{R}} \Rightarrow V_e = \sqrt{2gR}$$

$$\left( g = \frac{GM}{R^2} \Rightarrow GM = gR^2 \right)$$

10) Geo stationary satellite:

a) Satellite whose time period of revolution is equal to the time period of revolution of earth (i.e. 24 hours) is called Geostationary satellite.

b) This satellite appears at rest with respect to the earth.

c) The period of revolution of a Geostationary satellite is 24 hours.

d) It rotates from west to east equatorial plane of earth.

Uses:

i) To study the upper layers of the atmosphere.

ii) Used in the weather forecast.

iii) To know the shape and size of the earth.

iv) To identify the minerals and natural resources present inside and on the surface of the earth.

v) To transmit the T.V. programmes to the distant places.

11) Gravitational potential energy: The amount of work done in bringing the body from infinity to a point is called Gravitational Potential Energy.

$$U = -\frac{Gm_1 m_2}{r}$$

12) Basic forces in nature :

i) Gravitational force

ii) Electromagnetic force

iii) Strong nuclear force

iv) Weak nuclear force

The ratio of strengths of gravitational, weak

nuclear, Electromagnetic and strong nuclear forces are respectively  $1:10^{31}:10^{36}:10^{38}$

### 13. Newton's law of Gravitation:

The force of attraction between any two bodies is directly proportional to product of their masses and is inversely proportional to square of distance between them

$$F = \frac{Gm_1 m_2}{r^2}$$

$$\text{In vector form } \vec{F} = \frac{Gm_1 m_2}{r^3} \vec{r}$$

where G is universal gravitational constant

**Value and units of G:**

$$\text{In S.I., } G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

**Dimensional formula:**  $[M^{-1} L^3 T^{-2}]$

### 14) Gravitational Constant

$$'G' = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}; \text{ Radius of earth } 'R' = 6400 \text{ km}; \text{ Mass of earth } 'M_E' = 6 \times 10^{24} \text{ kg}$$

$$\begin{aligned} 15) \text{ Mass of the sun} &= 2 \times 10^{30} \text{ kg}; \text{ mass of} \\ \text{mars} &= 6.4 \times 10^{23} \text{ kg}; \text{ radius of mars} \\ &= 3395 \text{ km} \end{aligned}$$

## MECHANICAL PROPERTIES OF SOLIDS

### 1. Elasticity :

The property of a material by virtue of which it regains its original size and shape when deformation force is removed is called elasticity.

**Ex :** Steel, Rubber.

No body is perfectly elastic, but quartz is the nearest example.

Elasticity is molecular property of matter.

### 2. Plasticity :

The property of a material by virtue of which it does not regain the size and shape when

the deformation force is removed is called Plasticity.

**Ex :** Putty dough, Chewing gum, Soldering lead

No body is perfectly plastic but putty is nearest example.

### 3. Stress :

**The restoring force per unit area is called stress.**

$$\text{Stress} = \frac{\text{restoring force}}{\text{area of cross section}} = \frac{F}{A}$$

**Unit :**  $\text{N/m}^2$  or Pascal.

**Dimensional Formula :**  $M^1 L^{-1} T^{-2}$

If the stress is normal to the surface, it is called normal stress. If the stress is tangential to the surface, it is called tangential stress.

### 4. Types of stress:

$$\text{i) Normal stress} = \frac{\text{Normal restoring force}}{\text{Area of cross section}}$$

$$\text{Longitudinal stress} = \frac{\text{restoring force}}{\text{area}}$$

$$\text{ii) Volume stress} = \text{Pressure} = \frac{\text{normal force}}{\text{area}},$$

It is also called hydraulic stress

iii)

$$\text{Shearing stress} = \frac{\text{Tangential restoring force}}{\text{Area of cross section}}$$

### 5. Strain :

**The change in dimension produced per unit dimension is called strain.**

$$\text{Strain} = \frac{\text{change in dimension}}{\text{original dimension}}$$

Strain has no units and dimensions.

### 6. Types of strain:

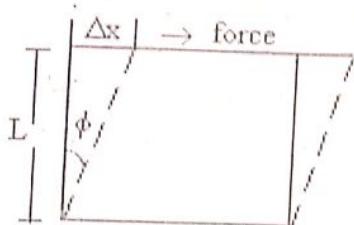
$$\text{i) Longitudinal strain} = \frac{\text{change in length}}{\text{original length}} = \frac{e}{\ell}$$

$$\text{ii) Volume strain (or) Bulk strain}$$

$$= \frac{\text{change in volume}}{\text{original volume}} = \frac{-\Delta V}{V}$$

Negative sign indicates decrease in volume

### iii) Shearing strain:-



$$\text{Shearing strain} = \frac{\text{relative displacement between two layers}}{\text{distance between the layers}}$$

$$\phi = \frac{\Delta x}{L}$$

This strain is due to the change in shape of the body.

### 7. Elastic limit :

The maximum value of the stress within which the body regains its original size and shape is called elastic limit.

### 8. Hooke's law :

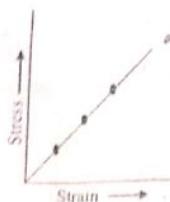
Within the elastic limit, stress is directly

$$\text{proportional to strain. } E = \frac{\text{Stress}}{\text{Strain}}$$

E = modulus of elasticity

S.I. Unit :-  $N/m^2$

Within the elastic limit, stress-strain graph is a straight line passing through the origin.



Slope of the graph is E.

### 9. Young's modulus (Y) :

Within the elastic limit, the ratio of longitudinal stress to longitudinal strain is called as young's modulus.

$$Y = \frac{\text{longitudinal stress}}{\text{longitudinal strain}} = \frac{F\ell}{Ae}$$

If load attached to the wire is M, then  $F = Mg$ , and  $A = \pi r^2$

$$Y = \frac{Mg\ell}{\pi r^2 e} \text{ N/m}^2$$

If Y is large for a body, it can't be elongated.

### 10. Rigidity modulus :

Within the elastic limit, the ratio of tangential stress to the shearing strain is called rigidity modulus.

$$\text{Rigidity modulus} = \frac{\text{tangential stress}}{\text{shearing strain}}$$

$$\Rightarrow \eta = \frac{F}{A\theta}$$

If  $\eta$  is small for a wire, it can be twisted easily.

### 11. Bulk modulus (K) :

Within the elastic limit the ratio between volume stress and bulk strain is called bulk modulus.

$$\text{Bulk modulus} = \frac{\text{volume stress}}{\text{bulk strain}}$$

$$K = -\left(\frac{\Delta V}{V}\right)$$

(- sign shows decrease in volume)

12. The reciprocal of bulk modulus is called compressibility

### 13. Poisson's ratio ( $\sigma$ ) :

The ratio of lateral strain to the longitudinal strain is called Poisson's ratio.

$$\sigma = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

$$\sigma = -\left(\frac{\Delta r}{r}\right) / \left(\frac{\Delta l}{l}\right)$$

## JR PHYSICS

## CDF MATERIAL

- i) As it is a ratio, it has no units and dimensions.
- ii) Theoretical limits of  $\sigma = -1$  to 0.5  
Practical limits of  $\sigma = 0$  to 0.5
- iii) For an incompressible substance  $\sigma = 0.5$
- 14. Thermal force is  $F = AY\alpha\theta$   
Thermal force is independent of length of the bar.  
Thermal stress (linear compressive stress)  
$$= \frac{\text{force}}{\text{area}} = \frac{AY\alpha\theta}{A} = Y\alpha\theta$$
- 15. The work done in stretching a wire  
$$W = \frac{1}{2} \text{ Stress} \times \text{Strain} \times \text{Volume}$$
  
$$W = \frac{1}{2} Fe = \frac{1}{2} \frac{e^2 AY}{\ell}$$
- 16. Strain energy per unit volume (energy density)  
$$E = \frac{1}{2} \times \text{stress} \times \text{strain} = \frac{1}{2} Y(\text{Strain})^2$$
  
Also,  $E = \frac{(\text{Stress})^2}{2Y} \left[ \because Y = \frac{\text{Stress}}{\text{Strain}} \right]$
- 17. **Ductile materials :** The materials which show the large plastic range beyond elastic limit are called Ductile materials.  
Ex. Copper, Gold, Lead etc.,
- 18. **Brittle materials :** The materials which show very small plastic range beyond the elastic limit are called Brittle materials.  
Ex. Glass, Ceramic, Cast Iron etc.,

  - i) Nearly perfect elastic bodies are quartz fiber & steel.
  - ii) Nearly perfect plastic bodies are clay, wax, butter etc.

## MECHANICAL PROPERTIES OF FLUIDS

### ARCHIMEDES PRINCIPLE

1. The loss of weight of body submerged in a fluid is equal to weight of the fluid displaced

2.

### Average pressure :-

Average pressure is defined as the normal force acting per unit area.

$$P = \frac{F}{A}$$

SI Unit :  $Nm^{-2}$  (or) Pascal.

It is a scalar.

Dimensional formula :  $[M^1 L^{-1} T^{-2}]$

3.

**Gauge pressure:** The excess of pressure  $P - P_a$ , at depth  $h$  is called a gauge pressure at that point

$$P - P_a = h\rho g$$

4.

### Pascal's law:-

Pressure in a fluid at rest is same at all points which are at same height. A change in pressure applied to an enclosed fluid is transmitted equally to every point of the fluid and the walls of the containing vessel.

5.

### Buoyancy :-

The buoyancy force on a body immersed in a fluid is equal to the weight of the fluid displaced by that body. This statement is true even when the objects float on the surface of a fluid.

Fraction of the volume of the object submerged in a fluid

$$= \frac{\text{density of the object}}{\text{density of the fluid}}$$

### Stream line flow :-

A fluid flow in which the velocity of all the particles passing through the same point remains constant, is called streamline flow.

### Turbulent flow :-

A fluid flow in which the velocity of all the particles passing through the same point is different, is called turbulent flow.

### Viscosity:

The property of a fluid by virtue of which it opposes the relative motion between its layers which

7.

7.

8.

**JR PHYSICS**

a) **Coefficient of viscosity ( $\eta$ )**: The ratio of shearing stress to the velocity gradient is measure of viscosity of the fluid and its called the coefficient of viscosity.

b) Dimensional formula of  $\eta = [M^1 L^{-1} T^{-1}]$ ;

The SI unit of  $\eta$  is Pa-s.

\* Its CGS unit is poise.

\* 1 Pa-s=100 poise

9. When temperature increases viscosity of liquids decreases and viscosity of gases increases

10. **Stoke's formula**

a) Stoke's formula is given by

$$F = 6\pi\eta r V_t$$

Where F = Viscous force,

$$V_t = \text{terminal velocity}$$

$$b) V_t = \frac{2}{9} r^2 \frac{(d_1 - d_2)g}{\eta}$$

Where  $d_1$  = density of solid

$d_2$  = density of liquid

r = radius of liquid drop

11. **Critical velocity**

Critical velocity is defined as the minimum velocity at which the flow of a liquid changes from laminar (or streamline) to turbulent state is called critical velocity

$$v_c = \frac{R_e \eta}{\rho d}$$

Where,  $R_e$  = Reynold's Number

$\eta$  = Coefficient of viscosity

$\rho$  = Density

d = Diameter of the tube

For stream line flow  $R_e < 1000$

for unsteady flow  $R_e$  is between 1000 &

2000

For turbulent flow  $R_e > 2000$

12. **Equation of continuity**

Equation of continuity is given by

$$av = \text{const} \Rightarrow a_1 v_1 = a_2 v_2$$

Where, a = area and v = velocity

13. **Bernoulli's principle**: "When an incompressible and non viscous fluid flowing steadily through a tube of non uniform area of cross section then at every point in the path of the fluid, the total energy per unit volume remains constant".

$$P + \rho hg + \frac{1}{2} \rho V^2 = \text{constant}$$

For a horizontal pipe

$$P + \frac{1}{2} \rho V^2 = \text{constant}$$

According to Bernoulli's principle  $P \propto \frac{1}{V}$

14. **Torricelli's theorem**

$$V = \sqrt{2gh} \text{ where } V = \text{Velocity of efflux}$$

15. **Magnus effect**:

When the ball is spinning and moving in the air, it experience a net upward force called dynamic lift. This dynamic lift due to spinning is called 'Magnus effect'.

16. Surface tension  $T = \frac{F}{l}$

S.I. Unit : N/m

$$\text{Dimensional formula : } M^1 L^0 T^{-2}$$

Rain drops and bubbles are spherical due to surface tension.

17. **Surface Energy**:

The potential energy per unit area of the surface film is called surface energy

**Surface Energy** =

Work done in increasing surface area

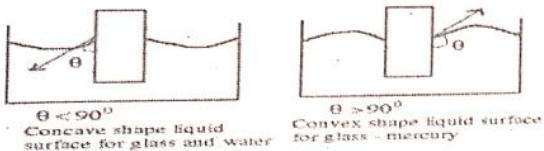
Increase in surface area

18. Surface tension of a liquid is numerically equal to its surface energy.

- a) Work done in forming a liquid drop is,  
 $W = \text{Change in surface Area} \times \text{Surface tension} = \Delta AT = 4\pi r^2 T$
- b) Work done in blowing a soap bubble of radius  $r$  is  $W = 8\pi r^2 T$ . (Soap bubble has two free surfaces)
- c) Work done in forming a circular liquid film of radius ' $r$ ' is,  $W = 2\pi r^2 T$ .

#### 19. Angle of contact:

The angle between the tangent to the liquid surface and the solid surface, at the point of contact, inside the liquid is known as angle of contact.



#### 20. Important Points:

- i) For pure water and glass, angle of contact is zero.
- ii) Angle of contact increases on increasing temperature.
- iii) Angle of contact changes on adding impurities to liquids
- iv) Angle of contact is independent of inclination of solid.
- v) If angle of contact is less than 90°
  - a. The liquid wets the solid surface
  - b. The liquid spreads on solid surface
  - c. There is a capillary rise
  - d. The shape of meniscus is concave.
- vi) If the angle of contact is greater than 90°.
  - a. The liquid does not wet the solid surface
  - b. The liquid does not spread on solid surface
  - c. There is a capillary depression.
  - d. The shape of meniscus is convex up.

#### 21. i) Water proofing agents increases the angle of contact.

Ex: Wax

#### ii) Wetting agents reduces the angle of contact.

Ex: Soaps, detergents

#### 22. Capillarity :-

The rise (or) fall of liquid inside a capillary tube when immersed in a liquid is called Capillarity

#### Importance of capillarity in daily life :-

- i) Ink absorbed by paper
- ii) Water soaked by plant
- iii) Oil rises in wick of a lamp
- iv) Water absorbed by towel

23. Surface tension by capillary rise method.

$$T = \frac{h r d g}{2 \cos \theta}$$

h : capillary rise.

r : Inner radius of bore

d : density of liquid

$\theta$  : Angle of contact.

#### 24. Excess pressure in a liquid drop

$$\Delta P = \frac{2T}{r}$$

where  $T$  = Surface tension of the liquid

$r$  = radius of the drop

#### 25. Excess pressure in an air bubble inside the liquid

$$\Delta P = \frac{2T}{r}$$

( Just below the surface)

where  $T$  = Surface tension of the liquid

$r$  = radius of the drop

#### 26. Excess pressure inside a soap bubble

$$\text{in air } \Delta P = \frac{4T}{r}$$

where  $T$  = Surface tension of the liquid

$r$  = radius of the drop

#### 27. As temperature increases surface tension decreases except in the case of molten copper and cadmium

## THERMAL PROPERTIES OF MATTER

1. TEMPERATURE : It is the thermal condition of a body which determines

**JR PHYSICS**

its ability to transfer heat to other bodies

2. Relation between Celsius and Fahrenheit scales is  $F = \frac{9}{5}C + 32$

3. Relation between  ${}^{\circ}F$ ,  ${}^{\circ}C$ ,  $K$  is

$$\frac{F - 32}{180} = \frac{C - 0}{100} = \frac{K - 273}{100}$$

4. General relation for any arbitrary scale of temperature.

$$\frac{S - L.F.P}{U.F.P - L.F.P} = \text{Constant}$$

Where 'S' is reading on a scale.

LFP = lower fixed point

UFP = upper fixed point

5. **Coefficient of Linear expansion of solids ( $\alpha$ )**:

The ratio of increase in length of a metal rod per  ${}^{\circ}C$  rise in temperature to its original length is called linear coefficient

$$\text{of expansion } \alpha = \frac{(l_2 - l_1)}{l_1(t_2 - t_1)} / {}^{\circ}C$$

$(l_2 - l_1)$  = Increase in length

$l_1$  = initial length

$(t_2 - t_1)$  = Increase in Temperature.

6. **Coefficient of Areal expansion ( $\beta$ )**: The ratio of increase in area of metal plate per  ${}^{\circ}C$  rise in temperature to its original area is called coefficient of Areal expansion ( $\beta$ ).

$$\beta = \frac{(a_2 - a_1)}{a_1(t_2 - t_1)} / {}^{\circ}C$$

$(a_2 - a_1)$  = Increase in area

$a_1$  = initial area

$(t_2 - t_1)$  = increase in temperature.

**Volume Coefficient Expansion ( $\gamma$ )**:

The ratio of increase in volume of metal cube per  ${}^{\circ}C$  rise in temperature to its original volume is called coefficient of volume expansion ( $\gamma$ ).

$$\gamma = \frac{(V_2 - V_1)}{V_1(t_2 - t_1)} / {}^{\circ}C$$

$(V_2 - V_1)$  = Increase in volume

$V_1$  = initial volume

$(t_2 - t_1)$  = Increase in temperature

8. **Relation between  $\alpha$ ,  $\beta$  and  $\gamma$**

$$\alpha : \beta : \gamma = 1 : 2 : 3 \text{ (or) } \frac{\alpha}{1} = \frac{\beta}{2} = \frac{\gamma}{3}$$

$\alpha$ ,  $\beta$  and  $\gamma$  are measured in  ${}^{\circ}C$ .

9 (a). Relation between  $\alpha$  and  $\beta$  is  $\beta = 2\alpha$ .

(b). Relation between  $\gamma$  and  $\alpha$  is  $\gamma = 3\alpha$ .

(c). Relation between  $\beta$  and  $\gamma$  is  $\beta = \frac{2\gamma}{3}$ .

10. **Variation of density of solids with temperature:**

$$d_0 = d_t(1 + \gamma t)$$

$d_0$  and  $d_t$  are densities at  $0^{\circ}C$  and  $t^{\circ}C$  respectively.

$\gamma$  = coefficient of volume expansion..

11. Platinum is used to seal with glass due to both have same coefficient of linear expansion.

12. **Anomalous expansion of water:**

Generally all liquids expand on heating but pure water contracts from  $0^{\circ}C$  to  $4^{\circ}C$  temperature. This peculiar behaviour of water is called Anomalous expansion of water.

(Mar - 14)

13. Density of water is maximum at  $4^{\circ}\text{C}$  (or) 277 K  
and minimum volume at  $4^{\circ}\text{C}$  (or) 277K

14. **Boyle's law** : At constant temperature, the volume of a given mass of a gas is inversely proportional to its pressure.

$$(i.e.) V \propto \frac{1}{P} \quad (or) \quad PV = k \quad (T = \text{const})$$

$$\Rightarrow P_1V_1 = P_2V_2$$

At high temperature and low pressure, gases obey Boyle's law.

15. **Charle's I law** : At constant pressure, the volume of a given mass of a gas is directly proportional to its absolute temperature. i.e.,  $V \propto T$

$$(i.e) \frac{V}{T} = \text{constant} \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

**Charle's II law** : At constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

$$(i.e) P \propto T \quad (or) \quad \frac{P}{T} = \text{constant} \quad (or) \quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

16. **Volume coefficient of a gas ( $\alpha$ )** : volume coefficient of a gas is the ratio of increase in its volume per degree rise of temperature to its volume at  $0^{\circ}\text{C}$ , Keeping the pressure constant

$$\alpha = \frac{V_t - V_0}{V_0 t} \quad (or) \quad \alpha = \frac{V_2 - V_1}{V_1 t_2 - V_2 t_1} / ^{\circ}\text{C}$$

17. **Pressure coefficient of a gas : ( $\beta$ )**: Pressure coefficient of a gas is the ratio of increase in pressure per degree rise of temperature to its pressure at  $0^{\circ}\text{C}$ , Keeping the volume constant.

$$\beta = \frac{P_t - P_0}{P_0 t} \quad (or) \quad \beta = \frac{P_2 - P_1}{P_1 t_2 - P_2 t_1} / ^{\circ}\text{C}$$

18. **Relation between  $\alpha$  and  $\beta$ :**  
For all gases,

$$\alpha = \beta = \frac{1}{273.15} = 0.00367 / ^{\circ}\text{C}$$

19. **Ideal gas** :- The gas which obey gas laws, at all temperatures and pressures is called ideal gas

20. **Real gas** :- The gas which obey gas laws at high temperatures and low pressures only is called real gas.

21. Real gases behave like an ideal gas at **low pressures and high temperatures**.

22. Ideal gas equation is :  $\frac{PV}{T} = R$

where P is the pressure, V is the volume of 1gram mole of a gas, T is the absolute temperature and R is the universal gas constant.

$$R = 8.31 \text{ Joule/mole-K} = 2 \text{ cal/gm mole-K}$$

23. From gas equation  $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

24. If d is the density of the gas  $\frac{P}{dT} = \text{Constant}$

$$(or) \frac{P_1}{d_1 T_1} = \frac{P_2}{d_2 T_2}$$

25. **Boltzmann's constant** :

$$K = \frac{R}{N} \quad \text{and} \quad K = 1.38 \times 10^{-23} \text{ J/K}$$

where  $N = 6.02 \times 10^{23}$  molecules per mole.  
N is the avagadro's number.

26. The gas equation for unit mass of a gas is  $pv = rT$ .

Here r = specific gas constant.

**Units of r** :  $\text{JKg}^{-1}\text{K}^{-1}$

**Dimensional formula** :  $M^0 L^2 T^{-2} K^{-1}$

27. The relation between R and r is  $r = \frac{R}{M}$

Where M is the molecular weight. Number of moles in a gas  $n = m/M$ .

### 28. Heat capacity (or) Thermal capacity (H)

The quantity of heat required to rise the temperature of a substance through  $1^\circ C$  is called heat capacity.

$$H = \frac{\text{Change in heat energy}}{\text{rise in temperature}} = \frac{dQ}{dT}$$

**Units:**  $JK^{-1}$  in S.I.

$cal/^\circ C$  in C. G. S

**Dimensional formula.**  $ML^2T^{-2}K^{-1}$

### 29. Specific heat(C):

The quantity of heat required to rise the temperature of unit mass of a substance through  $1^\circ C$  is called specific heat 'c'

$$\therefore c = \frac{1}{m} \cdot \frac{dQ}{dT} \Rightarrow dQ = mcdT$$

**Units:**  $J/kg K$  in S.I.

$Cal/gm ^\circ C$  in C. G. S

**Dimensional formula:**  $\frac{ML^2T^{-2}}{M \times K} = L^2T^{-2}K^{-1}$

### 30. Relation between heat capacity and specific heat:

Specific heat of a substance is given by

$$c = \frac{1}{m} \cdot \frac{dQ}{dT}$$

But  $\frac{dQ}{dT} = H$  heat capacity

$$c = \frac{H}{m} \Rightarrow H = mc$$

i) Water has high specific heat, so it is used in radiators.

ii) Of all the solids and liquids water has highest specific heat so that water is used in radiators of motor vehicles

iii) Specific heat of a substance during its change of state is infinity during change of state  $dT = 0$

$$\therefore c = \frac{1}{m} \cdot \frac{dQ}{0}$$

$c = \infty$  (infinite)

### 31. Latent heat (L):

The amount of heat absorbed (or) released by unit mass of a substance during its change of state at constant temperature is called latent heat

$$\therefore \text{Latent Heat, } L = \frac{\text{heat energy}}{\text{mass}} = \frac{Q}{m}$$

$Q = mL$

**Units:**  $J/kg$  in S.I.  
 $cal/gm$  in C. G. S

**Dimensional formula**  $[L^2T^{-2}]$

#### (a) Latent heat of fusion of ice ( $L_{ice}$ ):

The quantity of heat required to change the state of 1 gram of ice into water at  $0^\circ C$  is called latent heat of fusion of ice.

In C.G.S,  $L_{ice} = 80 cal/gm$

In SI,  $L_{ice} = 0.336 \times 10^6 J/kg$

#### (b) Latent heat of steam ( $L_s$ ):

The quantity of heat required to change the state of 1 gram of water into steam at  $100^\circ C$  is called latent heat of steam.

In C.G.S,  $L_{steam} = 540 cal/gm$

In S.I,  $L_{steam} = 2.268 \times 10^6 J/kg$

**Note:** Liquids with low latent heat of steam are called volatile liquids

### 32. Coefficient of Thermal conductivity (K):

In steady state the quantity of heat Q flowing through a metal rod of length  $l$  and cross-section A in a time  $t$  when its ends are at temperatures  $\theta_1$  and  $\theta_2$  ( $\theta_1 > \theta_2$ ) is given by



$$Q = \frac{KA(\theta_1 - \theta_2)}{l} t$$

where K is coefficient of thermal conductivity. K depends on the nature of the metal.

**Temperature gradient :** It is change in temperature per unit length in the direction of flow of heat.

**Def. of K :** It is defined as the rate of flow of heat per unit area and per unit temperature gradient in steady state.

33. **Thermal Resistance :** Thermal resistance R of a conductor of length  $\ell$ , cross-section A and conductivity K is given by  $R = \frac{l}{KA}$

#### 34. BLACK BODY RADIATION:-

A body completely absorbing the radiation of all wavelengths falling on it is called a black body.

Black bodies do not exist in nature. Carbon black and platinum black approximately behave like a black body, but their absorptivity is less than 1 in the far infrared region.

#### Wien's Displacement Law :

It states that the wavelength carrying the maximum energy is inversely proportional to the absolute temperature of a black body.

$$\text{i.e., } \lambda_{\max} \propto \frac{1}{T} \Rightarrow \lambda_{\max} \times T = b \text{ (const)}$$

Value of  $b = 2.9 \times 10^{-3} \text{ mK}$

#### 35. EMISSIVE POWER ( $e_\lambda$ ) :

- i) The amount of energy emitted per second per unit surface area of a body at a given temperature for a given wavelength range ( $\lambda$  and  $\lambda + d\lambda$ ) is called emissive power.
- ii) At a given temperature if the radiations emitted have a wavelength difference  $d\lambda$ , then

the emissive power is equal to  $e_\lambda d\lambda$ .

- iii) S.I unit of emissive power is  $\text{Wm}^{-2}$  and its dimensional formula is  $MT^{-3}$ .

36. **EMISSIVITY (e):** The ratio of radiant energy emitted by a surface to radiant energy emitted by a black body under same conditions is called emissivity.

For a perfect black body, emissivity  $e=1$ .

#### 37. ABSORPTIVE POWER ( $a_\lambda$ ) :

At a given temperature, for a given wavelength range, the ratio of energy absorbed to the energy incident on the body is absorptive power.

$$\therefore a_\lambda = \frac{\text{Amount of radiant energy absorbed}}{\text{Amount of radiant energy incident}}$$

For a perfect black body,

the absorptive power,  $a_\lambda = 1$ .

#### Prevost theory of heat exchange:

- i) Every object emits and absorbs radiant energy at all temperatures except at absolute zero.
- ii) The rate of emission increases with the increase in the temperature of the body.
- iii) If the body emits more radiant energy than absorbed, its temperature decreases
- iv) If the body absorbs more radiant energy than it emits, its temperature increases.

#### 39. KIRCHHOFF'S LAW:

- i) At a given temperature, for a given wavelength range, the ratio of emissive power to absorptive power of a substance is constant.

$$\text{i.e., } \frac{e_\lambda}{a_\lambda} = \text{const} = E_\lambda$$

Where ' $E_\lambda$ ' is the emissive power of perfect black body. ' $e_\lambda$ ' and ' $a_\lambda$ ' are emissive and absorptive powers of a given substance respectively.

- ii) This constant ( $E_\lambda$ ) is equal to the emissive power of a perfect black body at the given temperature and wavelength.
- iii) Good absorbers are good emitters and poor

**JR PHYSICS**

- absorbers are poor emitters.
40. Sea breezes, land breezes and trade winds are the examples for natural convection.
41. **STEFAN'S LAW:**

The amount of heat radiated by a black body per second per unit area is directly proportional to the fourth power of its absolute temperature (T).

$$E \propto T^4 \Rightarrow E = \sigma T^4.$$

Where  $\sigma$  = Stefan's constant

$$= 5.67 \times 10^{-8} W m^{-2} K^{-4}$$

42. **STEFAN-BOLTZMANN'S LAW:**
- i) If a black body at absolute temperature T is surrounded by an enclosure at absolute temperature  $T_o$ , then the rate of loss of heat energy by radiation per unit area is given by.

$$E = \sigma(T^4 - T_o^4)$$

- ii) For any hot body,  $E = \sigma A e(T^4 - T_o^4)$   
Where 'e' is the emissive power and 'A' is the area of cross-section of the hot body.

43. **NEWTON'S LAW OF COOLING:**  
The rate of cooling of a hot body is directly proportional to the mean excess of temperature of the body above that of the surroundings, provided the difference in temperature of the body and that of surroundings is small.

$$\frac{d\theta}{dt} = K \left( \frac{\theta_1 + \theta_2}{2} - \theta_s \right).$$

Here,  $\frac{d\theta}{dt}$  = Rate of cooling.

$\theta_1, \theta_2$  are the initial and final temperatures of the body respectively.  $\theta_s$  is temperature of surroundings and K is the cooling constant.

Animals curl in winter in order to decrease the area of radiating surface. So rate of

cooling is less.

**TERMODYNAMICS**

1. **Heat:**  
Heat is a form of energy which transfer from a body at higher temperature to a body at lower temperature.  
Units: Unit of heat in SI - Joule  
Unit of heat in C. G. S - calorie  
 $1 \text{ cal} = 4.2 \text{ J}$
2. **Thermal equilibrium:**  
Two bodies are said to be in thermal equilibrium if there is no exchange of heat energy between them when they are thermally in contact with each other.
3. **Zeroth law of thermo dynamics:**  
If two systems A and B are in thermal equilibrium with third system C separately, then, they (A, B) must be in thermal equilibrium with each other.
4. **Calorie:**  
Calorie is defined as the amount of heat required to raise the temperature of 1g of water from  $14.5^\circ C$  to  $15.5^\circ C$ .
5. **Internal energy:**  
Internal energy of a thermodynamic system is defined as the energy possessed by the system by virtue of its molecular constitution and the position of the molecules
- a) The sum of potential energy and kinetic energy of individual molecules in the system is called internal energy.  
Internal energy  $U = P.E. + K.E$   
change in internal energy  $dU = U_f - U_i$   
where  $U_f$  is final internal energy  
 $U_i$  is initial internal energy
- b) Internal energy of a system increases with temperature.
- ⇒ **External Work:**  
When the force is exerted by the system on its surroundings produces a displacement the work done by the system is called external work.
- a. The work done by the system is '+ve'  
b. The work done on the system is '-ve'.
6. **External work done by an ideal gas**

during expansion,  $dW = PdV$

**7. First law of thermodynamics:**

When certain amount of heat is given to a system a part of it is used to increase the internal energy and the remaining part is used in doing external work.

This law is particular form of the law of conservation of energy.

i)  $dQ = dU + dW$

where  $dQ$  amount of heat

$dU$  increase in internal energy

$dW = PdV$  work done

$$dQ = dU + PdV$$

**8. Significance:**

a) Heat is a form of energy

b) Energy is conserved in thermodynamic system

c) Every thermodynamic system in equilibrium state possesses internal energy.

**9. Specific heats of gases: Every gas has two specific heats**

Specific heat of gas at constant volume

Specific heat of gas at constant pressure.

**10. Specific heat of gas at constant volume:**  
It is defined as the amount of heat required to rise the temperature of unit mass of gas through  $1^\circ C$  at constant

$$\text{volume, } C_v = \frac{1}{m} \cdot \frac{dQ}{dT}$$

**11. Specific heat of gas at constant pressure.**

It is defined as the amount of heat required to rise the temperature of unit mass of gas through  $1^\circ C$  at constant pressure.

$$C_p = \frac{1}{m} \cdot \frac{dQ}{dT}$$

**12. Molar specific heat at constant volume**

It is defined as the amount of heat required to rise the temperature of one mole of gas through  $1^\circ C$  at constant volume.

$$C_v = \frac{1}{n} \cdot \frac{dQ}{dT}$$

$\Rightarrow$  at constant volume the system uses given heat energy to increase internal energy only and  $dW=0$

$$\therefore dQ = dU + dW$$

$$dU = dQ$$

$$dU = nC_v \cdot dT$$

**13. Molar specific heat at constant pressure.**

It is defined as the amount of heat required to rise the temperature of one mole of gas through  $1^\circ C$  at constant pressure.

$$C_p = \frac{1}{n} \cdot \frac{dQ}{dT}$$

$$dQ = nC_p \cdot dT$$

$$nC_p \cdot dT = dU + PdV$$

**14. Relation between  $C_p$  and  $C_v$**

$$C_p - C_v = R$$

b) The ratio of  $C_p$  and  $C_v$  is a constant

$$\text{i.e. } \frac{C_p}{C_v} = \gamma$$

**15. Law of method of mixtures:**

Heat lost by the hot bodies = Heat gained by the cold bodies (when there is no loss of heat to the surroundings)

$\Rightarrow$  Two substances of masses  $m_1$  and  $m_2$  specific heats  $C_1$  and  $C_2$  are at temperatures  $\theta_1$  and  $\theta_2$  are mixed then final temperature of mixture is

$$\theta = \frac{m_1 C_1 \theta_1 + m_2 C_2 \theta_2}{m_1 C_1 + m_2 C_2}$$

**16. Mechanical equivalent of heat (or) Joules law:**

The amount of work performed is directly proportional to the amount of heat generated  
 $W \propto Q$

$W = JQ$  where  $J$  = Joules constant (or) mechanical equivalent of heat

**17. Isothermal process:**

(Eamcet-2008)

a) The changes in volume and pressure of a gas taking place at constant temperature is called isothermal process

b) Isothermal process obeys Boyle's law i.e.  $PV = \text{constant}$

c) In this process the system is enclosed with perfect heat conducting walls

d) Due to exchange of heat from system to surroundings (or) vice versa through heat conducting walls so that temperature

**JR PHYSICS**

- of the system is constant.  $dT = 0$   
 e) In this process the change in internal energy of the system is zero  $dU = 0$   
 f) This process is slow process  
 g) Molar specific heat is infinity in this process

$$C = \frac{1}{n} \left( \frac{dQ}{dT} \right) = \frac{1}{n} \left( \frac{dQ}{d0} \right) = \infty \text{ (infinite)}$$

- h) Work done in isothermal process is

$$W = 2.303 nRT \log_{10} \left( \frac{V_2}{V_1} \right)$$

$$\text{(or)} \quad W = 2.302 nRT \log_{10} \left( \frac{P_1}{P_2} \right)$$

**18. Adiabatic process**

- a) The changes in pressure, volume of a gas taking place at constant heat energy is called adiabatic process  
 b) This process do not obey any gas laws but it obeys piossons law

$$PV^\gamma = \text{constant}$$

- c) In this process the system is enclosed with bad conductor of heat  
 d) In this process there will not be any exchange of heat from system to surroundings & vice versa, through bad conductor of heat so that heat energy remains constant.  
 e) Change in heat energy in this process is zero. i.e.,  $dQ = 0$   
 f) Molar specific heat is zero. i.e.,

$$C = \frac{1}{n} \cdot \frac{dQ}{dT}$$

$$C = 0 \quad (\because dQ = 0)$$

- g) It is quick and sudden process  
 Ex: When cycle tube bursts suddenly pressure, volume, temperature of the gas changes but heat energy remains same.  
 h) Work done in adiabatic process is

$$W = \frac{R}{(1-\gamma)} (T_2 - T_1)$$

**19. Triple point:**

The pressure and temperature at which the given substance can exists in 3 states (liquid, solid and gas) simultaneously is known as triple point. Pressure and temperatures of triple point of water are 610.13 Pa and 273.16K

**20. Second law of thermodynamics:  
Clausius statement**

It is impossible for a self acting machine unaided by any external agency to transfer heat from a body at lower temperature to a body at higher temperature

(or)

Heat cannot flow by it self from a colder body to a hotter body.

**Kelvin Plank statement:**

It is impossible to construct a heat engine operating in a cycle to convert the heat energy completely into work with out any change of working system.

21. Heat engine is a device used to convert Heat energy into work or mechanical energy. Its efficiency is

$$\eta = \frac{(Q_1 - Q_2)}{Q_1} = \frac{(T_1 - T_2)}{T_1} = 1 - \frac{T_2}{T_1}$$

22. Refrigerator (heat pump) is reverse of heat engine. In the refrigerator, working substance extracts heat  $Q_2$  from cold reservoir at temperature  $T_1$ . Its coefficient

$$\text{of performance } \alpha = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$$

23.  $\eta$  value never exceed 1 but  $\alpha$  value can be greater than 1.

**KINETIC THEORY**

1. The average distance covered by a molecule between two successive collisions, is called mean free path .

2. The relation between pressure, temperature, volume of a gas is  $PV = KT$   
 T temperature in kelvin scale  
 K constant for given sample  
 The Perfect gas equation

$$PV = \mu RT$$

$$\mu = \frac{M}{M_0} = \frac{\text{mass of the gas}}{\text{molar mass}}$$

Above equation can be written as  $P = \frac{\rho RT}{M_0}$

$\rho = \text{density of gas}$  .

Kinetic theory of an ideal gas gives the

$$\text{relation } P = \frac{1}{3} n m v^2$$

where  $n$  is number density of molecules,  $m$  the mass of the molecule and  $v^2$  is the mean of squared speed.

5. Kinetic interpretation of temperature

$$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}K_B T$$

$$v_{rms} = \sqrt{\frac{3K_B T}{m}}$$

6. The translational kinetic energy

$$E = \frac{3}{2}K_B NT$$

7. Dalton law of partial pressures:

The total pressure exerted by a mixture of perfect gases is the sum of the individual pressures that each gas would exert, if it were present alone in the container at the same temperature.

$$P = P_1 + P_2 + P_3, \dots \quad (\text{Mar - 14})$$

8. Two prominent phenomena which provide conclusive evidence of molecular motion are Brownian motion, Diffusion.

9. At low pressures and high temperatures real gases almost behave like an ideal gas. (Mar - 14)

10. Pressure exerted by a gas is due to the collisions of molecules made on the walls of the container. Hence it is independent of the shape of the container.

11. Degrees of freedom: The total number of independent modes (ways) in which a system can possess energy is called degree of freedom ( $f$ ).

The number of degree of freedom of the system is  $f = 3N - K$

Where  $N$  is number of independent motions,  $K$  is number of independent restrictions.

- (i) Mono atomic gas molecule possess 3 degrees of freedom ( $N = 1, K = 0$ )
- (ii) Diatomic gas molecule possess 5 degrees of freedom ( $N = 2, K = 1$ )
- (iii) Triatomic gas molecule possess 6 degrees of freedom ( $N = 3, K = 3$ ).

ATOMIC STRUCTURE

1. Charge of  $e^-$  is  $-1.6022 \times 10^{-19} C$
  2. Mass of  $e^-$  is  $9.1094 \times 10^{-31} Kg$
  3. Charge to mass ratio  $\left(\frac{e}{m}\right)$  of electron is  $\Rightarrow 1.7588 \times 10^{11} C/Kg$
  4. Charge of one mole of electrons = charge of electron  $\times$  Avagadro number
  5. Mass of one mole of electrons = mass of electron  $\times$  Avagadro number
  6. Mass of one mole of protons = mass of proton  $\times$  Avagadro number
  7. Mass of one mole of neutrons = mass of neutron  $\times$  Avagadro number
  8. **black body** : An ideal body which emits and absorbs radiations of all frequencies is called black body.
  9. **Planck's quantum theory** : The emitted radiation is not continuous, but it is in the form of small discrete packets of energy called "quantum".  
 $E = h\nu$ ; where  $\nu$  = frequency of radiation  
 'h' is the Planck's constant.  $(6.625 \times 10^{-34} Js \text{ (or)} 6.625 \times 10^{-27} erg.s)$
  10. **Photo-electric effect** : When a beam of light ( $h\nu$ ) of suitable wave length is allowed to fall on, the surface of the alkali metal the electrons are emitted from the metal surface. This phenomenon is called photo electric effect. It is represented as follows.  
 i.e.  $h\nu = W_0 + K.E$
  11. **Heisenberg's uncertainty principle** : It is impossible to determine the exact position and momentum of a fast moving particle like electron simultaneously and accurately.
- $$\Delta x \times \Delta p \geq \frac{h}{4\pi}$$
- Postulates of Bohr's atomic model:**
12. The electron in hydrogen atom revolves around the nucleus in a fixed circular paths called orbits
  13. Each orbit is associated with definite energy. So these are called energy levels or energy shells.
  14. These energy levels are designated as 1,2,3,4..... or K,L,M,N.... respectively
  15. As long as the electron revolves in a particular orbit, it neither loose nor gain energy. So the energy of an electron in a particular orbit remains constant, Hence these orbits are called stationary orbits.
  16. The angular momentum of electron is always integral multiple of  $\frac{h}{2\pi}$ . It is given by

$$mv r = \frac{nh}{2\pi}. \quad (\text{Where } m = \text{mass of electron}, v = \text{velocity of electron}, r = \text{radius of an orbit}, \\ h = \text{planck's constant}, n = \text{principal quantum number})$$

17. If an electron jumps from one level to another level it may emit or absorb energy.
18. If electron jumps from lower orbit to higher orbit it absorbs energy.
19. If electron jumps from higher orbit to lower orbit then it emits energy.

**Bohr's Explanation to Hydrogen Spectrum :**

20. Hydrogen atom has one proton and one electron in the ground state.
21. By the absorption of 13.56 e.v. energy, electron jumps to the higher energy level which is unstable. Hence it comes back to ground state by emitting the energy.

22. The emission of energy may occur in one step or in several steps. Since a sample of hydrogen contains many atoms several spectral lines are formed.  
They are Lyman, Balmer, Paschen, Brackett and pfund series.
23. The wave number and wave length of these spectral lines can be calculated by using Rydberg's equation.

$$\frac{1}{\lambda} = R \left[ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right], \quad R = \text{Rydberg's constant} = 109677 \text{ cm}^{-1}$$

**Limitations :**

24. **Zeeman effect :** The splitting of one spectral line into several fine lines in the presence of strong magnetic field is called Zeeman effect.
25. **Stark effect :** The splitting of one spectral line into several fine lines in the presence of strong electric field is called Stark effect.
26. **Quantum numbers** Quantum numbers are introduced to explain the main shell, subshell, orientation and spin of the electrons. The four quantum numbers are
27. **Principal quantum numbers( $n$ ):** a) It was proposed by Neil's Bohr. It is denoted by ' $n$ '.  
b) The value of  $n$  are 1,2,3,4 .... (or) K,L,M,N..... respectively  
c) The total number of orbitals in an orbit =  $n^2$   
d) The maximum number of electrons in an orbit =  $2n^2$   
e) **Significance:** It indicates the size and energy of the orbit.
28. **Azimuthal quantum number ( $l$ ):** a) It was proposed by Sommerfeld. It is denoted by ' $l$ '  
b) The value of  $l$  depends on ' $n$ '. The value of  $l$  are from 0 to  $(n-1)$ .  
c) When  $l$  values are 0,1,2,3... the sub shells are called s,p,d,f..... respectively.  
d) The number of subshells in an energy level = ' $n$ ' value  
e) **Significance:** It indicates the shape of orbitals.
29. **Magnetic quantum number ( $m$ ):**  
a) It was proposed by Lande. It is denoted by ' $m$ '.  
b) The values of ' $m$ ' depends on ' $l$ '. The values of ' $m$ ' are from  $-l$  to  $+l$  including 0.  
c) The total  $m$  values or orbitals in subshell =  $2l+1$ .  
d) The number of orbitals in s,p,d and f sub shells are 1,3,5 and 7 respectively.  
e) The number of electrons in a subshell =  $2(2l+1)$ .  
f) The total number of electrons in s,p,d and f sub shells are 2,6,10 and 14 respectively.  
g) **Significance:** It indicates the orientation of orbitals in space
30. **Spin quantum number(s or  $m_s$ ):**  
a) It was proposed by Goudsmith and Uhlenbeck It is denoted by 's'.  
b) It is independent. The values of  $s$  are  $+\frac{1}{2}$  and  $-\frac{1}{2}$   
c) If the electron revolves in clock wise ( $\uparrow$ ) direction - spin is given as  $+\frac{1}{2}$   
d) If the electron revolves in anti clock wise ( $\downarrow$ ) direction - spin is given as  $-\frac{1}{2}$   
e) The maximum number of electrons in an orbital = 2.  
f) **Significance:** It indicates the direction of the spin of the electron

31. Schrodinger wave equation is  $\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{8\pi^2m}{h^2}(E-V)\psi = 0$   
 $\Rightarrow \hat{H}\psi = E\psi$

$\hat{H}$  = Hamiltanion operator (total energy operator)

32. **Atomic orbital :** The three dimensional space around the nucleus, where the probability of finding electron ( $\psi^2$ ) is maximum is called atomic orbital.
33. Shape of s-orbital is spherical
34. Shape of p-orbital is dumb-bell
35. Shape of d-orbital is double dumb-bell
36. **Pauli's exclusion principle :** No two electrons in an atom can have the same set of all four quantum numbers.
37. **Aufbau principle :** In the ground state of the atoms, the orbitals are filled with electrons in the order of their increasing energies.  
 $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < \dots$
38. **Hund's rule :** In the degenerate orbitals pairing of electrons takes place, when each orbital is filled with one electron.
39. **Anamolous electronic configurations of Cr & Cu is :**



## CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES

1. **Differentiating electron :** The last electron entering into atomic orbital is called differentiating electron. Based on this differentiating electron the elements are classified into four blocks. They are 1. s-Block 2. p-Block 3. d-Block 4. f-Block
2. **s-block elements :**  
The elements in which differentiating electrons enters into s-orbital are called s-block elements.  
It contains two groups namely alkali metals and alkaline earth metals (IA and IIA) or groups 1 and 2.  
The general electronic configuration is  $ns^{1-2}$ .
3. **p-block elements :-**  
The elements in which differentiating electrons enters into p-orbital are called p-block elements. It contains '6' groups. The general electronic configuration is  $ns^2 np^{1-6}$   
p-block contains all non-metals, metalloids and few metals.
4. **d-block elements :**  
The elements in which the differentiating electron enters into penultimate shell or (n-1)d sub shell are called d-block elements.  
These are placed in between s- and p-block elements. It contains 10 groups.  
The general electronic configuration of these elements is  $(n-1)d^{1-10} ns^{1-2}$

**5. f-block elements :**

The elements in which the differentiating electron enters into anti penultimate shell or  $(n-2)f$  subshell are called f-block elements.

The general electronic configuration is  $(n-2)f^{1-14} (n-1)d^{0-1} ns^2$

**6. Transition elements :**

The elements in which two outermost sub shells are incompletely filled [  $(n-1)$  and  $n$  ] are called transitional elements.

The general electronic configuration is  $(n-1)d^{1-9} ns^{1-2}$ .

IIB elements (Zn, Cd, Hg) are not transitional elements due to fully filled  $(n-1)d$  orbital.

**7. Characteristic properties:**

They form mostly coloured ions

They show variable oxidation states.

They form complexes and interstitial compounds.

They show paramagnetism and ferromagnetism.

They form alloys. They act as good catalysts.

The characteristic properties of transition elements are due to

a) Vacant or partially filled d-orbitals b) Small atomic radius c) High nuclear charge.

**Periodicity :** The repetition of properties of elements at certain regular intervals of electronic configuration is called as periodicity.

**8. ATOMIC RADIUS :** The distance between the centre of the nucleus and the outer most shell of an atom is called as atomic radius.

It is of three types : These are (a) covalent radius (b) crystal radius (c) Van der Waals radius.

**9. Metallic radius or crystal radius :** This is generally used for metals.

The half of the distance between the centres of the nuclei of two adjacent metal atoms in the metallic crystal is called crystal radius or metallic radius.

It is measured in Angstrom units or in nanometers or in picometers.

$$(1A^\circ = 10^{-10} m, 1nm = 10^{-9} m, 1pm = 10^{-12} m)$$

**10. Covalent radius :** This is generally used for non-metals.

The half of the inter nuclear distance of two atoms, which are held together by a covalent bond is called covalent radius.

**11. Variation of atomic radii in a group:** In a group, from top to bottom the atomic radius gradually increases.

**Reason :** The differentiating electron enters into a new sub shell and increase of screening effect.

**12. Variation of atomic radii in a period:** In a period, from left to right the atomic radius gradually decreases.

**Reason :** In period the differentiating electron is added to same subshell. As the atomic number increases nuclear charge over outermost electrons increases. Hence the atomic radius decreases gradually.

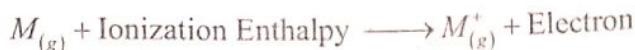
**13. Lanthanide contraction :** In lanthanides differentiating electron enters into 4f sub level. Due to peculiar shape and poor shielding effect of f-orbitals, the increased nuclear charge attracts valence electrons firmly causing a steady decrease in the size of atom or ion. It is called lanthanide contraction.**14. Consequences of lanthanide contraction :**

a) The melting, boiling points and hardness of lanthanides gradually increases.

b) The crystal structures and other properties of lanthanides becomes almost similar. So it is difficult to separate them from the mixture.

c) Inert pair effect is also a consequence of lanthanide contraction.

- d) Due to this, the atomic radius of following elements almost similar even though they belongs to 4d and 5d series.  
 Eg : Zr & Hf , Nb & Ta and Mo & W.
- 15. IONIZATION ENTHALPY :** The minimum amount of energy required to remove the mostly loosely bound electron from a neutral, isolated gaseous atom is called ionization enthalpy.



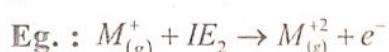
It is measured in electron volts per atom or kJ/mole or k.cal/mole

It is possible to remove first, second, third and successive electrons from atoms.

- 16. First Ionization enthalpy :** The energy required to remove an electron from a neutral, isolated gaseous atom is called first ionization potential.



- 17. Second ionization enthalpy :** The energy required to remove an electron from unipositive gaseous ion is called second ionization potential.



- 18. Second ionization enthalpy** is always more than first ionization enthalpy. ( $IE_2 > IE_1$ )

It is due to increase of effective nuclear charge from neutral atom to unipositive ion.

In successive ionization enthalpy values the order is  $IE_1 < IE_2 < IE_3 < \dots < IE_n$

#### Factors influencing Ionization Enthalpy :

- 19. Atomic radius or Atomic Size:** Larger is the atomic size smaller is the ionization enthalpy.

$$\text{Ionization enthalpy} \propto \frac{1}{\text{Atomic size}}$$

- 20. Nuclear charge :** As the nuclear charge increases, ionization enthalpy values also increases.

$$\text{Ionization Enthalpy} \propto \text{Nuclear charge}$$

- 21. Screening effect or Sheilding effect :**

The electrons present in inner orbitals decrease the nuclear attraction on the valency electrons. This is called Screening or Sheilding effect.

Higher the screening effect, the lesser is the value of ionization enthalpy.

$$\text{Ionization Enthalpy} \propto \frac{1}{\text{Screening effect}}$$

- 22. Extent of penetration of orbitals of valence electrons :**

More is the penetration of orbital more will be the ionization enthalpy.

So the order of penetration power or ionization enthalpies is  $s > p > d > f$ .

$$\text{Ionization Enthalpy} \propto \text{Penetration power}$$

- 23. Half filled or completely filled subshells :**

Atoms with half filled (or) completely filled subshells are more stable. So ionization enthalpy values of these atoms are high.

- 24. Variation in a group:** In a group from top to bottom, ionisation enthalpy decreases.  
 Reason : It is due to increase in atomic size and screening effect.

- 25. Variation of ionisation enthalpy in period:**

In a period from left to right, the ionisation enthalpy gradually increases.

Reason : It is due to decrease in atomic size and increase in the nuclear charge.

- 26. In second period :** The high values of Be and N are due to stable configurations.

So the increasing order of ionization enthalpy is  $Li < B < Be < C < O < N < F < Ne$

- 27. In third period :** The high values of Mg, P and Ar are due to stable configurations.

So the increasing order of ionization enthalpy is  $Na < Al < Mg < Si < S < P < Cl < Ar$

28. In periodic table the group with highest ionization enthalpy values is - 0 group  
The element with highest ionization enthalpy value is - Helium

**29. IE<sub>1</sub> of Na is less than of Mg**

**Explanation :** The electronic configuration of  $Na - [Ne]3s^1$ . It readily loses electron to attain a stable octet configuration. Hence  $IE_1$  value is less.

Where as the electronic configuration of  $Mg - [Ne]3s^2$ .

Since 'Mg' has stable fulfilled configuration. Hence the  $IE_1$  value is very high.

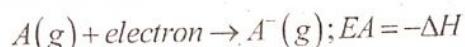
**30. IE<sub>2</sub> of Na is higher than that of Mg.**

**Explanation :** In this electron has to be removed from  $Na^+$  and  $Mg^+$

The electronic configuration of  $Na^+$  is similar to neon which is octet configuration. Hence the  $IE_2$  value is very high.

Where as in case of magnesium after loosing one electron the electronic configuration will be similar to sodium atom. Hence  $IE_2$  value is less.

**31. Electron gain enthalpy ( Electron Affinity ) :** The amount of energy released when an electron is added to the valence shell of neutral gaseous atom is called as electron gain enthalpy or electron affinity.



**32. Variation in a group:** In a group from top to bottom, electron affinity decreases.

Reason : It is due to increase in atomic size and screening effect.

**33. Variation in a period:** In a period from left to right, electron affinity increases.

Reason : It is due to decrease in atomic size and increase of nuclear attraction.

In periodic table the group with highest electron gain enthalpy values is - VIIA group.

The element with highest electron gain enthalpy values is - Chlorine. (3.7)

**34. Electron affinity of chlorine is more than that of fluorine**

Reason : In fluorine due to small atomic size, large electron density, strong inter electronic repulsions takes place while electron is adding. As a result the EA is less.

Where as in chlorine the atomic size is large. The added electron occupies a larger region of space and electron-electron repulsions are much less. So EA is more.

**35. Electronegativity :** The relative tendency of an atom to attract the shared electron pair towards itself in a hetero diatomic molecule is called electronegativity.

It is the property of a bonded atom. It has no units, since it is a relative property.

**36. An arbitrary value of 4.0 has been assigned to fluorine (most electronegative element).**

**37. Variation in a group:** In a group from top to bottom, electronegativity decreases.

Reason : It is due to increase in atomic size.

**38. Variation in a period:** In a period from left to right, electronegativity increases.

Reason : It is due to decrease in atomic size, increase of nuclear attraction.

**39. Diagonal Relationship :** The first three members of second period (Li, Be and B) shows much similarity with second element of next group. It is termed as diagonal relationship. This phenomenon is observed only in IA, IIA and IIIA groups.

a) Li - Mg                    b) Be - Al                    c) B - Si

**40. Reasons for Diagonal relationship :** 1) Similar size of atoms or ions

2) Similar electronegativities of the respective elements.

3) Similar polarizing power

$$\text{Polarizing power} = \frac{\text{Ionic charge}}{(\text{Ionic radius})^2}$$

**Nature of oxides of elements :**

41. **Variation in group :** IA group posses active metals. So they forms strong basic oxides. In a group from top to bottom, the basic nature of the oxides increases due to increase of metallic character.
42. **Variation in third period:** Third period contains metals and non metals. While moving across a period the basic nature of the oxides decreases and the acidic nature of oxides gradually increases due to increase of non metallic character in a period.

Group	IA	IIA	IIIA	IVA	VA	VIA	VIIA
Element	Na	Mg	Al	Si	P	S	Cl
Nature	Metal	Metal	Metal	Non metal	Non metal	Non metal	Non metal
Oxide	$Na_2O$	$MgO$	$Al_2O_3$	$SiO_2$	$P_4O_{10}$	$SO_3$	$Cl_2O_7$
Oxide Nature	Strongly basic	Basic	Amphoteric	Weakly acidic	Acidic	Strongly acidic	Strongly acidic

## CHEMICAL BONDING AND MOLECULAR STRUCTURE

**Octet rule**

- 1) The phenomenon of having eight electrons in valency shell is called octet rule. The atom or molecule with octet configuration is more stable.
- 2)  $Ca^{2+}$  is more stable than  $Zn^{2+}$  because  $Ca^{2+}$  has octet configuration in valency shell whereas  $Zn^{2+}$  has pseudo octet configuration in valency shell.
- 3)  $Cl^-$  ion is more stable than Cl atom, because  $Cl^-$  possesses stable octet configuration.
- 4) Argon is mono atomic gas as it possesses stable octet configuration in its valency shell
- 5) **Ionic Bond:** The strong electro static force of attraction formed between two oppositely charged ions is known as ionic bond.
- 6) **Favourable Conditions for the formation of ionic bond :** The formation of ionic bond is influenced by nature of cation and nature of anion
- 7) For cation formation favouring factors are large size, low charge, low IP
- 8) For anion formation favouring factors are small size, low charge, high EA
- 9) The bond formed by sharing of electron pair is contributed by one of the two bonded atoms is known as coordinate covalent bond (or) dative bond.
- 10) The atom which donates electron pair is called donor and the atom which accepts the electron pair is called acceptor.

Eg.: Formation of  $NH_4^+$  ion:  $H^+$  ion accepts a pair of electrons from nitrogen of ammonia and forms  $NH_4^+$  ion.

- 11) The bonds present in  $NH_4Cl$  are covalent bond, ionic bond, dative bond
- 12) **Dipole moment :** i) The product of magnitude of charge on the poles and the distance between the two poles is called dipole moment. It is represented by  $\mu$   
ii)  $\mu = q \times d$  ( $q$  = charge;  $d$  = bond length)
- 13) **Applications :** i) Geometry of the molecule can be determined  
ii) Percentage of ionic character of a bond can be calculated

$$\% \text{ of ionic character} = \frac{\mu_{\text{obs}}}{\mu_{\text{cal}}} \times 100$$

iii) cis and trans isomers can be separated

- 14) In  $H_2O$  molecule the net dipole moment is not zero.  
**Reason :** The bond moments are not cancel with each other due to its angular shape.
- 15) In  $CO_2$  molecule the net dipole moment is zero.  
**Reason:** The bond moments are cancel with each other due to linear shape.
- 16) **Fajan's rules :** i) Fajan's rules explain the partial covalent character of ionic bonds.  
ii) For a given cation covalent character increases with increase in size of anion.  
Ex: KI is more covalent than KF  
iii) Covalent character increases with increasing charges either on cation or anion.  
Ex:  $SnCl_4$  is more covalent than  $SnCl_2$ .  
iv) For a given anion covalent character increases with decrease in size of cation.  
Ex: LiF is more covalent than KF.  
v) Covalent character is higher for compounds with cations with pseudo inert gas configurations than with inert gas configurations.  
Ex:  $CuCl$  is more covalent than  $NaCl$ .
- 17) **VSEPR Theory :** Valence Shell Electron Pair Repulsion theory was proposed by Sidgwick and Powell. Later it was developed by Nyholm and Gillespie
- 18) The shape of the molecule depends upon number of electron pairs in valency shell of central atom.
- 19) The shape of the molecule also depends upon repulsion between electron pairs.
- 20) The bond angle of the molecule depends upon repulsion between electron pairs and electro negativity difference between central atom and bonding atom.
- 21) A lone pair of electrons occupies more space around the central atom than bond pair of electrons
- 22) The repulsions among electron pairs decrease in the order.  $l.p - l.p > l.p - b.p > b.p - b.p$
- 23) Repulsion among triple, double, single bonds decrease in the order  
triple bond > double bond > single bond
- 24) Repulsion forces decreases sharply with increase in angle between electron pairs.
- 25) Shape and bond angle of the molecule basing on bond pairs and lone pairs around central atom as follows.

Formula	Example	Bond pairs	Lone pairs	Shape	Bond angle
$AB_2$	$BeCl_2$	2	0	Linear	$180^\circ$
$AB_3$	$BCl_3$	3	0	Trigonal Planar	$120^\circ$
$AB_4$	$CH_4$	4	0	Tetrahedral	$109^\circ 28'$
$AB_5$	$PCl_5$	5	0	Trigonal bi pyramidal	$90^\circ, 120^\circ$
$AB_6$	$SF_6$	6	0	Octahedral	$90^\circ, 180^\circ$
$AB_3E$	$NH_3$	3	1	Pyramidal	$107^\circ$
$AB_2E_2$	$H_2O$	2	2	Angular	$104.5^\circ$

[Note : E=lone pair of electrons ; B=bond pair of electron ; A=central atom]

- 26) According to VSEPR theory, bond angle in Ammonia is reduced from  $109^\circ 28'$  to  $107^\circ$ . This is due to repulsion between loan pair and bond pair.
- 27) **Hybridization :** The inter mixing of atomic orbitals to form new, same number of equavalent orbitals is called Hybridisation and the formed orbitals are called hybrid orbitals.
- 28) **SP hybridisation :**  
i) Inter mixing of one S orbital and one P orbital to give two SP hybrid orbitals is called SP hybridization.

- ii) Shape is linear and bond angle is  $180^\circ$
- iii) S character is 50% and P character is 50%

**Eg: Formation of  $BeCl_2$**

- (a) In first excited state the central ‘Be’ atom undergoes ‘SP’ hybridisation to give two SP hybrid orbitals
- (b) These two orbitals overlap with P orbitals of Cl atoms and form two  $\sigma$  bonds
- (c) Shape is linear and bond angle is  $180^\circ$

**29)  $SP^2$  hybridisation :**

- i) Inter mixing of one S orbital and two P orbitals to give three  $SP^2$  hybrid orbitals is called  $SP^2$  hybridization
- ii) Shape is trigonal planar and bond angle is  $120^\circ$
- iii) S character is 33.3% and P character is 66.6 %

**Eg: formation of  $BCl_3$**

- (a) In first excited state the central ‘B’ atom undergoes  $SP^2$  hybridisation to give three  $SP^2$  hybrid orbitals
- (b) These three orbitals overlap with P orbitals of Cl atoms and form three  $\sigma$  bonds
- (c) Shape is trigonal planar and bond angle is  $120^\circ$

**30)  $SP^3$  hybridisation :**

- i) Inter mixing of one S orbital and three P orbitals to give four  $SP^3$  hybrid orbitals is called  $SP^3$  hybridization
- ii) Shape is tetrahedral and bond angle is  $109^\circ 28'$
- iii) S character is 25% and P character is 75%

**Eg: Formation of  $CH_4$**

- (a) In first excited state the central ‘C’ atom undergoes  $SP^3$  hybridisation to give four  $SP^3$  hybrid orbitals
- (b) These four orbitals overlap with S orbitals of hydrogen atoms and form four  $\sigma$  bonds
- (c) Shape is tetrahedral and bond angle is  $109^\circ 28'$

**31)  $SP^3d$  hybridization :**

- i) Inter mixing of one s-orbital, three p-orbitals and one d-orbital to give  $5sp^3d$  hybrid orbitals is called  $sp^3d$  hybridization.
- ii) Shape is trigonal bipyramidal and bond angles are  $120^\circ$  and  $90^\circ$ .
- iii) s character is 20%, p character is 60% and d character is 20%.

**Eg : Formation of  $PCl_5$**

- (a) In first excited state Inter mixing of one ‘s’ three ‘p’ and one ‘d’ orbitals of ‘P’ atom forms five  $SP^3d$  hybrid orbitals
- (b) These five orbitals overlap with  $3P_z$  orbitals of Cl atoms and form five  $\sigma$  bonds
- (c) Shape of the molecule is trigonal bi pyramidal and bond angles are  $90^\circ$  and  $120^\circ$

**32)  $SP^3d^2$  hybridization :**

- i) Intermixing of one s-orbital, three p-orbitals and two d-orbitals to give  $6sp^3d^2$  hybrid orbitals is called  $sp^3d^2$  hybridization.

**Formation of  $\text{SF}_6$  :**

ii) Ground state E.C of 'S' is  $[\text{Ne}]3s^2 3p_x^2 3p_y^1 3p_z^1 3d^0$

2nd excited state E.C of 'S' is  $[\text{Ne}]3s^1 3p_x^1 3p_y^1 3p_z^1 3d_{x^2-y^2}^1 3d_{z^2}^1$

iii) These six orbitals overlap with  $2P_z$  orbitals of 6 fluorine atoms and form six  $\sigma$ -bonds

iv) Shape of the molecule is octahedral and bond angles are  $90^\circ$  and  $180^\circ$

- 33) **Molecular orbital theory:** Molecular orbital theory is used to calculate bond order (number of bonds between atoms)

$$\text{Bond order} = \frac{1}{2}(\text{bonding electrons} - \text{Anti bonding electrons})$$

- 34) The distribution of electrons in the molecular orbitals of  $N_2$

$$\text{Ec of } N_2 = \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 (\pi 2p_x^2 = \pi 2p_y^2) \sigma 2p_z^2$$

$$35) \text{ Bond order in } N_2 \text{ molecule } (BO) = \frac{10-4}{2} = \frac{6}{2} = 3$$

- 36) As there are no unpaired electrons in MOED of  $N_2$  it is diamagnetic in nature.

- 37) The distribution of electrons in the molecular orbitals of  $O_2$

$$\text{EC of } O_2 = \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 \pi 2p_x^2 = \pi 2p_y^2 \pi^* 2p_x^1 = \pi^* 2p_y^1$$

- 38) As there are unpaired electrons in MOED of  $O_2$  it is paramagnetic in nature

$$39) \text{ Bond order in } O_2 \text{ molecule } (BO) = \frac{10-6}{2} = \frac{4}{2} = 2$$

**Hydrogen bond**

- 40) The weak electrostatic force of attraction between a partially positively charged hydrogen atom and a highly electro negative atoms like F, O, N of the same (or) different molecule is known as hydrogen bond. Hydrogen bonding is of two types

- 41) **Intermolecular hydrogen bonding :** The hydrogen bond is formed between two different polar molecules is called inter molecular hydrogen bonding

Examples:  $\text{NH}_3, \text{H}_2\text{O}, \text{HF}$

- 42) **Intramolecular hydrogen bonding :** The hydrogen bond is formed between two atoms of same molecule is called intra molecular hydrogen bonding.

Examples: o-hydroxybenzaldehyde, o-nitrophenol, o-nitroaniline

43) Due to the presence of Hydrogen bonding in molecule their melting and boiling points increases.

- 44)  $\text{H}_2\text{O}$  has higher boiling point than HF because more number of hydrogen bonds are present in  $\text{H}_2\text{O}$  molecule than HF

## STATES OF MATTER

**Kinetic molecular theory of gases:**

1. Gases contains large number of tiny and discrete particles called molecules.

**JR CHEMISTRY**

2. Gas molecules move randomly in all directions with high speeds
3. Molecules motions are unaffected by gravity.
4. Collisions of gas molecules are perfectly elastic.
5. Average kinetic energy of the gas molecules is directly proportional to the absolute temperature

$$KE \propto T$$

6. Kinetic gas equation  $PV = \frac{1}{3}mn\bar{v}^2$

7. Kinetic energy of 'n' molecules in a gas is  $KE = \frac{1}{2}mn\bar{v}^2$

8. According to Boyle's law  $PV = \text{constant}$  (At constant T)

9. According to Charle's law  $V \propto T$  (or)  $V/T = K$  (At constant P)

10. At constant temperature and pressure rate of diffusion of given mass of gas is inversely proportional to square root of its density.

$$r \propto \frac{1}{\sqrt{d}} \quad (\text{At constant T, P})$$

11. At constant temperature and volume the total pressure exerted by the mixture of non-reacting gases is equal to the sum of the partial pressures of all individual gases. this is called Dalton's law of partial pressures.

$$P_{\text{total}} = P_1 + P_2 + P_3$$

12. Kinetic energy of 'n' moles of gas  $E_k = \frac{3}{2}nRT$

13. Kinetic energy of 1 mole of gas  $E_k = \frac{3}{2}RT$

14. Kinetic energy of 5 moles of nitrogen gas at 27°C is  $E_k = \frac{3}{2}nRT$

$$\therefore E_k = \frac{3}{2} \times 5 \times 2 \times 300 = 4500 \text{ cal.}$$

14. Ideal gas equation is  $PV = nRT$

16. Molar mass is directly proportional to its density  $M \propto d$

17. Vapour density (VD) =  $\frac{\text{molar mass}}{2} = \frac{M}{2} \Rightarrow M = 2 \times VD$

18. Molar mass is directly proportional to the vapour density (VD).  $M \propto VD$

19. If  $r_1, r_2$  are rates of diffusion of two different gases then Graham's law is  $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{VD_2}{VD_1}}$

20. (a) The rate of diffusion of a gas  $r = V/t$ .

(b) If  $t_1$  and  $t_2$  are time taken for the diffusion of  $v_1$  and  $v_2$  are volumes of two different gases then

Graham's law is  $\frac{r_1}{r_2} = \frac{t_2 v_1}{t_1 v_2}$

**Deduction of gas laws from Kinetic gas equation:**

**21. Deduce Boyle's law :** according to kinetic gas equation

$$PV = \frac{1}{3} mnc^2 = \frac{2}{3} \times \frac{1}{2} mnc^2 \quad (\because \frac{1}{2} mnc^2 = KE)$$

$$PV = \frac{2}{3} KE \dots\dots\dots(1) \quad (But KE \propto T)$$

$$KE = KT \dots\dots\dots(2)$$

$$\text{From eq (1) \& (2)} \quad PV = \frac{2}{3} KT$$

$PV = \text{constant}$  (at cont. temperature) This is Boyle's law

**22. Deduce Charles's law:** According to kinetic gas equation

$$PV = \frac{1}{3} mnc^2 = \frac{2}{3} \times \frac{1}{2} mnc^2$$

$$PV = \frac{2}{3} KE \dots\dots\dots(1)$$

$$KE = KT \dots\dots\dots(2) \quad (\text{But } K = \text{Cont})$$

From Eq 1&2,

$$PV = \frac{2}{3} KT ; \quad V = \frac{2}{3} \frac{KT}{P}$$

$V \propto T$  (at cont P) This is Charles's law

**23. Deduce graham's law :** According to kinetic gas equation

$$PV = \frac{1}{3} mn u^2$$

$$pv = \frac{1}{3} Mu^2 \quad (M = mn)$$

$$u^2 = \frac{3pv}{M} \Rightarrow u = \sqrt{\frac{3pv}{M}} \quad \left( \frac{M}{V} = D \right)$$

$$\Rightarrow u = \sqrt{\frac{3p}{d}} \Rightarrow u \propto \sqrt{\frac{1}{d}} \quad \text{This is graham's law}$$

If the no. of molecules 'n' is equal to Avogadro's number

If the no. of molecules 'n' is equal to Avogadro's number

**24. Deduce Dalton's law :** Two gases present in a container with volume V. if mass of each molecules

$m_1, m_2$ , velocities  $u_1, u_2$  and number of moles  $n_1, n_2$

According to kinetic gas Eq.

$$PV = \frac{1}{3} mn u^2 \Rightarrow p = \frac{1}{3} \frac{mn u^2}{v}$$

$$\text{For 1st gas } p_1 = \frac{1}{3} \frac{m_1 n_1 u_1^2}{v}, \text{ For 2nd gas } p_2 = \frac{1}{3} \frac{m_2 n_2 u_2^2}{v}$$

$$pv = \frac{1}{3} m_1 n_1 u_1^2 + \frac{1}{3} m_2 n_2 u_2^2$$

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$$p = \frac{1}{3} \frac{m_1 n_1 u_1^2}{v} + \frac{1}{3} \frac{m_2 n_2 u_2^2}{v}$$

$p = p_1 + p_2$  This is Dalton's law

25. The root of mean of squares of speeds of gas molecules is called rms speed.

26. To calculate RMS velocity when the temperature is given, then the formula

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{d}}$$

27. The average of velocities of all the molecules present in the gas is called average speed.

$$u_{av} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8PV}{\pi M}} = \sqrt{\frac{8P}{\pi d}}$$

28. The velocity possessed by maximum number of molecules present in gas is called most probable velocity.

$$u_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2PV}{M}} = \sqrt{\frac{2P}{d}}$$

29. The ratio of 3 types of molecular velocities is  $u_{mp} : u_{av} : u_{rms} = 1 : 1.128 : 1.224$

30. Partial pressure = mole fraction  $\times$  total pressure

31. Mole fraction ( $X$ ) =  $\frac{\text{number of moles of one component}}{\text{total number of moles of all components}}$

32. Rate of diffusion of gas is  $r = \frac{\text{volumes of the gas diffused}}{\text{time taken for diffusion}} = \frac{V}{t}$

33. The graphs between P & V at constant temperature is called Isotherms.

34. 273.15K temperature and 1 atm pressure are S.T.P conditions.

35. One mole of any gas occupied volume is 22.4 lit at STP conditions is known as gram molar volume.

36. Gas constant( $R$ ) is same for all gases. Hence it is called universal gas constant.

$$R = \frac{PV}{nT} = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$$

37. Methane gas diffuses faster among  $N_2, O_2$ . Because it is lighter gas. or It has low molecular weight

38. Methane gas diffuses 2 times faster than sulphur dioxide ( $SO_2$ )

39. Pressure exerted by saturated water vapour is called aqueous tension

$$P_{drygas} = P_{total} - \text{Aqueous tension}$$

40. Gas constant per molecule is known as Boltzmann constant  $k = \frac{R}{N} = 1.38 \times 10^{-16} \text{ erg.K}^{-1} \text{ molecule}^{-1}$

$$= 1.38 \times 10^{-23} \text{ Joule.K}^{-1} \text{ molecule}^{-1}$$

41. Ratio between PV and nRT is called compressibility factor. it is represented by Z.  $Z = \frac{PV}{nRT}$

## JR CHEMISTRY

## CDF MATERIAL

42. It is the high temperature at which a gas can be liquefied by the application of external pressure.  
Critical temperature of  $CO_2 = 31.1^\circ C$
43. At which temperature Real gas behaves as Ideal gas is known as Boyle's Temperature.
44. The force acting per unit length perpendicular to line drawn on surface of liquid is called surface tension ( $\gamma$ ). Its units  $\frac{N}{m^2}$  or  $\frac{J}{m}$ .
45. The viscosity coefficient is the force when velocity gradient is unity and the area of contact is unit area

$$F = \eta A \frac{dV}{dz}$$

$\frac{dV}{dz}$  = velocity gradient, A = area of contact  $\eta$  = viscosity coefficient.

46. Units of viscosity coefficient is  $N\text{Sm}^{-2}$  in SI units. In CGS system poise.

**Significance of VanderWaals constants 'a' and 'b':**

The value of 'a' measure the magnitude of attractive forces between two molecules.

The value of 'b' gives an idea about the effect size of gas molecule.

**Derivation of ideal gas equation.**

A gas which obeys all the gas laws under all temperature and pressure is called Ideal gas.

Ideal gas equation is obtained by combining three gas laws. They are

(i) Boyles law :  $V \propto \frac{1}{P}$  .....(1)

(ii) Charles law :  $V \propto T$  .....(2)

(iii) Avagadros law :  $V \propto n$  .....(3)

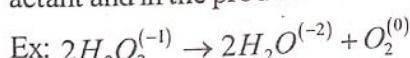
from (1) (2) and (3)  $V \propto \frac{nT}{P}$

$PV = nRT$       (R=universal gas constant)

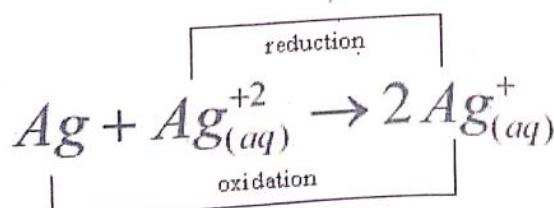
## ✓ STOICHIOMETRY

01. **Disproportionation:** These reactions involve the same element in the given form to undergo both oxidation and reduction simultaneously.

The element that undergoes disproportionation is with an intermediate oxidation state as reactant and in the products one with higher oxidation state and other with lower oxidation state.



02. **Comproportionation:** The reverse of disproportionation is called as comproportionation. In these two species with same element in two different oxidation states form a single product in which the element is in intermediate oxidation state.



03. Number of moles =  $\frac{\text{Wt. of substance}}{\text{G.M.Wt. of substance}}$

Ex. How many number of moles of glucose are present in 540 gms of glucose

Glucose gram molecular weight ( $C_6H_{12}O_6$ ) =  $12 \times 6 + 1 \times 12 + 16 \times 6 = 72 + 12 + 96 = 180$  gm

$$\text{number of moles of glucose} = \frac{w}{\text{G.M.wt}} = \frac{540}{180} = 3 \text{ moles}$$

04. Wt. of substance = No. of moles  $\times$  G.M.Wt. of substance

Ex. Calculate the weight of 0.1 mole of sodium carbonate

$Na_2CO_3$  gram molecular weight =  $23 \times 2 + 12 + 16 \times 3 = 46 + 12 + 48 = 106$  gm

No. of moles (n) = weight/G.m.wt

weight =  $n \times$  G.m.wt

weight =  $0.1 \times 106 = 10.6$  gm

05. Molecular formula = (empirical formula)<sub>n</sub>

Ex: The empirical formula of a compound is  $CH_2O$ . Its molecular weight is 90. Calculate the molecular formula of the compound.

Empirical formula =  $CH_2O$

Empirical formula weight =  $12 + 2 + 16 = 30$

molecular weight = 90

$$n = \frac{\text{molecular wt}}{\text{empirical formula wt}} = \frac{90}{30} = 3$$

molecular formula = (empirical formula)<sub>n</sub> =  $(CH_2O)_3 = C_3H_6O_3$

#### 06. Oxidation numbers:



$$+1 + 2 + x + 4(-2) = 0$$

$$x - 5 = 0$$

$$x = +5$$



$$+1 + 1 + x + 4(-2) = 0$$

$$x - 6 = 0$$

$$x = +6$$



$$4(+1) + 2x + 7(-2) = 0$$

$$+4 + 2x - 14 = 0$$

$$2x = +10,$$

$$x = +5$$



$$2(+1) + x + 4(-2) = 0$$

$$x - 6 = 0$$

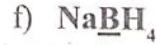
$$x = +6$$



$$+2 + 2x = 0$$

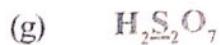
$$2x = -2$$

$$x = -1$$



$$1(+1) + x + 4(-1) = 0$$

$$x = +3$$



$$2(+1) + 2x + 7(-2) = 0$$

$$2 + 2x - 14 = 0$$

$$2x = 12$$

$$x = +6$$



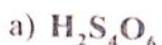
$$+1 + 3 + 2(x + 4(-2)) = 0$$

$$+4 + 2x - 16 = 0$$

$$2x - 12 = 0$$

$$x = +6$$

## 07. Oxidation numbers:



$+2 + 4x - 12 = 0,$

$4x = 12 - 2$

$4x = 10, x = 2.5$

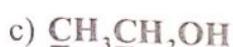


$3x - 8 = 0, 3x = 8$

$x = \frac{8}{3}$

oxidation number of  $\text{Fe}$  is average of  $\text{FeO}$  &  $\text{Fe}_2\text{O}_3^{(+3)}$

$\text{Fe}_3\text{O}_4 = \frac{+2 + 6}{3} = \frac{8}{3}$



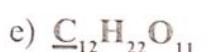
$+2x + 6 - 2 = 0, 2x = -4$

$x = -\frac{-4}{2} = -2$



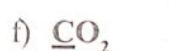
$2x + 4 - 4 = 0$

$x = 0$



$12x + 22(1) + 11(-2) = 0$

$x = 0$



$x + 2(-2) = 0$

$x = +4$

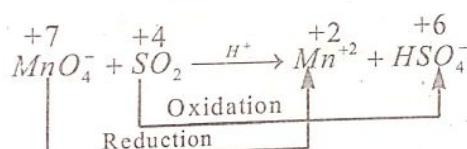
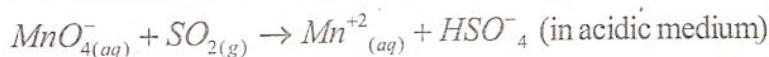
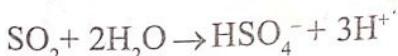
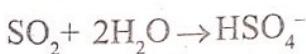
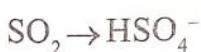


$3x + 2(-2) = 0$

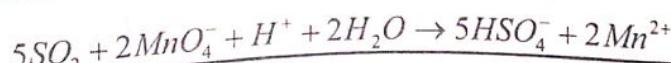
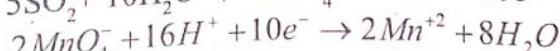
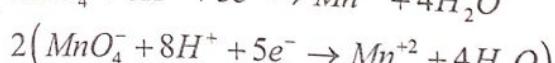
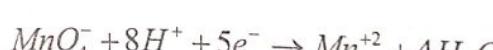
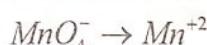
$3x - 4 = 0$

$x = \frac{4}{3}$

## 08. Balance the following redox reactions by ion electron method

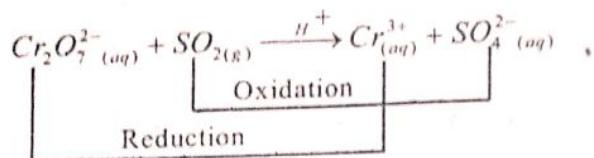
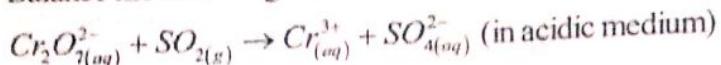
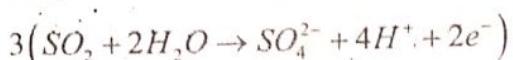
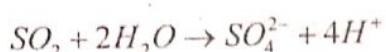
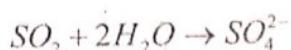
Oxidation half reaction

By adding both

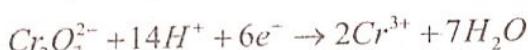
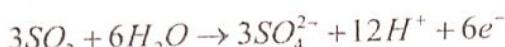
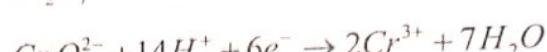
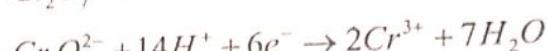
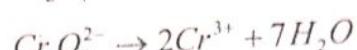
Reduction half reaction

**JR CHEMISTRY**

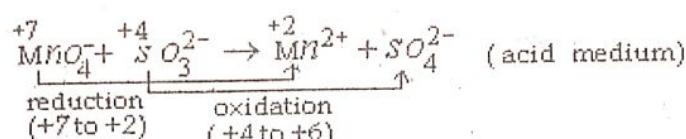
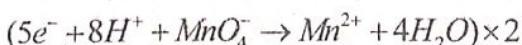
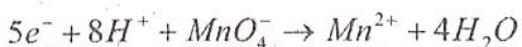
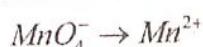
09. Balance the following redox reactions by ion electron method

Oxidation half reaction

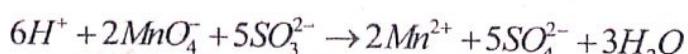
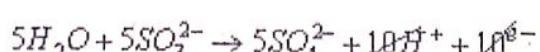
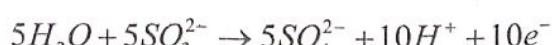
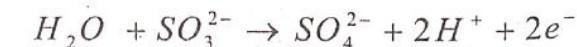
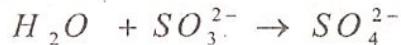
By adding both

Reduction half reaction

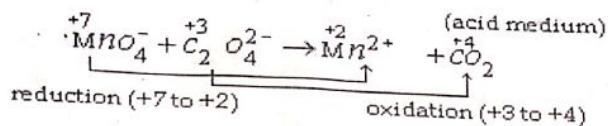
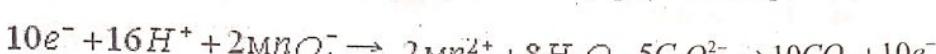
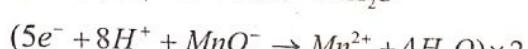
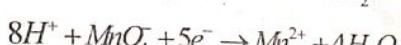
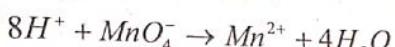
10. Balance the following redox reactions by ion electron method

Reduction

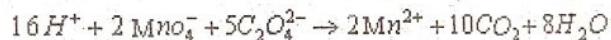
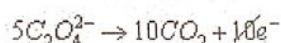
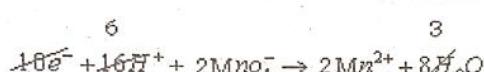
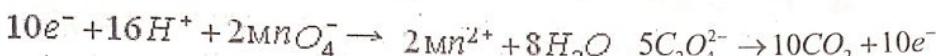
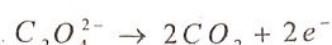
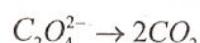
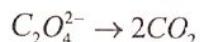
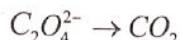
By adding both

Oxidation

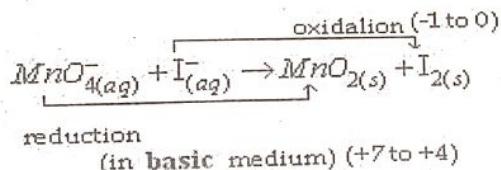
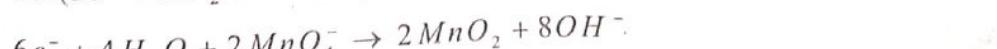
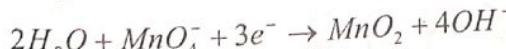
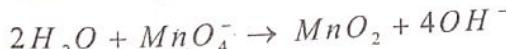
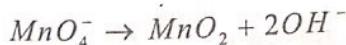
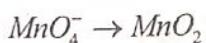
11. Balance the following redox reactions by ion electron method

Reduction

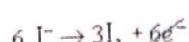
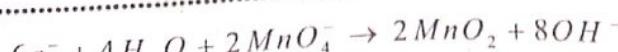
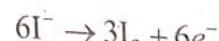
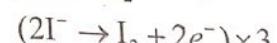
By adding both

Oxidation

12. Balance the following redox reactions by ion electron method

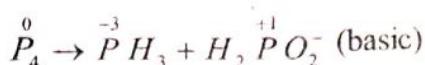
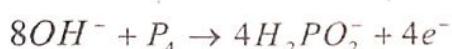
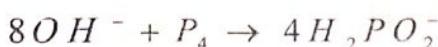
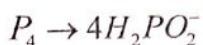
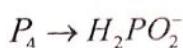
Reduction

By adding both

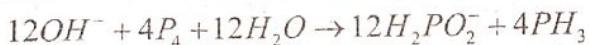
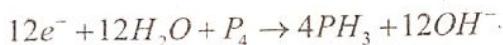
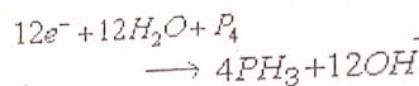
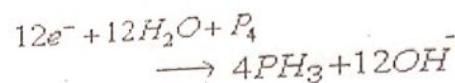
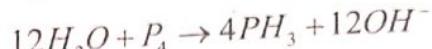
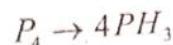
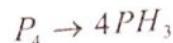
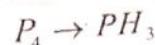
Oxidation

**JR CHEMISTRY**

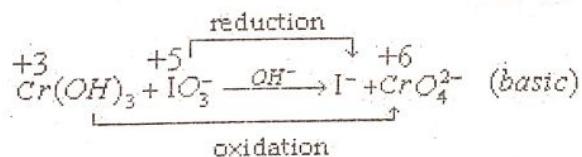
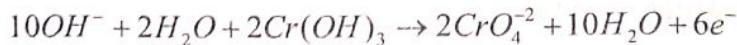
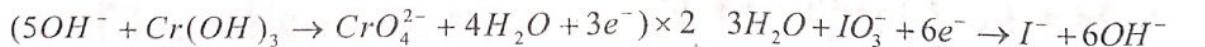
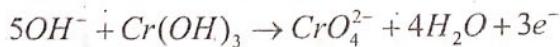
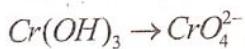
13. Balance the following redox reactions by ion electron method

Oxidation

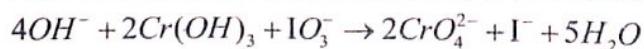
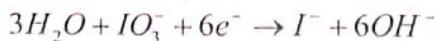
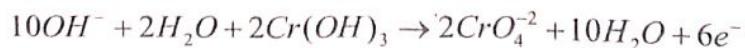
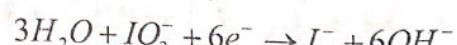
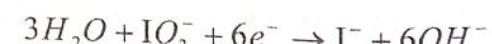
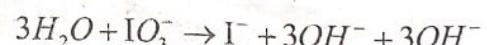
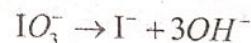
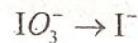
By adding both

Reduction

14. Balance the following equation  $Cr(OH)_3 + IO_3^- \xrightarrow{OH^-} I^- + CrO_4^{2-}$

Oxidation

By adding both

Reduction

15. Chemical analysis of a carbon compound gave the following percentage composition by weight of the elements present. carbon=10.06% hydrogen=0.84%. Chlorine=89.10%. Calculate the empirical formula of the compound.

Symbol of the element	percentage of composition	Atomic weight	Atomic Ratio=%/At.wt	Simple Ratio	whole number
C	10.06	12.00	0.84	$\frac{0.84}{0.84} = 1$	1
H	0.84	1.00	0.84	$\frac{0.84}{0.84} = 1$	1
Cl	89.1	35.5	2.50	$\frac{2.50}{0.84} = 3$	3

$$\therefore \text{Empirical formula} = \underline{\underline{CHCl_3}}$$

16. Calculate the empirical formula of a compound having percentage composition "potassium(K)=26.57 chromium(Cr)=35.36 oxygen(O)=38.07  
(Given the atomic weights of K, Cr, O as 39, 52 and 16 respectively)

Symbol of the element	percentage of composition	Atomic weight	Atomic Ratio = % / At.Wt	Simple Ratio	whole number
K	26.57	39	0.68	$\frac{0.68}{0.68} = 1$	2
Cr	35.36	52	0.68	$\frac{0.68}{0.68} = 1$	2
O	38.07	16	2.38	$\frac{2.38}{0.68} = 3.5$	7

$$\text{Empirical formula} = \underline{\underline{K_2Cr_2O_7}}$$

## JR CHEMISTRY

17. A carbon compound contains 12.8% "C" 2.1 % H, 85.1% (Br). The molecular weight of the compound is 187.9 calculate the molecular formula

Symbol of the element	percentage of composition	Atomic weight	Atomic Ratio=%/At.wt	Simple Ratio	whole number
C	12.8	12	1.06	$\frac{1.06}{1.06} = 1$	1
H	2.1	1	2.1	$\frac{2.10}{1.06} = 2$	2
Br	85.1	80	1.06	$\frac{1.06}{1.06} = 1$	1

$$EF = CH_2Br; \quad EF\text{ wt} = 12 + 2 + 80 = 94$$

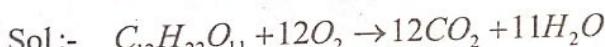
$$n = \frac{m\text{wt}}{EF\text{wt}} = \frac{187.9}{94} = 2$$

$$MF = (EF)_n = (CH_2Br)_2 = C_2H_4Br_2$$

18. Calculate the molarity of  $Na_2Co_3$  in a solution prepared by dissolving 5.3g in enough water to form 250 ml of the solution.

$$\text{Sol.: } M = \frac{Wt}{GMW} \times \frac{1000}{V(\text{in ml})} \Rightarrow M = \frac{5.3}{106} \times \frac{1000}{250} = 0.2M$$

19. An astronaut receives the energy required in his body by the combustion of 34g of sucrose per hour. How much oxygen he has to carry along with him for his energy



$$342g \quad 12 \times 32g O_2$$

$$34g \rightarrow ?$$

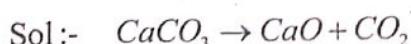
$$\frac{34 \times 12 \times 32}{342} = 38.17g$$

$$1 \text{ hour} \rightarrow 38.17g$$

$$24 \text{ hour} \rightarrow ?$$

$$38.17 \times 24 = 916.21g \text{ of } O_2$$

20. What volume of  $CO_2$  is obtained at STP by heating 4g of  $CaCO_3$ ?



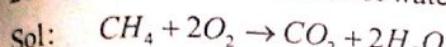
$$100g \text{ of } CaCO_3 \rightarrow 22.4 \text{ lit of } CO_2$$

$$4g \rightarrow ?$$

$$\frac{4 \times 22.4}{100} = \frac{89.6}{100} = 0.896 \text{ lit of } CO_2$$

**JR CHEMISTRY****CDF MATERIAL**

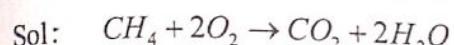
21. Calculate the amount of water (g) produced by the combustion of 16g of methane



1 mole	2 mole
16g	$2 \times 18 = 36\text{ g}$
Given 16g	_____
React 16g	?

Amount of water (g) produced by the combustion of 16g of methane =  $\frac{36}{16} \times 16 = 36\text{ g}$

22. How many moles of methane are required to produce 22g  $CO_2$  (g) after combustion ?



1mole  $CH_4 \rightarrow 44\text{ g of } CO_2$

? ← 22g of  $CO_2$

$$\frac{22}{44} = 0.5 \text{ moles}$$

23. Calculate the molarity of NaOH in the solution prepared by dissolving 4g in enough water to form 250ml of the solution

Sol:  $M = \frac{w}{GMW} \times \frac{1000}{V(\text{in ml})}$

$$= \frac{4}{40} \times \frac{1000}{25} = 0.4M$$

24. Calculate the normality of oxalic acid solutions containing 6.3g of  $H_2CO_4 \cdot 2H_2O$  in 500 ml of solution

Sol: GEW of solute =  $\frac{126}{2} = 63$

$$N = \frac{w}{GEwt} \times \frac{1000}{V(\text{in ml})} = \frac{6.3}{63} \times \frac{1000}{500} = 0.2N$$

25. Calculate the mass of  $Na_2CO_3$  required to prepare 250 ml of 0.5N solution

Sol:  $N = \frac{w}{GEwt} \times \frac{1000}{V(\text{in ml})}$

$$0.5 = \frac{w}{53} \times \frac{1000}{250}$$

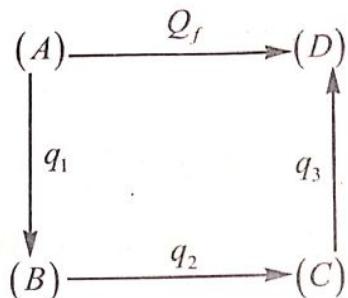
$$w = \frac{0.5 \times 53 \times 250}{1000} = 6.62\text{ g}$$

### THERMODYNAMICS

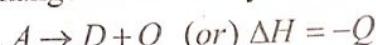
1. **First law of the thermodynamics :** 1<sup>st</sup> law : It states that " The energy in a process may be transformed from one form into the other but is neither created nor destroyed". (or)  
 "The impossibility of construction of a perpetual motion machine of first kind"  
 → It is also known as law of conservation of energy

**JR CHEMISTRY**

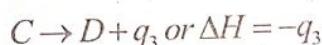
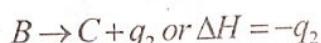
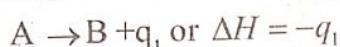
- ✓ 2.  $\Delta U = q + w$   
 Hess law of constant heat summation states that "The total heat change in a reaction is the same whether the chemical reaction takes place in a single step or in several steps".



a) in path I, 'A' changes to D directly i.e single step



b) in path II, A changes to D in three consecutive steps



c) The total heat change in the path is  $-Q$

$$Q = q_1 + q_2 + q_3$$

3. **The spontaneity of a process :** A process is said to be spontaneous if it occurs on its own without the intervention of any external agency of any kind.

Eg : a) Heat flows from hot end to cold end

b) Water flows from higher level to lower level

c) Gas flows from higher pressure region to lower pressure region

4. **Gibbs energy :** Hence, Gibbs introduced another thermodynamic function which involved both enthalpy (H) and entropy functions. This is called free energy function (G). It is given by the equation.

$$G = H - TS$$

G = Gibbs energy (or) Gibbs function but not "Gibbs free energy"

In a thermodynamical system, the decrease in whose value during a process is equal to useful workdone by the system is called "Gibbs energy"  $\Delta G = \Delta H - T\Delta S$

The sign of  $\Delta_r H^0$ ,  $\Delta_r S^0$  and  $\Delta_r G^0$  for different process at different temprature.

$\Delta_r H^0$	$\Delta_r S^0$	$\Delta_r G^0$	Description
-	+	-	Reaction spontaneous at all temperature
-	-	-	Reaction spontaneous at low temperature
-	-	+	Reaction non spontaneous at high temperature
+	+	+	Reaction non spontaneous at low temperature
+	+	-	Reaction spontaneous at high temperature
+	-	+	Reaction non spontaneous at all temperature

**5.** **Second law of thermodynamics is stated in different forms.**

(1) It is impossible to construct a machine working in cycles which transforms heat from a lower temperature region to higher temperature region without the intervention of any external agency. Such a machine is called perpetual motion machine of second kind (This is not possible)

(2) All spontaneous processes are thermodynamically irreversible and entropy of the system increases in all spontaneous processes.

Ex : All natural processes are spontaneous.

**6.** **Entropy :** The thermodynamical quantity which measures "disorder" of molecules or randomness of the system is called "Entropy"

It is a state function & extensive property

It is denoted by "S" & Change in entropy is denoted by  $\Delta S$

Example -1:  $\text{Ice} \rightleftharpoons \text{water} \rightleftharpoons \text{vapour}$

$$S_{\text{ice}} < S_{\text{water}} < S_{\text{vapour}}$$

$$\text{Thermodynamical representation : } \Delta S = \frac{q_{\text{rev}}}{T} = \frac{\Delta H_{\text{rev}}}{T}$$

q = Quantity of heat

T = Absolute temperature

Units of  $\Delta S \rightarrow J \text{ mol}^{-1} K^{-1}$

**7.** **Heat capacity of a substance (C):** Heat capacity of a substance is defined as the amount of heat required to raise its temperature through one degree

$$C = q/dT; q \text{ is heat absorbed; } dT \text{ rise in temperature}$$

But from first law of thermodynamics

$$q = dU + PdV;$$

**8.** The relationship between  $C_p$  and  $C_v$  is  $C_p - C_v = R$

$C_p$  = molar heat capacity at constant pressure

$C_v$  = molar heat capacity at constant volume

R = Universal gas constant

**9.** **The third law of thermodynamics :** The entropy of a pure and perfectly crystalline substance is zero at the absolute zero of temperature ( $-273^{\circ}\text{C}$ )

$$\lim_{T \rightarrow 0} S = 0$$

This is known as the third law of thermodynamics.

**10.** **The equation for ' $W_{\text{rev}}$ ' in isothermal reversible process.**

The small amount of work done ' $W_{\text{rev}}$ ' when the gas expands through a small value,  $dv$ , against the external pressure,  $P_{\text{ext}}$  is given by

$$W_{\text{rev}} = -P_{\text{ext}} dv$$

$$W_{\text{rev}} = -2.303 nRT \log \frac{V_2}{V_1}$$

$$W = -2.303 nRT \log \frac{P_1}{P_2}$$

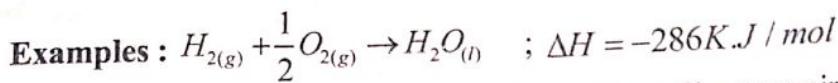
The sign indicates work of expansion.

**11. Enthalpy of a reaction:** During a chemical change heat is either liberated or absorbed the heat change involved in a chemical reaction is called Enthalpy of the reaction.

The chemical reactions which take place with the liberation of heat are called exothermic reactions

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- 12. Standard enthalpy of formation:** The amount of heat absorbed or evolved when 1 mole of a substance is obtained from its constituent elements is called Enthalpy of formation. The elements should be in their standard state for the formation reaction.



- 13. Standard enthalpy of sublimation:** The amount of heat required to convert one mole of a simple substance in the solid state into the gaseous state without decomposition of the substance.



- 14. The enthalpy of combustion ( $\Delta_cH^\theta$ ):** The heat evolved when one mole of a substance is completely burnt in excess of oxygen or air is called enthalpy of combustion.



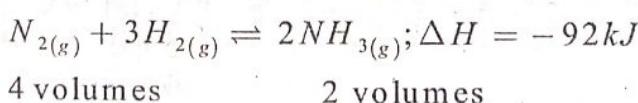
## CHEMICAL EQUILIBRIUM AND ACIDS & BASES

- 01. Le Chatelier's principle:** - "If a system at equilibrium is subjected to a change in concentration, temperature or pressure then the equilibrium will shift in that direction to nullify the effect of change"

**Factors which influence equilibrium:**

02. Increase of reactants concentrations shifts the equilibrium state to the products side.  
(forward direction)
03. Increase of the products concentrations pushes the equilibrium to the reactants side.  
(backward direction).
04. Pressure will have no effect when no. of moles of reactants is equal to no. of moles of products i.e.  $\Delta n = 0$ .
05. Increase of pressure pushes the reaction equilibrium in the direction in which there is a decrease in the number of moles.
06. Increase of pressure favours the backward reaction (towards less number of moles).
07. The decrease of pressure favours the forward reaction (towards more number of moles).
08. Increase of temperature favours the endothermic reaction and decrease of temperature favours exothermic reactions
09. Increase of temperature shifts the equilibrium, in that direction where there is absorption of heat (endothermic reaction).
10. Decrease of temperature shifts the equilibrium, in that direction where there is liberation of heat (exothermic reaction).
11. Increase of temperature favours the forward reaction and more and more NO is formed.
12. Decrease of temperature favours the backward reaction i.e. the dissociation of NO into  $N_2$  and  $O_2$ .

**Application of Lechatlier's principle - Synthesis of Ammonia by Haber's process**



Nitrogen and Hydrogen combine to form ammonia.

The formation of ammonia is reversible and exothermic reaction.

It is accompanied by decrease in volume.

- 13. Effect of Concentration:** Increase of reactants  $N_2$  and  $H_2$  in 1:3 ratio favours the formation of  $NH_3$ .
- 14. Effect of Pressure:-**  $NH_3$  formation is a volume decreasing reaction.  
According to Lechatlier - High pressure favours the reactions towards lesser volume side. Hence high

pressures are required for the more yield of  $NH_3$ .

Low pressures favour the reverse reaction i.e., decomposition of  $NH_3$ .

15. **Effect of Temperature :** Formation of ammonia is Exothermic reaction.

According to Le Chatelier - Low temperatures favours exothermic reactions. Hence low temperatures are required. But at low temperature the reaction is slow. Therefore optimum temperature (725 K–775K) is used in Haber's process.

16. **Effect of Catalyst :** To speed up the reaction, finely divided iron is used as catalyst.

To increase the activity of the catalyst molybdenum or a mixture of oxides of K and Al is used as promoter

High temperatures decomposes the formed  $NH_3$ . Hence high temperatures are avoided in Haber's process.

17. Thus the optimum conditions are

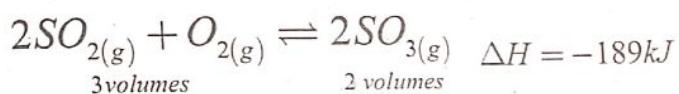
Pressure : 200 atm

Temperature : 725 – 775K

Catalyst : Fe (Powdered)

Promoter : Mo (or) ( $K_2O + Al_2O_3$ )

#### Application of Le Chatelier's principle to the synthesis of $SO_3$



The formation of  $SO_3$  is reversible and exothermic reaction. It is accompanied by decrease in volume.

18. **Effect of concentration:** If  $SO_2$  and  $O_2$  are increased the equilibrium shifts in forward direction and more and more  $SO_3$  is produced.

By continuous removal of  $SO_3$  the equilibrium shifts in the forward direction.

If the concentration of the  $SO_3$  is increased the equilibrium shifts in the backward direction i.e. more dissociation of  $SO_3$  takes place.

19. **Effect of pressure:** 2 volumes of  $SO_2$  and one volume of  $O_2$  combine to give 2 volumes of  $SO_3$ . According to Le Chatelier's principle high pressure favours the reaction where there is decrease in volume. The formation of  $SO_3$  is accompanied by decrease in volume (3 volumes to 2 volumes). Higher the pressure greater is the yield of  $SO_3$  but in contact process high pressures are not used because towers used in the manufacture are corroded by the acid at these high pressures. Low pressures favour the decomposition of  $SO_3$  as there is increase in volume. (2 volumes to 3 volumes) Therefore optimum pressures are used (1.5 to 1.7 atmosphere)

20. **Effect of Temperature :** The formation of  $SO_3$  is exothermic i.e., 189 kJ of heat is evolved. High temperatures favour the reverse reaction which is endothermic and do not favour the forward reaction which is exothermic. Low temperatures are favourable for the formation of  $SO_3$ . At low temperature the reaction is too slow. Therefore an optimum temperature 673 K is used. To speed up the reaction  $V_2O_5$  is used as catalyst.

optimum conditions.

Pressure : 1.5 to 1.7 atm

Temperature : 673K

Catalyst :  $V_2O_5$  (or) Platinised asbestos

#### Lowry - Bronsted theory (proton theory)

21. **Acid :** A chemical species which shows a tendency to lose or donate a proton or protons to other substance is called an acid. An acid is a proton donor

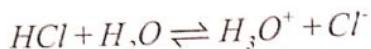
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eg: HCl,  $H_3PO_4$ ,  $CH_3COOH$ .

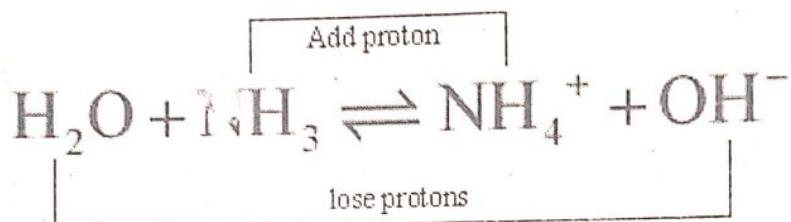
22. **Base**: A chemical species which shows a tendency to gain a proton or protons from other substance.  
A base is proton acceptor.

**Ex**:  $H_2O$ ,  $HSO_4^-$ ,  $HCO_3^-$

23. **Neutralisation**: The transfer of proton from acid to base is called neutralization.  
**Ex-1**: When hydrogen chloride is dissolved in water,  $HCl$  donates proton and  $H_2O$  accepts proton.  $HCl$  is acid and  $H_2O$  is base. The Bronsted-Lowry reaction is represented as:

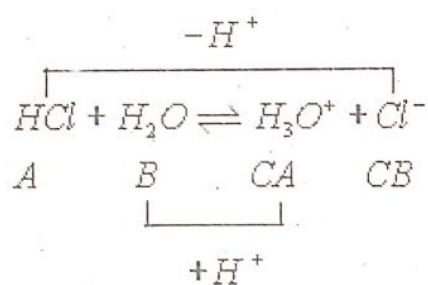


- Ex-2**: When ammonia is dissolved in water,  $NH_3$  accepts proton and  $H_2O$  donates proton.  $NH_3$  is base and  $H_2O$  is acid. The Bronsted-Lowry reaction is represented as



24. **Conjugate acid-base pair**:

A pair of species which differ in a single proton is called conjugate acid-base pair.



$HCl$  loses a proton to  $H_2O$  and forms a conjugate base  $Cl^-$ .

$H_2O$  accepts proton from  $HCl$  and forms  $H_3O^+$ .

Here  $HCl$  and  $Cl^-$  ion are conjugate acid-base pair.

similarly,  $H_2O$  and  $H_3O^+$  are conjugate acid-base pair.

Species	Conjugate acid	Conjugate base
$H_2O$	$H_3O^+$	$OH^-$
$HCO_3^-$	$H_2CO_3$	$CO_3^{2-}$
$HSO_4^-$	$H_2SO_4$	$SO_4^{2-}$

**Lewis Acid-base theory:**

25. **Lewis acid**: A substance that can accept an electron pair from other substance to form co-ordinate covalent bond is called Lewis acid. It is electron pair acceptor.

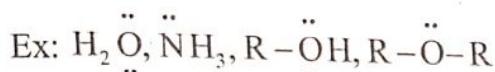
**Type of Lewis acids:**

26. Simple cations  $Ag^+$ ,  $Co^{+3}$ ,  $Cu^{+2}$ ,  $Fe^{+3}$ ,  $Al^{+3}$  act as Lewis acids.  
27. Compounds in which the central atom has an incomplete octet and possessing an empty

- p-orbital can act as a lewis acid. Ex:  $\text{BF}_3$ ,  $\text{BCl}_3$ ,  $\text{AlCl}_3$
28. Compounds in which the central atom has vacant d-orbitals and may expand its octet can act as Lewis acids. Ex:  $\text{SiF}_4$ ,  $\text{SF}_4$ ,  $\text{SnCl}_4$ ,  $\text{FeCl}_3$
29. Molecules having multiple bonds between atoms of dissimilar electronegativities can be like Lewis acids. Ex:  $\text{CO}_2$ ,  $\text{SO}_2$ ,  $\text{SO}_3$ ,  $\text{NO}_2$ .
30. Elements with six electrons in the valence shell or electron sextet can act as Lewis acids. Ex: O, S.
31. **Lewis base** : A base is a substance which can donate an electron pair to other substance to form co-ordinate covalent bond. It is electron pair donor.

#### Type of Lewis bases:

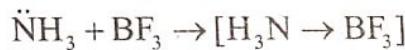
32. All simple anions like  $\text{Cl}^-$ ,  $\text{OH}^-$ ,  $\text{CN}^-$ ,  $\text{F}^-$  can act as Lewis bases.
33. Molecules with one or two lone pairs on the central atom can act as Lewis bases.



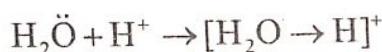
34. Molecules containing multiple bonds between similar atoms can act as Lewis bases.  
Ex:  $\text{C}_2\text{H}_2$ ,  $\text{C}_2\text{H}_4$

35. **Neutralisation** : The formation of a co-ordinate covalent bond, between a base and an acid is called neutralisation.

**Ex.1: Formation of  $\text{NH}_3 - \text{BF}_3$**  : In a reaction between  $\text{BF}_3$  and  $\text{NH}_3$ , boron of  $\text{BF}_3$  accepts a lone pair from nitrogen of  $\text{NH}_3$  and forms a coordinate covalent bond.

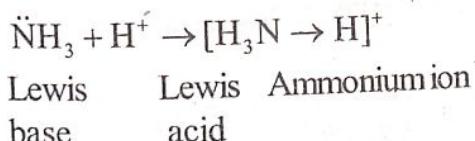


**Ex.2: Formation of hydronium ion** : In this  $\text{H}^+$  combines with  $\text{H}_2\text{O}$ . Oxygen of water donates a pair of electrons to  $\text{H}^+$  ion.



Lewis Lewis Hydronium ion  
base acid

**Ex.3: Formation of  $\text{NH}_4^+$  ion** :  $\text{H}^+$  ion accepts a pair of electrons from nitrogen of  $\text{NH}_3$  and forms  $\text{NH}_4^+$  ion.



#### Limitations of Lewis theory :

36. One of the serious defects in the theory is that it cannot explain the strengths of acids and bases.
37. Acids like  $\text{HCl}$ ,  $\text{H}_2\text{SO}_4$  react with bases such as  $\text{NaOH}$  or  $\text{KOH}$  but do not form coordinate covalent bond.
38. The negative logarithm, to the base 10, of the hydrogen ion concentration in a solution is known as the  $\text{pH}$  of the solution.

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39.  $pH = -\log_{10}[H^+]$ ;  $pOH = \log_{10} \frac{1}{[H^+]}$ ; Similarly,  $pOH = -\log_{10}[OH^-]$
40. for a given solution at  $25^\circ C$ ,  $pH + pOH = 14$
41. for acids,  $pH < 7$  and  $pOH > 7$
42. for bases,  $pH > 7$  and  $pOH < 7$
43. for neutral solutions  $pH = pOH = 7$
44. As the pH increases, the acidic nature of a solution decreases and basic nature increases, as temperature increases, pH of water decreases, although it is neutral.
45. **Buffer Solution:** The solution which can resist change in its  $pH$  value on dilution or on addition of small amount of strong acid or strong base. Is known as buffer solution.
46. **Types of Buffer solution:** There are two types of buffer solutions.  
 1) Acid buffer solution      2) Base buffer solutions
47. **Acid Buffer solution :** An acid buffer consists of a weak acid and its salt with a strong base  
 Ex:  $CH_3COOH + CH_3COONa$
48. **Base buffer solution :** A basic buffer consists of a mixture of a weak base and its salt with a strong acid  
 Ex:  $NH_4OH + NH_4Cl$
49. **Henderson's equation:** The pH of a buffer solution can be calculated using Henderson's equation. For an acidic buffer, the weak acid  $HA$  and its conjugate base  $A^-$  in the form of salt are present in solution.  $HA \rightleftharpoons H^+ + A^-$

The dissociation constant  $K_a$  is given as,

$$K_a = \frac{[H^+][A^-]}{[HA]} \Rightarrow [H^+] = K_a \frac{[HA]}{[A^-]}$$

by taking logarithms and rearranging we get

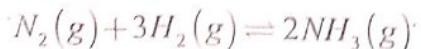
$$-\log H^+ = -\log K_a - \log \left( \frac{[HA]}{[A^-]} \right)$$

since  $pH = -\log H^+$ ,  $pK_a = -\log K_a$  then  $[A^-] = [salt]$

$$pH = pK_a + \log \frac{[A^-]}{[HA]} \quad \text{this is called Henderson's equation.}$$

This is also written for acidic buffer solution as  $pH = pK_a + \log \frac{[Salt]}{[Acid]}$

**50.  $K_c$  and  $K_p$  relation:**



$$K_p = \frac{P^2 NH_3}{P_{N_2} \times P^3 H_2}; K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

But  $PV = nRT$

$$P = \left( \frac{n}{V} \right) RT = CRT$$

Where C = Conc of the gas

$$P_{NH_3} = [NH_3]_{(g)} RT$$

$$P_{N_2} = [N_2] RT$$

$$P_{H_2} = [H_2] RT$$

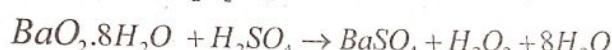
$$K_p = \frac{[NH_3]^2 (RT)^2}{[N_2] RT [H_2]^3 (RT)^3}$$

$$K_p = \frac{[NH_3]^2 (RT)^2}{[N_2][H_2]^3 (RT)^4} = K_c (RT)^{-2} \text{ or } K_p < K_c$$

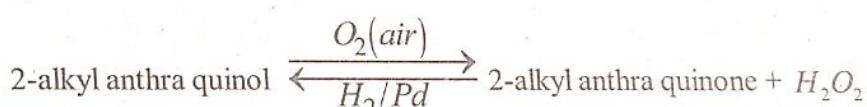
## HYDROGEN & ITS COMPOUNDS

### Hydrogen Peroxide ( $H_2O_2$ ):

01. When barium peroxide solution is treated with dilute  $H_2SO_4$ . Excess water can be evaporated  
Under reduced pressure  $H_2O_2$  is produced

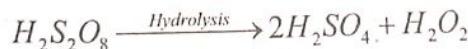
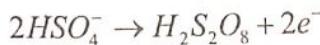
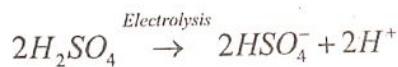


02. From auto Oxidation method :-  $H_2O_2$  is prepared by auto oxidation of 2-alkyl anthraquinol.  
This oxidises in atmospheric air to give 2 alkyl anthraquinone and  $H_2O_2$



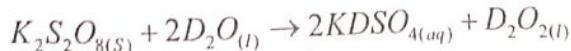
03. From peroxodisulphuric acid :- when 50%  $H_2SO_4$  solution is electrolysed gives peroxodisulphuric acid

This on hydrolysis gives hydrogen peroxide.



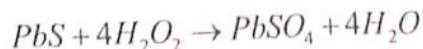
### Preparation of $D_2O_2$ :

$K_2S_2O_8$  is treated with heavy water to prepare  $D_2O_2$ .

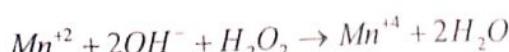


### Oxidising properties ( $H_2O_2$ ):

1.  $H_2O_2$  oxidizes black lead sulphide to white lead sulphate

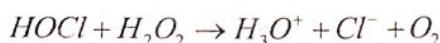


02. In alkaline medium  $H_2O_2$  oxidises the  $Mn^{+2}$  to  $Mn^{+4}$



**Reducing properties ( $H_2O_2$ ):**

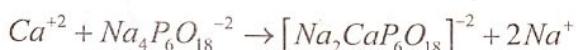
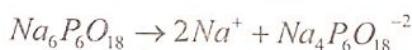
01. Hypochlorous acid is reduced to  $Cl^-$  ion



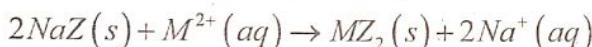
02. In presence of base  $I_2$  is reduced to iodide ( $I^-$ ) ion

**Removal of hardness:****I. Calgon method :**

1. Sodium hexametaphosphate ( $Na_6P_6O_{18}$ ) is known as calgon.
2. When hardwater is passed over calgon calcium and magnesium cations are removed as follows. So hardwater is changed to soft water

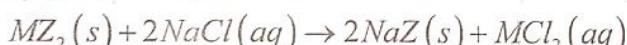
**II. Ion Exchange Method :**

This method is also called zeolite / permutit process. Hydrated sodium aluminium silicate is zeolite / permutit. For the sake of simplicity, Sodium aluminium Silicate ( $NaAlSiO_4$ ) can be written as  $NaZ$ . When this is added in hard water, exchange reactions take place.



$$(M = Mg, Ca)$$

Permutit / zeolite is said to be exhausted when all the sodium in it is used up. It is regenerated for further use by treating with an aqueous sodium chloride solution.

**Uses of Hydrogen as a fuel:**

1. Hydrogen releases large quantity of heat energy on combustion comparing to any other fuels like methane, L.P.G etc.
2. Pollutants in combustion of hydrogen will be less than petrol. the only pollutants will be the oxides of Nitrogen but this can be minimised by injecting small amount of water into the hydrogen cylinder.
3. Atomic hydrogen and oxy hydrogen torches are used for welding and cutting the metals
4. Hydrogen also used as a rocket fuel
5. Hydrogen also used in fuel cells for generating electrical energy

**Uses of  $D_2O$** 

6. 1) It is used as a moderator in nuclear reactor  
2) It is used in exchange reaction for the study of reaction mechanism.

**Hydrides of Hydrogen :**

Dihydrogen, under certain reation conditons, combines with almost all elements, except noble gases, to form binary compounds, called hydrides. If 'E' is the symbol of an element then hydride can be expressed as  $EH_x$  (e.g.  $MgH_2$ ) or  $E_mH_n$  (e.g.  $B_2H_6$ ).

The hydrides are classified into three categories.

- i) Ionic or saline or saltlike hydrides.
- ii) Covalent or molecular hydrides.
- iii) Metallic or non-stiochiometric hydrides.

**Covalent or Molecular Hydride :** Dihydrogen forms molecular compounds with most of the p-block elements. Most familiar examples are  $CH_4$ ,  $NH_3$ ,  $H_2O$  and HF. For convenience hydrogen compounds of non metals have also been considered as hydrides. Being covalent, they are volatile compounds. Molecular hydrides are further classified according to the relative numbers of electrons and bonds in their Lewis structures into.

- i) Electron-deficient, ii) Electron-precise, and iii) Electron-rich hydrides.

An electron - deficient hydride, as the name suggests, has too few electrons for writing its conventional Lewis structure. Diborane ( $B_2H_6$ ) is an example. In fact all elements of group 13 will form electron - deficient compounds. What do you expect from their behaviour? They act as Lewis acids i.e., electron acceptors.

Electron - precise compounds have the required number of electrons to write their conventional Lewis structures. All elements of group 14 form such compounds (e.g.. $CH_6$ ) which are tetrahedral in geometry.

Electron rich hydrides have excess electrons which are present as lone pairs. Elements of group 15-17 form such compounds. ( $NH_3$  has 1-lone pair,  $H_2O$ -2 and HF-3 lone pairs). They will behave as Lewis bases i.e., electron donors. The presence of lone pairs on highly electronegative atoms like N, O and F in hydrides results in hydrogen bond formation between the molecules.

## S-BLOCK ELEMENTS - IA & IIA GROUPS

(Alkali, Alkaline earth metals)

1. **Electronic Configuration of K and Rb**

Potassium ( $Z = 19$ ) -  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Rubidium ( $Z = 37$ ) -  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^1$

2. **Density of Alkali metals**

Potassium (K) Shows abnormal density due to abnormal increase in atomic size of K. The order of density  $Li < K < Na < Rb < Cs$

3. **Alkali metals don't occur in free state**

All alkali metals have one valency electron,  $ns^1$ . The loosely held s-electron in the outermost valency shell of these elements makes them the most electropositive metals. They readily lose electron to give monovalent  $M^+$  ions. So they are not found in free state in nature.

4. **The solvay process can not be extended for the manufacture of  $K_2CO_3$ ,**

The solvay process can not be extended for the manufacture of  $K_2CO_3$  because  $KHCO_3$  is more soluble in water unlike  $NaHCO_3$ . So it can not be isolated.

5. **Uses of NaOH**

It is used in i) the manufacture of soaps, paper, artificial silk and a number of chemicals

ii) in petroleum refining

iii) in the Purification of bauxite

iv) in the textile industries for mercirising cotton fabrics

v) for the preparation of pure fats and oils

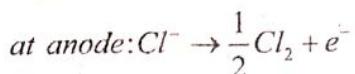
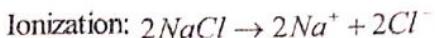
vi) as a laboratory reagent

6. **Castner-Kellner process**

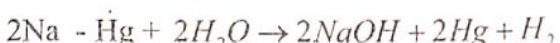
Sodium hydroxide can be prepared by the electrolysis of sodium chloride in Castner-Kellner process. In this process, the brine solution is electrolysed using a carbon anode and a mercury cathode.

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The sodium metal, which is discharged at cathode, combines with mercury to form an amalgam.

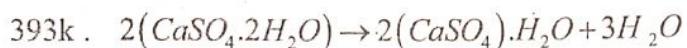


The amalgam is treated with water to give sodium hydroxide and hydrogen gas



### 7. Preparation and uses of Plaster of paris

1) It is a hemihydrate of calcium sulphate. It is obtained when gypsum  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  is heated to



2) Above 393k, it loses water molecules to form anhydrous calcium sulphate ( $\text{CaSO}_4$ ). This is known as "dead burnt plaster".

3) It has a remarkable property of setting with water on mixing with an adequate quantity of water it forms a plastic mass that gets into a hard solid in 5 to 15 minutes.

#### USES:

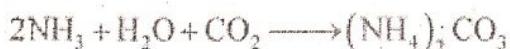
- 1) The largest use of plaster of paris is in the building industry as well as plasters.
- 2) It is used for immobilising the affected part of organ where there is a bone fracture or sprain
- 3) It is also employed in dentistry, in ornamental work and for making casts of statues and busts.

### 8. Solvay process

Solvay process is used to prepare sodium carbonate.

When carbon dioxide gas is bubbled through a brine solution saturated with ammonia, sodium hydrogen carbonate is formed. This sodium bi carbonate is then converted to sodium carbonate.

**Step 1:** Brine solution is saturated with ammonia.



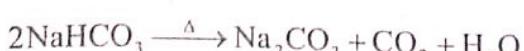
This ammoniated brine is filtered to remove any impurity.

**Step 2:** Carbon dioxide is reacted with this ammoniated brine to result in the formation of insoluble sodium bi carbonate.

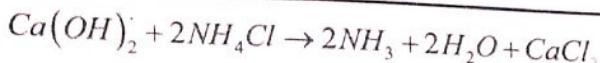


**Step 3:** The solution containing crystals of  $\text{NaHCO}_3$  is filtered to obtain  $\text{NaHCO}_3$ .

**Step 4:**  $\text{NaHCO}_3$  is heated strongly to convert it into  $\text{Na}_2\text{CO}_3$ :



**Step 5:** To recover ammonia, the filtrate (after removing  $\text{NaHCO}_3$ ) is mixed with  $\text{Ca}(\text{OH})_2$  and heated.



The overall reaction taking place in Solvay process is  $2NaCl + CaCO_3 \rightarrow Na_2CO_3 + CaCl_2$

9.

### Importance of sodium, potassium, magnesium, and calcium in biological fluids:

**(i) Sodium (Na):** Sodium ions are found primarily in the blood plasma. They are also found in the interstitial fluids surrounding the cells.

- (a) Sodium ions help in the transmission of nerve signals.
- (b) They help in regulating the flow of water across the cell membranes.
- (c) They also help in transporting sugars and amino acids into the cells.

**(ii) Potassium (K):**

Potassium ions are found in the highest quantity within the cell fluids.

- (a)  $K^+$  ions help in activating many enzymes.
- (b) They also participate in oxidising glucose to produce ATP.
- (c) They also help in transmitting nerve signals.

**(iii) Magnesium (Mg)**

- (a) All enzymes that utilize ATP in phosphate transfer require magnesium as the cofactor.
- (b) The main pigment for the absorption of light in plants is chlorophyll which contains magnesium

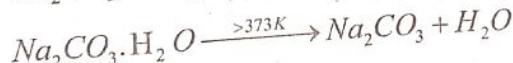
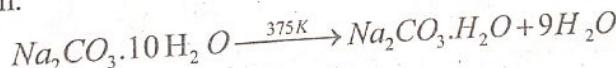
**(IV) Calcium(Ca)**

- (a) about 99% of the body calcium is present in bones and teeth.
- (b) It is also plays important roles in neuromuscular function, interneuronal transmission, cell membrane integrity and blood coagulation.
- (c) The calcium concentration in plasma is regulated at about  $100\text{ mg L}^{-1}$ .
- (d) It is maintained by two hormones: calcitonin and parathyroid hormone.

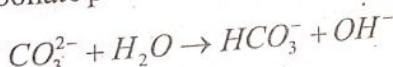
10.

### Properties of Washing soda:

- (a) Sodium carbonate is a white crystalline solid which exists as a decahydrate,  $Na_2CO_3 \cdot 10H_2O$ .
- (b) This is also called washing soda. It is readily soluble in water on heating, the decahydrate loses its water of crystallisation to form monohydrates. Above 373K.
- (c) The mono hydrate becomes completely undhydrous and changes to a white powder called soda ash.



- (d) Carbonate part of  $Na_2CO_3$  gets hydrolysed by  $H_2O$  to form an alkaline solution.



11. **Important uses of Quick lime:**

- (a) It is an important primary material for manufacturing cement and is the cheapest form of alkali.
- (b) It is used in the manufacture of sodium carbonate from caustic soda.
- (c) It is employed in the purification of sugar and in the manufacture of dye stuffs.

12. A suspension of magnesium hydroxide in water (called milk of magnesia) is used as antacid in medicine.

## THE P-BLOCK ELEMENTS – GROUP 13

1. Borax -  $Na_2B_4O_7 \cdot 10H_2O$
2. Colemanite -  $Ca_2B_6O_{11} \cdot 5H_2O$
3. Borazole or Borazine or Inorganic Benzene -  $B_3N_3H_6$
4. Ortho boric acid -  $H_3BO_3$
5. The general electronic configuration of IIIA group elements is  $ns^2np^1$
6. **Inert pair effect:** The reluctance of  $ns^2$  electrons to take part in bond formation is known as inert pair effect.  
Due to inert pair effect  $Tl$  shows stable +1 oxidation state  
Due to inert pair effect  $Pb$  shows stable +2 oxidation state.  
Due to inert pair effect  $Bi$  shows stable +3 oxidation state.
7. The common oxidation number of IIIA group elements is +3. From B to  $Tl$  stability of +3 oxidation number gradually decreases.
8. Compounds in which the central atom does not have eight electrons in the valence shell are called electron deficient molecules. Eg :  $BF_3$ ,  $BCl_3$ ,  $B_2H_6$  etc...
9. **Borax bead test :** On heating, borax first loses water molecules and swells up on further heating it turns into a transparent liquid, which modifies into glass like material known as borax bead.
10. The metaborates of many transition elements have characteristic colours and, therefore, borax bead test can be used to identify them in the laboratory.
11.  $B_2O_3$  reacts with CoO and forms blue coloured meta borate, its formula is  $[Co(BO_2)_2]$
12. Diborane is an electron deficient molecule

### Preparation of Diborane :

13.  $BCl_3$  reacts with  $LiAlH_4$  to form Diborane in presence of diethyl ether
14. Sodium borohydride ( $NaBH_4$ ) reacts with Iodine to form Diborane by the oxidation.
15.  $BF_3$  reacts with  $NaH$  to form Diborane.
16. Diborane reacts with water to give Boric acid.
17. Diborane reacts with carbon monoxide to give Boron carbonyl.
18. Diborane reacts with trimethyl ammine to give Borazine adduct.
19. Diborane reacts with ammonia at  $120^\circ C$ , diammoniate of diborane is formed. This on again heating at  $200^\circ C$  gives borazole
20. Formula of borazine is  $B_3N_3H_6$ .
21. Borazine is also known as Borazole (or) Inorganic benzene
22. In  $B_3N_3H_6$ , each boron undergoes  $sp^2$  hybridization.
23. Borazine on strong heating gives boron nitride  $[(BN)_n]$ .
24. In diborane each boron atom undergoes  $SP^3$  Hybridisation.
25. Diborane contains 4 terminal Hydrogens atom and 2 bridged Hydrogen atoms
26. Boron atoms in diborane bonded to 4 terminal Hydrogens through  $\sigma sp^3 - s$  bonds

27. B-H-B bond is formed by the overlapping of  $sp^3$  hybrid orbital with one electron from one boron atom, 1S orbital of hydrogen atom and vacant  $sp^3$  hybrid orbital of another boron atom
24. Three centred two electron bond is known as banana bond or tau bond.

## THE P-BLOCK ELEMENTS – GROUP 14

- 1) The general outermost shell electronic configuration of the elements of group 14 is  $ns^2np^2$
- 2) **Allotropy** :- The Phenomenon of existence of an element in different physical properties with same chemical properties is called allotropy.  
Ex: Crystalline allotropes of carbon are diamond & graphite.
- 3) **Inert pair effect**: The reluctance (dislike) of 'ns' pair of electrons to take part in bond formation is known as inert pair effect  
Ex:- Pb shows stable +2 oxidation state due to inert pair effect.
- 4) **Catenation**: The Phenomenon of self linkage of identical atoms to form long chains (or) rings is called catenation.  
Ex:- Carbon shows highest catenation property among all elements.
- 5) Silicon can form  $SiF_6^{2-}$  but not  $SiCl_6^{2-}$

**The main reasons are :**

- a) Si $^{+4}$  is smaller in size. Six large chloride ions can not be accommodated around it.
- b) The interaction between lone pair of chloride ion and Si $^{+4}$  is not very strong. Hence  $SiCl_6^{2-}$  does not exists.

- 6) **Crystalline allotropes of carbon**: diamond and graphite
- 7) **Diamond**: a) In diamond each carbon atom undergoes  $sp^3$  hybridisation.  
b) Each carbon is bonded to four other carbon atoms tetrahedrally.  
c) It is a three dimensional polymer.  
d) C – C bond length is  $1.54\text{ \AA}$  and bond angle is  $109^\circ 28'$ .  
e) Carbon atoms are strongly held by covalent bonds. Hence it is harder, abrasive and has high melting point. It is bad conductor of electricity due to absence of free electrons.
- 8) **Diamond is used as precious stone**:  
Diamond has high refractive index value and glitter due to total internal reflection. So, it is used as precious stone.
- 9) **Graphite** :- a) In Graphite each carbon atom undergoes  $sp^2$  hybridisation  
b) Each carbon is bonded to three other carbon atoms to form hexagonal rings.  
c) It is a two dimensional polymer.  
d) C – C bond length is  $1.42\text{ \AA}$  and bond angle is  $120^\circ$ . It is shorter than diamond.  
e) The hexagonal layers of carbons are held by weak Vander Waal's forces  
f) Graphite is soft, slippery, lubricant. Due to Hexagonal layers.  
g) It is good conductor of electricity due to presence of free electrons.
- 10) **Synthesis gas** : The mixture of CO and H<sub>2</sub> is known as water gas or synthesis gas or Blue gas (or) Syn gas. It is obtained passing steam over white hot coke.
- 11) **Producer gas** : The mixture of CO and N<sub>2</sub> is called producer gas. It is obtained by strong heating of cock with air
- 12) **Producer gas is less efficient fuel than water gas**

	Fuel gases	Calorific value	Reason
	a) Producer gas	5439.2 kJm <sup>-3</sup>	Low value due to presence of N <sub>2</sub>
	b) Water gas	13,000 kJm <sup>-3</sup>	High value due to presence of H <sub>2</sub>
13)	<b>Carboxy haemoglobin</b> :	The CO forms a stable complex with haemoglobin called carboxy haemoglobin. It is 300 times stable than oxy haemoglobin So it is highly poisonous.	

**JR CHEMISTRY**

- 14)  $\text{CO}_2$  exists as gas:**  
 a.  $\text{CO}_2$  has linear structure and discrete in nature.  
 b. In between  $\text{CO}_2$  molecules weak vander waal's forces are present. Hence  $\text{CO}_2$  exists as a gas.
- 15) Solid  $\text{CO}_2$  is called "Dry ice".**  
**Uses:** a) It is used as a refrigerant for ice-cream and frozen food.  
 b) It is used as fire extinguisher and also used in the manufacture of Urea.
- 16)  $\text{SiO}_2$  exist as solid :**  
 a. Each silicon is tetrahedral bonded to four oxygen atoms by single covalent bonds resulting in a giant three dimensional polymeric network structure. It is non polar it does not dissolve in water.  
 b. Hence it exists as solid compound.
- 17) On heating silicon dioxide with hydrogen fluoride gives silicon tetrafluoride. With excess of hydrogen fluoride gives hydro fluoro silicic acid.**
- 18) Reaction with  $\text{NaOH}$  :- Silicon reacts with sodium hydroxide to form sodium silicate**
- 19) Silicones : Silicones are organosilicon polymers containing  $\text{Si}-\text{O}-\text{Si}$  linkage. Silicones contain  $\text{R}_2\text{SiO}$  repeating unit. The unit  $\text{R}_2\text{SiO}$  has a structure, similar to that of ketones.**
- 20) Preparation :-** Silicones are prepared from hydrolysis of dimethyl dichlorosilane,  $(\text{CH}_3)_2\text{SiCl}_2$  followed by condensation polymerisation yields straight chain polymers.
- $$2\text{CH}_3\text{Cl} + \text{Si} \xrightarrow[570k]{\text{Cu powder}} (\text{CH}_3)_2\text{SiCl}_2 \xrightarrow[-2\text{HCl}]{+2\text{H}_2\text{O}} (\text{CH}_3)_2\text{Si(OH)}_2$$
- 21) Silicones are organo-silicon compounds in which silicon strongly linked to oxygen and carbon**
- 22) Uses of Silicones :**  
 a) Used in silicone rubber preparation  
 b) Used in the preparation of water proof clothes or papers  
 c) Used to prepare sealant, grease, lubricants in aero planes.  
 d) In electrical motors and tools silicones are used as electrical insulators  
 e) Used in paints and enamels  
 f) Since these are biocompatible, they are used in surgical and cosmetic implants
- 23) Silicates:**  
 a) The basic structural unit of silicates is  $\text{SiO}_4^{4-}$  in which silicon atoms is bonded to four oxygen atoms in a tetrahedron fashion.  
 b) When silicate units are linked together, they form chain, ring, sheet or three-dimensional structures.  
 c) A large number of silicate minerals exist in nature. ex: Mica and asbestos.  
 d) Glass and cement are two man made important silicates
- 24) Zeolites:** a) Zeolites are alumino silicates.  
 b) If aluminium atoms replaces few silicon atoms in three dimensional network of  $\text{SiO}_4$ , overall structure is known as aluminosilicate.  
 c) Generally zeolites having cage like structures with cavities.
- Uses of Zeolites:**  
 a) Zeolites acts as ion exchangers & molecular sieves  
 b) Used in softening of hard water.  
 c) ZSM – 5 Zeolite is used to convert alcohols directly into gasoline

**ENVIRONMENTAL CHEMISTRY**

(1m = 2mx2)

- 1. Pollutant:** The substance which is present in nature and causes the pollution is called as pollutant.
- 2. Contaminant:** The substance does not occur in nature but releases due to human activity and causes the pollution is known as contaminant
- 3. COD :** The amount of oxygen required to oxidise organic substances present in polluted water is

called as chemical oxygen demand.

**BOD :** The amount of oxygen used by the suitable micro-organisms present in water during five days at  $20^{\circ}\text{C}$  is called biochemical oxygen demand.

5. The BOD value for clean water is about 1 ppm.

6. The BOD value for municipal sewage water is about 100 - 4000 ppm

7. The BOD value for polluted water is 17 ppm.

8. **Sink:** The medium which reacts with pollutant is called the sink.

Ex: Oceans are important sinks for atmospheric  $\text{CO}_2$

9. **TLV (Threshold Limit Value):** The permissible level of the toxic substances (or) pollutants in the atmosphere, which affects a person adversely when he is exposed to this for 7 - 8 hrs. in a day is called TLV.

10. **Receptors :** The medium which is effected by a pollutant is called Receptor.

Eg: eye irritation caused by smoke.

11. **Speciation:** The detection of different chemical forms of inorganic, organic compounds present in the Environment causing pollution is known as speciation

12. **Green house effect or Global warming:** The process of increasing of temperature of surface of earth is called green house effect or global warming .

13. Green house effect is caused by  $\text{CO}_2$ , ozone, chlorofluoro carbons and water vapour when present in troposphere.

14. **Effects of green house effect are:**

- (i) It lead to melting of polar ice caps and flooding of low lying areas.
- (ii) Increase in the global temperature, increases the infectious diseases like dengue, malaria, yellow fever etc...

15. **Acid rains :** Sulphur dioxide and nitrogen dioxide after oxidation and reaction with water forms oxoacids of S, N which causes acid rains. The  $\text{pH}$  of acid rain water is less than 5.6

16. **Effects of acid rains are :**

- (i) It washes away nutrients needed for the growth of plants.
- (ii) It causes respiratory ailments in human beings and animals.
- (iii) It corrodes water pipes resulting in leaching of heavy metals like iron.
- (iv) It damages the life of buildings

17. Classical smog is a mixture of smoke, fog and sulphur dioxide.

18. Ozone, nitric oxide, acrolein, formaldehyde and peroxyacetyl nitrate are the common components of photochemical smog.

19. **Effects of photochemical smog :**

- (i) It causes serious health problems
- (ii) It also causes corrosion of metals, stones and building materials.

20. PAN is peroxyacetyl nitrate. It acts as powerful eye irritant.

21. **Ozone hole :** Depletion of ozone layer commonly known as ozone hole.

22. The depletion of ozone layer causes skin cancer, cataract, damage to fish production.

23. Sodium chlorate, Sodium arsinate, Aldrin, Dieldrin, etc. are responsible for water pollution.

24. **Eutrophication :-** Some times the water becomes over nutritious when organic substances from agriculture and industry are thrown into the water resources like ponds and lakes. Due to this, excess growth of algae occurs which leads to drying of lake. This phenomenon is commonly known as eutrophication.

### 13. ORGANIC CHEMISTRY

01. The valency of carbon in organic compounds is four
02. The carbon atom with  $sp$  hybridization is more electronegative
03. The organic compounds in which carbon forms a multiple bond (double (or) triple bonds) are called **unsaturated compounds**
04. Functional group of alcohol is  $-OH$  and its secondary suffix is *ol*
05. Functional group of aldehydes is  $-CHO$  and its secondary suffix is *al*

06. Functional group of ketone is  $\left(-C=O\right)$  and its secondary suffix is **one**

07. Functional group of cyanides is  $-CN$  and its secondary suffix is **nitrile**
08. Functional group of ether is  $R-O-R$
09. Functional group of carboxylic acid is  $-COOH$  and secondary suffix is **oic acid**
10. Functional group of ester is  $-COOR$  and secondary suffix is **oate**

11. Functional group of acid halide is  $\left(-C=O-X\right)$  and secondary suffix is **oylhalide**

12. The functional group of amines is  $(-NH_2)$  and secondary suffix is **amine**

13. The functional group of amides is  $\left(-C=O-NH_2\right)$  and secondary suffix is **Amide**

14. The order of stability of carbocations is  $(CH_3^+ < 1^\circ < 2^\circ < 3^\circ)$
15. Carbocations are **Trigonal planar** shaped and  $(sp^2)$  hybridized.
16. Heterolytic cleavage leads to the formation of **carbocation** and **carbanion**
17. The phenomenon of existence of two or more compounds possessing the same molecular formula but different properties is known as **isomerism**.
18. The phenomenon of existence of two or more compounds possessing the same molecular formula but

different in the nature of alkyl groups which are attached to the main functional group is called **metamerism**.

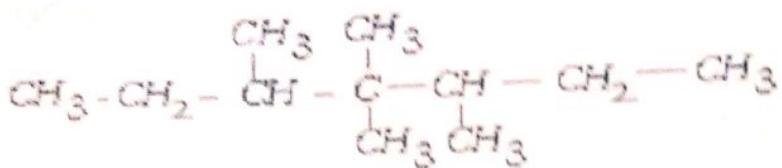
19. The reagent with an electron pair is **nucleophile**
20. The reagent which is electron seeking is called **electrophile**
21. The polarization of  $\sigma$  bond caused by the polarization of the adjacent  $\sigma$  bond is referred as **inductive effect**
22. The polarity produced in the molecule by the interaction of two  $\pi$  – bonds or between a  $\pi$  – bond and lone pair of electrons present on an adjacent atom is **resonance effect**
23. The transfer of shared pair of  $\pi$  electrons to one of the atoms joined by a multiple bond in presence of attacking reagent is **Electromeric effect**
24. The delocalization of  $\sigma$  electrons of C – H bond of an alkyl group directly attached to an atom of unsaturated system is **hyper conjugation**
25. The organic reactions in which reagent and substrate combined together to give a simple product are **addition reactions**
26. The organic reactions in which an atom or group of substrate species is replaced by another atom or group are called **substitution reactions**
27. The reactions in which two or more atoms or groups of an organic substrate are removed to form multiple bonds are called **elimination reactions**
28. The organic reactions involving rearrangement of less stable species to more stable species are called **rearrangement reactions**
29. The method used to separate volatile liquids from non-volatile impurities is called **distillation**
30. The liquids which differ in their boiling points are separated by **distillation**
31. Nitrogen, sulphur, halogens, phosphorus present in organic compounds are detected by **Lassaigne's test**
32. Ionic form of sodium nitro prusside is  $\left[ Fe(CN)_5 NO \right]^{2-}$
33. The organic compound with nitrogen and sulphur on reaction with sodium metal form **NaSCN**- Sodium thiocyanate

**IUPAC :**

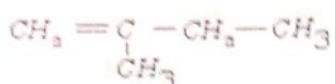
⊗ The IUPAC name of  $CH_3 - CH_2 - CH_2 - CH = CH_2$  is 1 - pentene

⊗ The IUPAC name of  $CH_3 - \overset{O}{\underset{\parallel}{C}} - CH_3$  is propanone

⊗ Structure of 3,4,4,5 tetramethyle heptane is



⊗ Structure of 2-methyl 1-butene



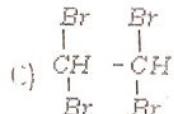
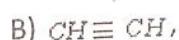
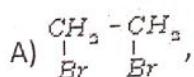
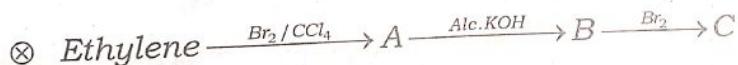
## ALKANES

34. The general formula of alkanes is  $\text{C}_n\text{H}_{2n+2}$
35. Carbon atom attached to one other carbon atom in methane is called **primary carbon ( $1^\circ$ ) atom**
36. Carbon atom attached to two carbon atoms is known as **secondary carbon ( $2^\circ$ ) atom**
37. Carbon atom is attached to three carbon atoms is known as **tertiary carbon ( $3^\circ$ ) atom**
38. Carbon atom is attached to four carbon atoms is known as **neo (or) quarternary carbon atom**
39. In alkanes, the C- C bond length and C- H bond lengths are **154 pm & 112 pm**
40. Sodalime is a mixture of  $(\text{NaOH} + \text{CaO})$
41.  $\text{CH}_3 - \text{CH}_2 - \text{COONa}$  (Sodium propionate) on decarboxylation gives  $\text{C}_2\text{H}_6$  - **ethane**
42. Alkyl halides give alkanes on reduction with **Zn and Dil HCl**
43. The reaction of alkylhalides with sodium metal in dry ether to give higher alkane is called as **wurtz reaction**
44. In the preparation of ethane by Wurtz reaction the reactants and reagents are  $\text{CH}_3\text{I}$  and **Na / dry ether** respectively
45. Nitro ethane ( $\text{C}_2\text{H}_5\text{NO}_2$ ), is the product obtained when  $\text{C}_2\text{H}_6$  reacts with  $(\text{HNO}_3)$  at   
  $400-450^\circ\text{C}$ .
46. Decomposition of higher alkanes to lower alkanes and alkenes due to strong heating in absence of air is called **Pyrolysis**
47. Methane on reaction with steam in the presence of nickel as a catalyst gives **CO and  $\text{H}_2$**
48. Conditions in aromatization are **773K, 10-20 atm,  $\text{Cr}_2\text{O}_3, \text{V}_2\text{O}_5, \text{Mo}_2\text{O}_3$  catalyst**

## ALKENES

49. The general formula of alkenes is  $\text{C}_n\text{H}_{2n}$

50. The bond length of  $C = C$  is 134 pm
51. The bond enthalpy of  $C = C$  is 384 KJ/mole
52. Straight chain alkenes have higher boiling point than isomeric branched chain compounds
53. Hybridisation of unsaturated carbon in alkenes is  $sp^2$
54. Name of  $CH_2 = CH - Cl$  is Vinyl chloride (or) Chloro ethene
55. The dipole moment of cis 2- butene is 0.33 debye
56. The dipole moment of trans 2- butene is zero
57. Reagent and temperature to convert ethyl alcohol into ethylene are conc.  $H_2SO_4$  at  $170^\circ C$  or anhydrous  $Al_2O_3$  at  $350^\circ C$
58. Reagent for dehydro halogenation is alcoholic KOH
59. Dehydro halogenation of ethyl bromide with alc. KOH gives ethylene
60. Reagent for dehalogenation is Zn dust in alcohol
61. Dehalogenation of 1, 2 – dibromo ethane with Zn in alcohol gives ethylene
62. Palladised charcoal and  $BaSO_4$  in quinoline is called Lindlar's catalyst.
63. Trans alkene is formed, when alkynes reacts with  $H_2$  in presence of Na / liq.  $NH_3$
64. Cis alkene is formed, when alkynes reacts with  $H_2$  in presence of Pd- $BaSO_4$ /Quinoline
65. Ethylene on ozonolysis and reduction with Zn gives formaldehyde.
66. In Vicinal dihalides, halogens are attached to adjacent carbons
67. In Gem dihalides, halogens are attached to same carbons
68. According to Markowni Koff's rule, propene reacts with HBr and gives 2-bromopropane as major product
69. According to anti Markowni Koff's rule, propene reacts with HBr and gives 1-bromopropane as major product
70. Propene on reductive Ozonolysis gives ethanal and methanal



### ALKYNES

71. Calcium carbide ( $CaC_2$ ) on hydrolysis gives  $C_2H_2$  Acetylene (or) ethyne
72. Complete dehydro halogenation of 1, 2 – dibromo ethane in the presence of alc KOH gives Acetylene
73. 1, 1, 2, 2 tetra bromo ethane ( $CHBr_2 - CHBr_2$ ) on heating with Zn dust gives Acetylene
74. Acetylene undergo addition with 2 molecules of  $Cl_2$  gives 1, 1 – 2, 2 - tetrachloroethane (or)  $CHCl_2 - CHCl_2$  as final product
75. Reagent used to convert Acetylene into acetaldehyde is 1%  $HgSO_4 + 30\% H_2SO_4$ ,  $60^\circ C$  &  $H_2O$

76. Acetylene reacts with molten Sodium metal in NH<sub>3</sub> gives **mono sodium acetylidyde** and **disodium acetylidyde**
77. In the presence of Red hot Cu tube, three acetylene molecules get polymerized to give **Benzene**
- BENZENE**
78. The molecular formula of Benzene is C<sub>6</sub>H<sub>6</sub>
79. The hybridization of carbon in Benzene is sp<sup>2</sup>
80. The distillation of Sodium Benzoate (C<sub>6</sub>H<sub>5</sub>COONa) with Soda lime (NaOH + CaO) gives C<sub>6</sub>H<sub>6</sub>
81. The reduction of Phenol (C<sub>6</sub>H<sub>5</sub>OH) in the presence of Zn-dust gives C<sub>6</sub>H<sub>6</sub>
82. Three molecules of acetylene (C<sub>2</sub>H<sub>2</sub>) undergo polymerization in the presence of Red-hot iron/copper tubes gives C<sub>6</sub>H<sub>6</sub>
83. Benzene undergoes **electrophilic substitution** reactions readily.
84. Under UV light, three chlorine molecules add to benzene to produce benzenehexachloride(BHC) or gamaxine
- $$\text{C}_6\text{H}_6 + 3\text{Cl}_2 \xrightarrow[500\text{K}]{\text{UV}} \text{C}_6\text{H}_6\text{Cl}_6$$
85. Hydrolysis of Benzene sulphonic acid (C<sub>6</sub>H<sub>5</sub>SO<sub>3</sub>H) gives C<sub>6</sub>H<sub>6</sub>
86. Mixture of Conc. HNO<sub>3</sub> and Conc. H<sub>2</sub>SO<sub>4</sub> is called **nitration mixture**
87. Benzene undergoes nitration in the presence of nitration mixture (conc. HNO<sub>3</sub> + conc. H<sub>2</sub>SO<sub>4</sub>) below 60°C gives **nitrobenzene**
88. Benzene undergoes sulphonation in the presence of fuming sulphuric acid gives **Benzene sulphonic acid**
89. Benzene reacts with alkyl halide in the presence of anhydrous AlX<sub>3</sub> (or) FeX<sub>3</sub> and gives **alkyl benzene** and it is called **Friedel-Craft's alkylation**
90. Catalytic hydrogenation of Benzene (Nickel catalyst) gives **cyclohexane** (C<sub>6</sub>H<sub>12</sub>)
91. Benzene undergoes addition with chlorine in the presence of sun light gives **hexachloro cyclo hexane (or) benzene hexa chloride (or) Gammaxane (or) Lindane (or) C<sub>6</sub>H<sub>6</sub>Cl<sub>6</sub>**
92. Benzene reacts with 3 moles of Ozone and form **Benzene triozonide** which undergo decomposition in the presence of Zn/H<sub>2</sub>O and gives **Glyoxal**
93. In the nitration, the electrophile is **Nitronium ion – NO<sub>2</sub><sup>+</sup>**
94. The groups which direct the incoming group to ortho and para positions are called **ortho and para directing groups**.
95. The groups which direct the incoming group to meta position are called **meta directing groups**.
96.  $\text{CaC}_2 \xrightarrow{\text{H}_2\text{O}} \text{A} \xrightarrow{\text{hot metal tube}} \text{B} \xrightarrow{\text{AlCl}_3 + \text{CH}_3\text{Cl}} \text{C}$

$$A = \text{C}_2\text{H}_2, B = \text{C}_6\text{H}_6, C = \text{C}_6\text{H}_5\text{CH}_3$$



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