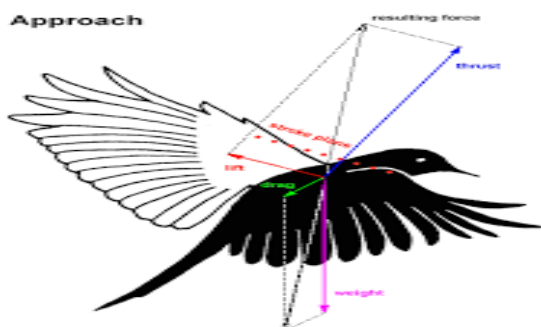


15SC03S - APPLIED SCIENCE



UNIT I: MECHANICS

Approach



UNIT-II: PROPERTIES OF SOLIDS AND LIQUIDS

State	Solid	Liquid	Gas
Diagram			
Arrangement of particles	Regular arrangement	Randomly arranged	Randomly arranged
Movement of particles	Vibrate about a fixed position	Move around each other	Move quickly in all directions
Closeness of particles	Very close	Close	Far apart

UNIT III: HEAT AND PROPERTIES OF GASES.

HEAT & TEMPERATURE

Note: This is only Basic Information for students. Please refer “Reference Books” prescribed as per syllabus

UNIT IV: WAVE MOTION**UNIT V: MODERN PHYSICS****UNIT VI: INDUSTRIAL CHEMISTRY**

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

UNIT I: MECHANICS

UNITS AND MEASUREMENTS

Physical quantities

All quantities that can be measured are called physical quantities.

Example: - time, length, mass, force, work, pressure etc.

Unit

The standard of reference used for the measurement of a physical quantity is called unit. For example when we say that the length of a rod is 2 meter, we compare the length of the rod with a standard quantity of length called meter. Hence meter is unit of length.

There are some basic properties of units

1. They must be well defined.
2. They should be easily available and reproducible.
3. They should be accepted to all.
4. They should be invariable.
5. Should be large, if the physical quantity to be measured is a big quantity.

Types of physical Quantities:

The physical quantities can broadly divided in to two types

- i) Fundamental Physical quantities
- ii) Derived physical quantities

Fundamental physical quantities:

A physical quantity which can exist independently is called Fundamental physical quantity.

Example: Length, mass and time etc.

Derived physical quantities:

A physical quantity which cannot exist independently is called derived physical quantity. (Or) A physical quantity which is dependent or derived from any other physical quantity is called derived physical quantity.

Example: Area, volume, density, speed, acceleration, force, energy etc.

Like the physical quantities we can divide the units in to two types.

- a) Fundamental units
- b) Derived units.

a) Fundamental units :

The units of fundamental physical quantities are called fundamental units, (or) the units which are independent or cannot derived from any other unit is called fundamental unit.

Note: This is only Basic Information for students. Please refer “Reference Books” prescribed as per syllabus

Example: -

Every unit of length is fundamental unit (irrespective of the system to which it belongs); millimetre, centimetre, meter, kilometre etc.

Every unit of time is a fundamental unit. Microseconds, millisecond, second, minute, hour, day etc. are units of time. All these units are fundamental units.

b) Derived units:

The units of derived physical quantities are called derived units. Units of area, volume, speed, density, energy etc. are derived units.

Example: -

Every unit of speed is a derived unit; m/sec, cm/sec, km/hr. etc.

Every unit of density is a derived unit; kg/m³, gm/cm³ etc.

Every unit of acceleration is a derived unit; m/sec², cm/sec², km/hr² etc.

Old systems of fundamental units

Different units were assigned for length, mass and time in different countries

System of Units:

To measure the fundamental physical quantities Length, Mass and Time we have three systems of units, they are

- i) C.G.S system.(Metric system)(centimetre, gram, second)
- ii) F.P.S system.(British system) (foot , pound, second) and
- iii) M.K.S system.(meter, kilogram, second)

In all these three systems only three physical quantities mass, length and time are considered to be fundamental quantities.

S I UNITS

The SI units (System of International) have been accepted by all the countries for scientific work. In this system seven basic quantities

Example: mass, length, time, electric current, temperature, luminous intensity and quantity of matter have been assigned standard units.

The units of all other physical quantities in science and engineering can be derived from the units of these seven fundamental quantities. In addition to these, two more supplementary units of *plane angle* and *solid angle* have been introduced in this system.

Basic Units

Quantity	Unit Name	Unit Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric Current	Ampere	A
Temperature	Degree Kelvin	°K
Luminous Intensity	Candela	cd
Quantity of Matter	Mole	mol

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Supplementary Units

Quantity	Unit Name	Unit Symbol
Plane Angle	Radian	rad
Solid Angle	Steradian	sr

Advantages of SI units:

The SI system has a number of remarkable advantages compare to other systems.

1. Decimal system: Like C.G.S and M.K.S system, SI is also a decimal system. This makes the calculation work a simple.

2. Rational system: It is a rational system of units i) It uses one unit for one physical quantity for example all types of energies (mechanical energy, heat energy, electrical energy) are measured in joules.

3. Coherent system of units: All the derived SI units can be obtained by dividing and multiplying the basic S I units. Example the unit of force is obtained when unit of mass is multiplied by unit of acceleration.

4. Comprehensive system: it has seven fundamental and two supplementary units which covers all the physical quantities in science and engineering.

MEASURING INSTRUMENTS

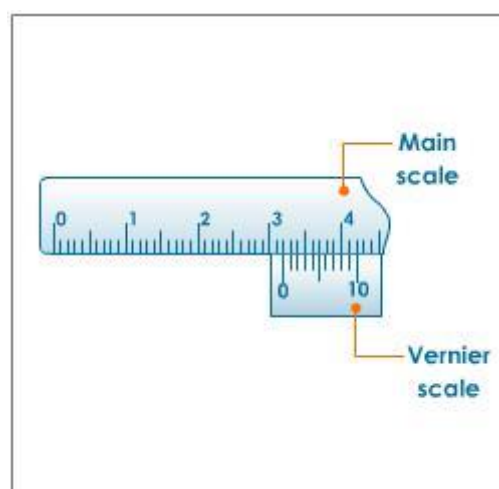
Measurement is the comparison of a quantity with a standard of the same physical quantity. The measurement of any quantity depends upon two principal factors:-

1. The magnitude of the physical quantity to be measured
2. The accuracy required in the measurement.

We have different measuring instruments for measuring length in laboratory, with varied degree of accuracy, by using a meter scale we can measure length correct to a millimetre. To achieve higher degree of accuracy in measurement, we use vernier callipers, screw gauge suiting the requirements.

Vernier calliperPrinciple of the Vernier:

Vernier is a secondary scale which slides along the main scale. It is used for measuring length accurately to any desired fraction of the smallest division on the main scale. In a forward reading vernier the graduations are marked in the same direction as that of the main scale. This vernier scale has a certain small standard length; this length is divided into a number of equal parts. The number of divisions on the vernier scale is one more than the number of divisions, in the same length on the main scale.



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Least Count (L.C)

The difference between 1 msd and 1 vsd is the smallest distance that can be measured with the help of vernier, it is called least count (L.C)

$$L.C = 1 \text{ MSD} - 1 \text{ VSD}$$

Suppose the length of vernier is $(n-1)\text{MSD}$ and is divided into $(n)\text{VSD}$

$$(n-1)\text{MSD} = (n)\text{VSD}$$

$$\text{Therefore } 1\text{VSD} = (n-1)/n \text{ MSD}$$

$$\text{Least count (L.C)} = 1 \text{ MSD} - 1\text{VSD}$$

$$\text{Least count (L.C)} = 1 \text{ MSD} - (n-1)/n \text{ MSD}$$

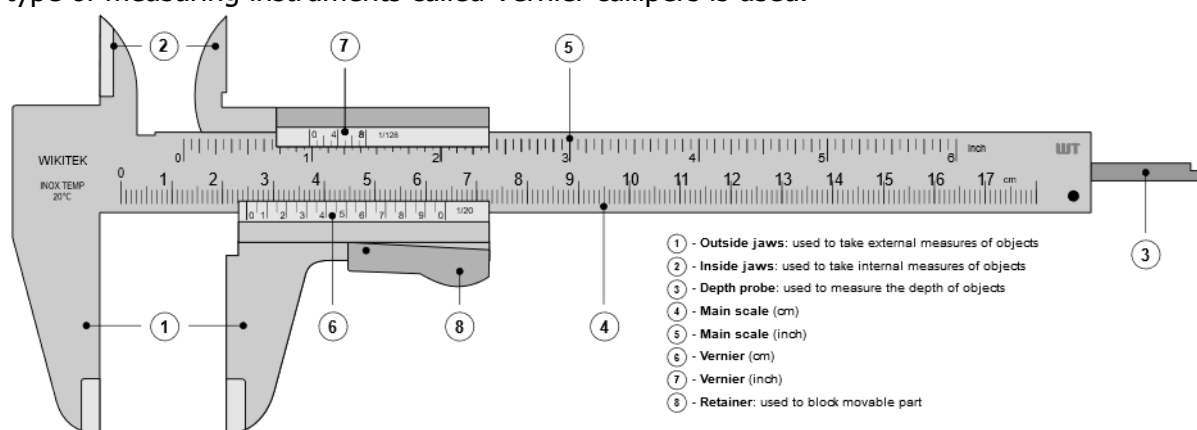
$$\text{L.C} = (1/n) \text{ MSD}$$

Thus least count is given as

$$\text{L.C} = \text{Value of one MSD/ Number of division on vernier}$$

Diagram of vernier callipers with labelling the parts

The meter scale enables us to measure the length to the nearest millimetre only. Engineers and scientists need to measure much smaller distances accurately. For this a special type of measuring instruments called Vernier callipers is used.



The Vernier calliper consists of a main scale graduated in centimetres and millimetres. On the Vernier scale 0.9 cm is divided into ten equal parts. The least count or the smallest reading which you can get with the instrument can be calculated as under:

$$\text{Least count} = \text{one main scale (MS) division} - \text{one vernier scale (VS) division.}$$

$$= 1 \text{ mm} - 0.09 \text{ mm}$$

$$= 0.1 \text{ mm}$$

$$= 0.01 \text{ cm}$$

The least count of the vernier

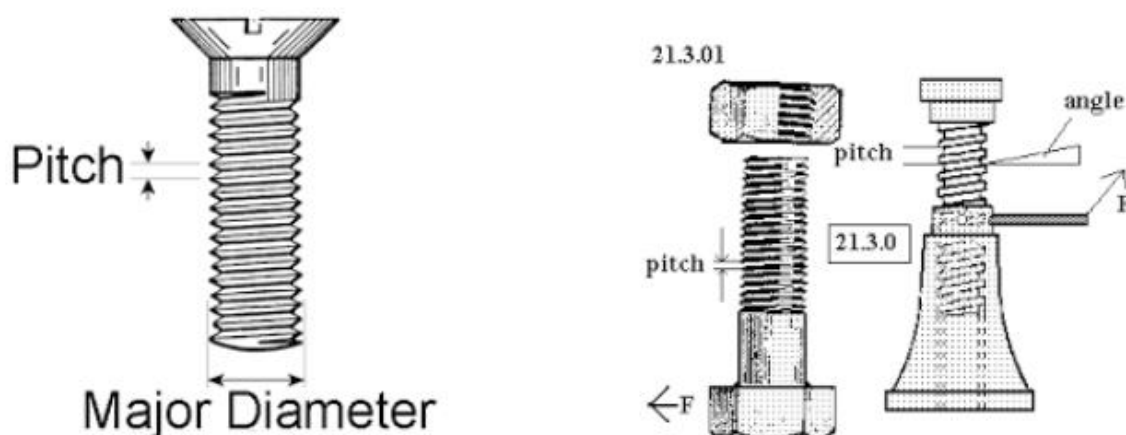
$$= 0.01 \text{ cm}$$

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Screw Gauge or the Micrometre

Principle of Screw gauge:

It works on the principle of a screw and nut. When a screw head is rotated the tip of the screw moves forward or backward through a small distance. This distance is the same for every complete rotation.



In a uniformly cut screw the distance between two consecutive threads is constant and it is called Pitch of the screw. When a screw working in a fixed nut is given full turns, it moves forward or backward through a distance equal to pitch.

If P is pitch of screw and head of the screw is divided into n equal parts. If screw is rotated through one such division then:

$$\text{Distance moved for one division rotation} = \frac{\frac{p}{n}}{\text{Pitch}}$$

Hence, Least count L.C = $\frac{\text{Pitch}}{\text{Number of divisions on head}}$

Errors in Micrometre

No zero error:

When the anvil and spindle end are brought in contact, the edge of the circular scale should be at the zero of the sleeve (linear scale) and the zero of the circular scale should be opposite to the datum line of the sleeve no zero error.

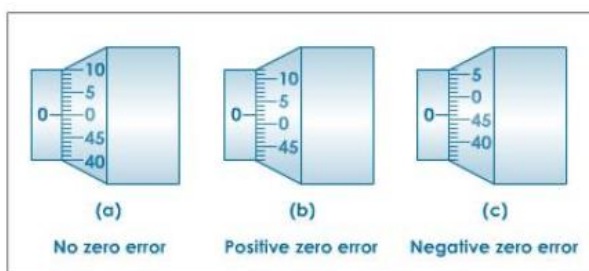
Positive zero error:

If the zero is not coinciding with the datum line and below the line then the error is positive as shown in figure below $ZE = + 2 \times LC$ and $ZC = - (+ 2 \times LC)$

Negative zero error:

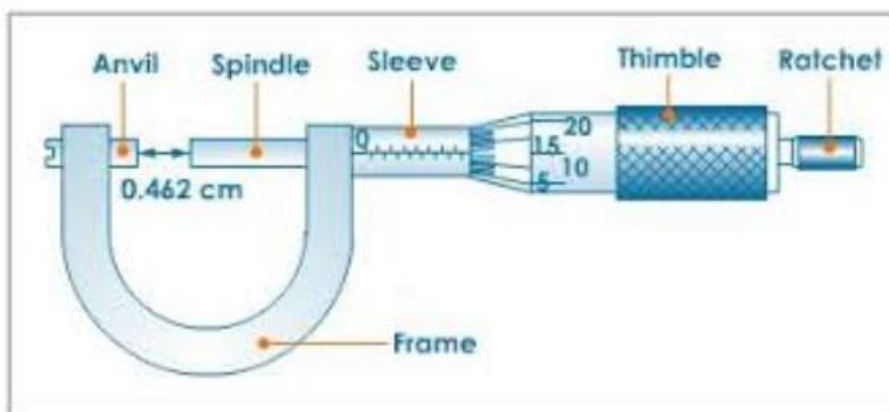
if the zero is not coinciding with the datum line and above the line then the error is negative as shown in figure below $ZE = - 4 \times LC$ and $ZC = - (- 4 \times LC)$

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Screw gauge with labelling the parts:

A micrometre is a precision instrument. It is used for measuring diameter of circular objects mostly wires, with an accuracy of 0.001cm. It consists of a hollow cylinder mounted on a U frame. The hollow cylinder leads to a ratchet which is meant for fine adjustment. The U frame consists of a flat end known as stud and a screw on the other side. This screw can be moved inside the nut by fitted in the U frame by rotating the hollow cylinder called the thimble. This is called the main scale. The hollow cylinder or the thimble is graduated into 50 or 100 equal parts. This is called the circular scale.



Simple problems

1. Calculate the L.C of the in a vernier callipers whose main scale is divided into 1/2mm and 49MSD are divided into 50VSD

Solution: The least count of the vernier callipers

$$= \frac{\text{Value of the smallest division on main scale}}{\text{Total divisions on vernier scale}}$$

$$= \frac{1/2}{50} = \frac{0.5}{50}$$

$$= 0.01 \text{ mm}$$

2. Calculate the L.C of the screw gauge whose pitch is 1/2mm and head scale divided into 100 equal parts.

Solution: The least count of the screw gauge

$$= \frac{\text{Pitch}}{\text{Number of divisions on circular scale}}$$

$$= \frac{1/2}{100} = \frac{0.5}{100}$$

$$= 0.005 \text{ mm}$$

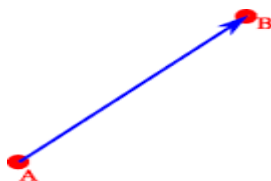
SCALAR AND VECTORS

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

Scalar quantity: Is a quantity which has only magnitude but no direction.

Vector quantity: Is a quantity which has both magnitude and direction.

Graphical representation:



A vector quantity can be represented by a straight line, with an arrow head such that the length of the straight line on a suitable scale represents the magnitude and arrow head, the direction.

Resultant:

"Resultant is a force which produces the same effect as the combined effect of two or more forces acting on a body simultaneously"

Equilibrium:

"Forces acting on a body are said to be in equilibrium if the body remains at rest".

Equilibrant:

"An equilibrant is a force applied on a body which is acted upon by a number of forces to keep it in equilibrium".

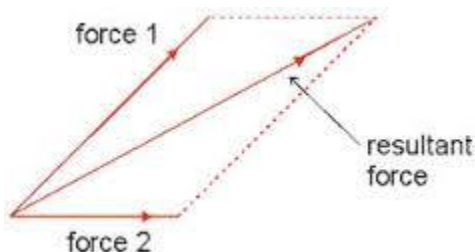
Note: Resultant and equilibrant are equal in magnitude but opposite in direction.

Laws of forces

(i) Parallelogram law of forces:

This is used to find the resultant of two forces acting at a point. It is stated as,

"If two forces acting simultaneously at a point are represented vectorially by the adjacent sides of parallelogram, then the diagonal of the parallelogram through that point represents the resultant of the two forces vectorially"

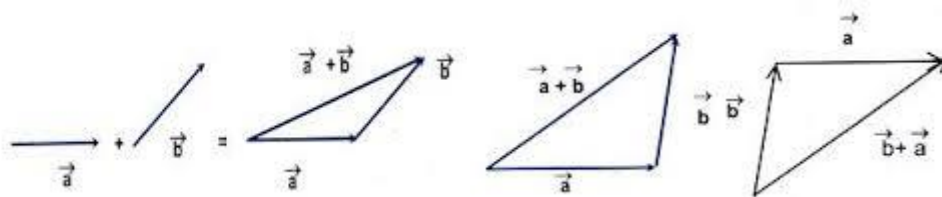


(ii) Triangle law of forces:

This is used to find the resultant of two forces acting at a point. It states that, "If two forces acting simultaneously at a point are represented vectorially by two sides of a triangle in order, then the third side in the reverse order indicates the resultant of the two forces vectorially".

Triangle law of forces can also be used to analyze the condition of equilibrium of three forces acting at a point simultaneously. Triangle law can also be stated as, "If three forces acting at a point simultaneously are represented vectorially by three sides of triangle taken in order, then the forces are said to be in equilibrium".

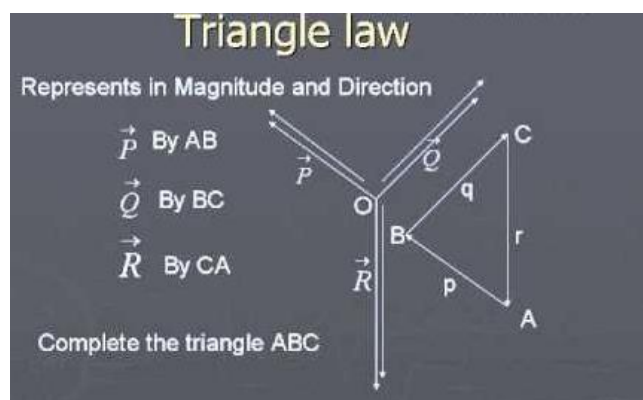
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Converse of triangle law of forces:

"If three forces acting at a point simultaneously are in equilibrium, then they can be represented vectorially by three sides of a triangle taken in order". In the figure, the triangle ABC is called the "Triangle of forces", because each side of the triangle indicates a particular force vectorially. Hence, in this triangle of forces, each force is proportional to the corresponding side of the triangle.

Thus,



$$\begin{aligned} P &\propto AB \\ Q &\propto BC \\ R &\propto CA \end{aligned}$$

Therefore, $\frac{P}{AB} = \frac{Q}{BC} = \frac{R}{CA} = k \text{ (constant)}$

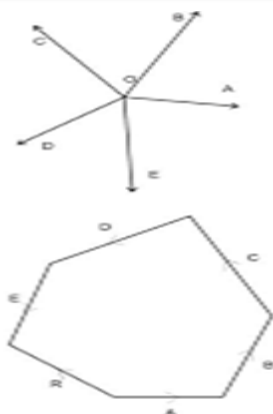
Polygon law of forces:

It is extension of triangle law of forces itself.

"If a number of forces acting at a point simultaneously are represented vectorially by the sides of polygon taken in order, then the closing side in the reverse order represents the resultant of all these forces vectorially"

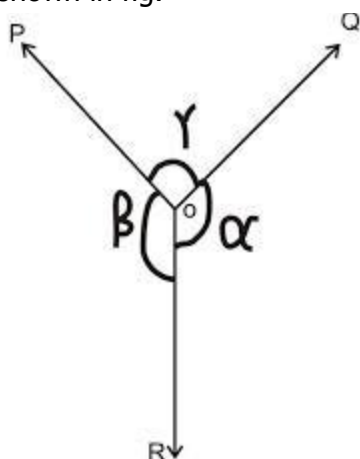
Let A, B, C, D and F be the forces acting at O simultaneously. If these forces are represented vectorially by the sides oa, ab, bc, cd and de respectively, then oe represents the resultant vectorially.

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**Lami's theorem:**

"If three forces acting at a point simultaneously are in equilibrium, then each force is proportional to the sine of the angle between other two forces"

Let P, Q and R three forces acting at O simultaneously and α , β and γ be the angles between the forces as shown in fig.



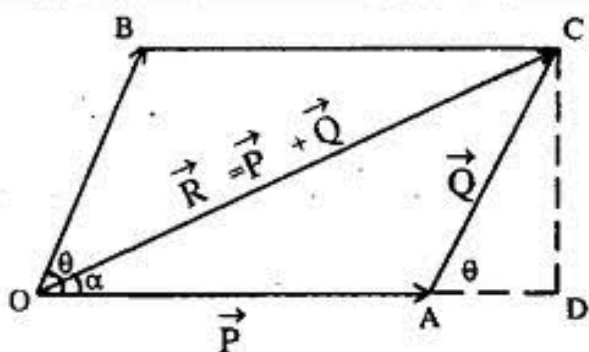
Then,

$$\begin{aligned} P &\propto \sin \alpha \\ Q &\propto \sin \beta \\ R &\propto \sin \gamma \end{aligned} \quad \text{Thus, } \frac{P}{\sin \alpha} = \frac{Q}{\sin \beta} = \frac{R}{\sin \gamma} = k, (\text{constant})$$

Derivation of Magnitude and direction of resultant of two coplanar concurrent forces.

Let P and Q be two forces acting at a point O simultaneously making an angle α with each other. When the sides OA and OB of the parallelogram OACB represents these two forces vectorially, then the diagonal OC represents the resultant both in magnitude and direction acting at an angle θ with the force P. Drawn CD perpendicular to OA to meet at D on OA produced.

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In triangle OCD,

$$\begin{aligned} OC^2 &= OD^2 + CD^2 \\ &= (OA + AD)^2 + CD^2 \\ &= OA^2 + 2OA \cdot AD + AD^2 + CD^2 \end{aligned}$$

But in triangle ACD,

$$AD^2 + CD^2 = AC^2$$

$$\cos \theta = \frac{AD}{AC} \Rightarrow AD = AC \cos \theta$$

$$OC^2 = OA^2 + 2OA \cdot AC \cdot \cos \theta + AC^2$$

$$R^2 = P^2 + Q^2 + 2PQ \cos \theta$$

$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \theta}$$

To find the expression for direction, consider the right angle triangle OCD in which,

$$\tan \alpha = \frac{CD}{OD} = \frac{CD}{OD + AD}$$

But in triangle ACD, we know that, $AD = AC \cdot \cos \theta$

$$\text{And } \sin \theta = \frac{CD}{AC} \Rightarrow \frac{CD}{OD + AD}$$

$$\tan \alpha = \frac{AC \sin \theta}{OA + AC \cos \theta} = \frac{Q \sin \theta}{P + Q \cos \theta}$$

$$\alpha = \tan^{-1} \left[\frac{Q \sin \theta}{P + Q \cos \theta} \right]$$

Special cases:

(i) When P and Q are perpendicular to each other:

Magnitude of the resultant is given by

$$R^2 = P^2 + Q^2 + 2PQ \cos \theta$$

$$R^2 = P^2 + Q^2 + 2PQ \cos 90^\circ$$

$$R^2 = P^2 + Q^2 + 0$$

$$R = \sqrt{P^2 + Q^2} \quad [\cos 90^\circ = 0]$$

Direction of the resultant is given by

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$$\alpha = \tan^{-1} \left[\frac{Q \sin \theta}{P + Q \cos \theta} \right]$$

$$\alpha = \tan^{-1} \left[\frac{Q \sin 90^\circ}{P + Q \cos 90^\circ} \right] = \tan^{-1} \left[\frac{Q \times 1}{P + Q \times 0} \right] = \tan^{-1} \left[\frac{Q}{P} \right]$$

(ii) When P and Q act along the same line in the same direction:

Magnitude of resultant is

$$\begin{aligned} R^2 &= P^2 + Q^2 + 2PQ \cos \theta \\ R^2 &= P^2 + Q^2 + 2PQ \quad \theta = 0 \quad \text{then} \quad \cos \theta = 1 \\ R^2 &= (P + Q)^2 \\ R &= P + Q \\ R &= \text{sum of the two forces} \end{aligned}$$

The direction is given by

$$\alpha = \tan^{-1} \left[\frac{Q \sin 0^\circ}{P + Q \cos 0^\circ} \right] = \tan^{-1} \left[\frac{Q \times 0}{P + Q \times 1} \right] = \tan^{-1} 0 = 0$$

Thus the resultant acts in the same direction as that of P and Q.

(iii) When P and Q act along the same straight line, but in opposite direction.

Magnitude of the resultant is

$$\begin{aligned} R^2 &= P^2 + Q^2 + 2PQ \cos \theta \\ R^2 &= P^2 + Q^2 - 2PQ \quad \theta = 180 \quad \text{then} \quad \cos \theta = -1 \\ R^2 &= (P - Q)^2 \\ R &= P - Q \\ R &= \text{difference of the two forces} \end{aligned}$$

The direction is given by

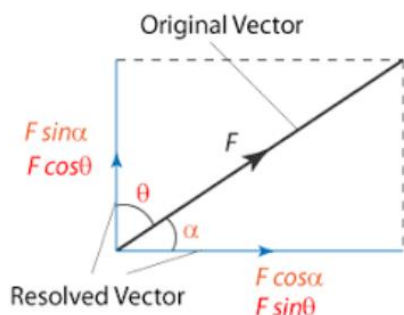
$$\alpha = \tan^{-1} \left[\frac{Q \sin 180^\circ}{P + Q \cos 180^\circ} \right] = \tan^{-1} \left[\frac{Q \times 0}{P + Q \times -1} \right] = \tan^{-1} 0 = 0$$

Thus the resultant acts in the direction of the greater force.

Resolution of vectors

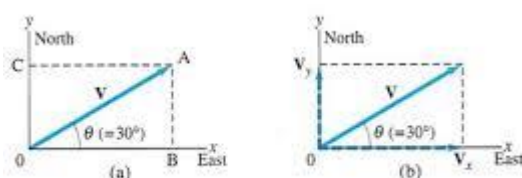
Consider a vector F acting at an angle with the horizontal. This single vector can be resolved into two components, one the horizontal component H along OX and the other vertical component V along OY making an angle of with each other.

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When Vectors are **not** Perpendicular to each other
 You must **Resolve Vectors into 2 Components**

- ❖ X component parallel to x axis
- ❖ Y component parallel to y axis
- ❖ Can either **positive** or **negative** values



As per this figure let us see

In

$$\Delta OAB, \quad \cos \theta = \frac{OB}{OA}$$

$$OB = OA \cos \theta$$

$$H = V \cos \theta$$

$$\text{similarly in } \Delta OAC, \quad \cos(90^\circ - \theta) = \frac{OC}{OA}$$

$$OC = OA \sin \theta$$

$$V = F \sin \theta$$

(i) Experimental verification of law of parallelogram of forces:

Aim: To verify the law of parallelogram of forces.

Apparatus: Gravesend's apparatus

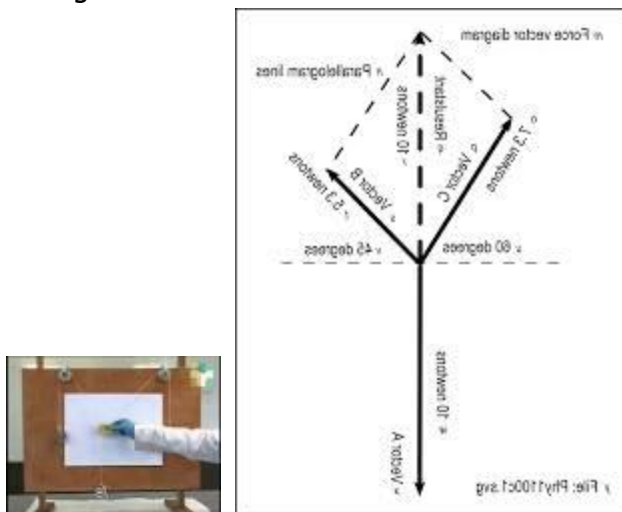
Procedure:

The weight P, Q and R are attached to three strings and are arranged as shown in the figure. The Weights P, Q and R are adjusted so that the knot remains in equilibrium. A sheet of drawing paper is fixed on the vertically supported board and images of the three

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strings together with the knot is taken on a drawing sheet. The weights P ,Q and R are noted with a suitable scale, the lengths OA,OB and OC are cut off along their directions. The parallelogram OACB is completed. Taking OA and OB as the adjacent sides of a parallelogram, the angle COC' and length OC' are measured

The experiment is repeated by changing the forces P , Q and R. It is found that $OC=OC'$ and angle $COC' = 180^\circ$



Trial No.	Forces in gm. wt			Length in cm		Angle COC' In degree
	P	Q	R	OC	OC'	

Result: In each case it is proved that $OC=OC'$ and angle $COC' = 180^\circ$ within experimental error.

(ii) Experimental verification of converse of Triangle law of forces:-

Aim: To verify the law of converse of triangle of forces

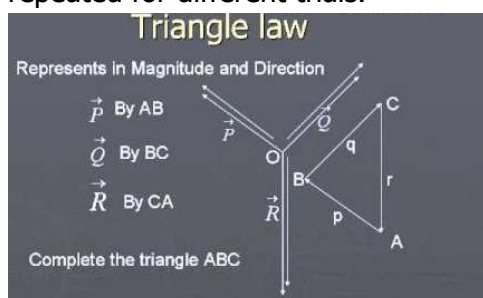
Apparatus: Gravesend's apparatus.

Procedure:

The weight P, Q and R are attached to three strings and are arranged as shown in the figure. The Weights P , Q and R are adjusted so that the knot remains in equilibrium. A sheet of drawing paper is fixed on the vertically supported board and images of the three strings together with the knot is taken on a drawing sheet. The weights P ,Q and R are noted with a suitable scale.

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The straight lines are drawn parallel to the direction of the forces P, Q and R respectively. These three lines will form the triangle ABC, the length AB, BC and CA are measured. The readings are tabulated and it is verified that $P/AB = Q/BC = R/CA = K$. The experiment is repeated for different trials.



Trial No.	Forces in gm. wt			Length in cm			P/AB	Q/BC	R/CA
	P	Q	R	AB	BC	CA			

Result: It is verified that in each case $P/AB = Q/BC = R/CA = K$ within experimental errors.

(iii) Experimental verification of Lami's Theorem:

Aim: To verify Lami's theorem.

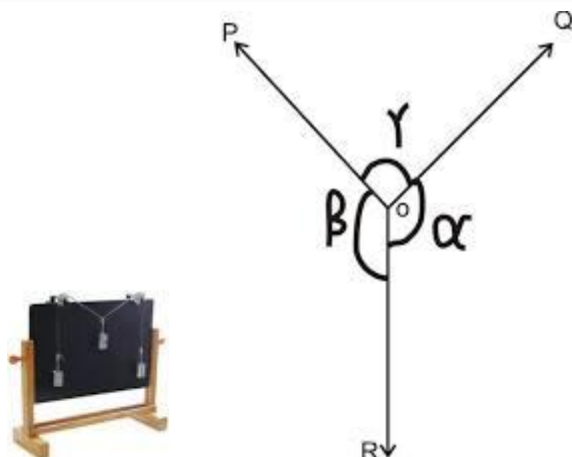
Apparatus: Gravesend's apparatus.

Procedure:

The weight P, Q and R are attached to three strings and are arranged as shown in the figure. The Weights P, Q and R are adjusted so that the knot remains in equilibrium. A sheet of drawing paper is fixed on the vertically supported board and images of the three strings together with the knot is taken on a drawing sheet. The weights P, Q and R are noted with a suitable scale.

The angles α , β and γ are measured, the experiment is repeated by the changing the suitable forces P, Q and R. It is tabulated that in each case $P/\sin\alpha = Q/\sin\beta = R/\sin\gamma = k$

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Trial No.	Forces in gm. wt			Angle in degree			P/Sin α	Q/Sin β	R/Sin γ
	P	Q	R	α	β	γ			

Result: It is verified that in each case $P/\sin\alpha = Q/\sin\beta = R/\sin\gamma = k$ within experimental errors.

Simple problems on laws of vectors

1. A force of 50 N act a point making an angle of 30° with the horizontal. Find the horizontal and vertical component.

Solution:

Horizontal component

$$\begin{aligned}
 &= 50 \times \cos 30^\circ \\
 &= 50 \times 0.86 \\
 &= 43 \text{ N}
 \end{aligned}$$

Vertical component

$$\begin{aligned}
 &= 50 \times \sin 30^\circ \\
 &= 50 \times 0.5
 \end{aligned}$$

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$$= 25 \text{ N}$$

2. Three forces P, Q and 100 N acting on a particle are in equilibrium. If the angles opposite P and Q are 120° and 150° respectively. Find P and Q.

Solution:

$$\text{Sum of two angles} = 120^\circ + 150^\circ = 270^\circ$$

$$\text{therefore angle opposite } 100 \text{ N} = 90^\circ$$

$$\text{By lami's theorem } P/\sin\alpha = Q/\sin\beta = R/\sin\gamma$$

$$P/\sin 120^\circ = Q/\sin 150^\circ = 100/\sin 90^\circ$$

$$P/0.580 = Q/0.5 = 100/1$$

$$P = 100 \times 0.580 = 58 \text{ N}$$

$$Q = 100 \times 0.5 = 50 \text{ N}$$

3. Find the magnitude of the resultant of two forces 3N and 4N acting at a point inclined at angle of 30° with each other.

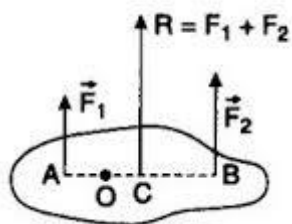
Solution

Magnitude of resultant is

$$\begin{aligned} R &= \sqrt{P^2 + Q^2 + 2PQ\cos\theta} \\ &= \sqrt{3^2 + 4^2 + 2 \times 3 \times 4 \times \cos 30^\circ} \\ &= \sqrt{9 + 16 + 24 \times 0.866} \\ &= \sqrt{25 + 20.784} \\ &= \sqrt{45.784} = 6.766 \text{ N} \end{aligned}$$

Parallel forces

"Forces are said to be parallel if their lines of action are parallel to each other". Since the lines of action of the forces are parallel in the fig(a), the forces F_1 , F_2 , are said to be parallel forces.



Types of parallel forces

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

Parallel forces are of two kinds

1. Like parallel forces
2. Unlike parallel forces

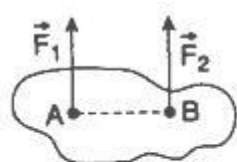
Like parallel forces: "Parallel forces which act in the same direction are called like parallel forces".

Let F_1 and F_2 , be two parallel forces acting on a body at the points A and B respectively in the same direction as shown fig. Now the body will move in the resultant direction which is same as that of F_1 and F_2 . The resultant act at C parallel with the given forces such that and it is the sum of the given two forces i.e., $R = F_1 + F_2$

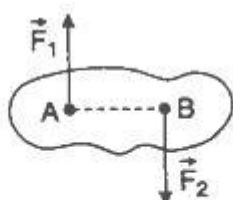
Unlike parallel forces: "Two parallel forces are said to be unlike, if they act in the opposite direction".

F_1 and F_2 are two forces acting in opposite direction at A and B respectively. The resultant acts in the direction of the greater force F_2 . This resultant is parallel to the given forces and is equal to the difference between the two forces. i.e.,

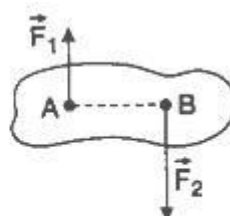
$$R = F_2 - F_1$$



(a) Like parallel forces



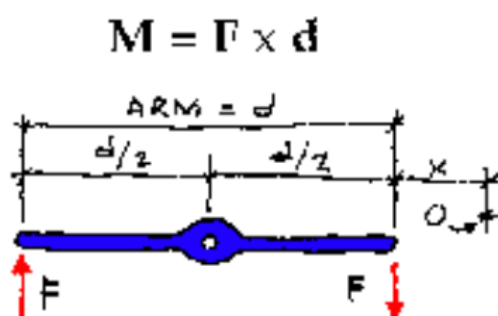
(b) Unlike parallel forces



(c) Unlike unequal forces

Moment of force:

"The rotating effect of a force is called moment of force". It is measured as the product of force and the perpendicular distance of line of action of force from the point/axis of rotation. Moment of force = force \times distance = $F \times d$. SI unit is Newton-meter.



Types of moments:

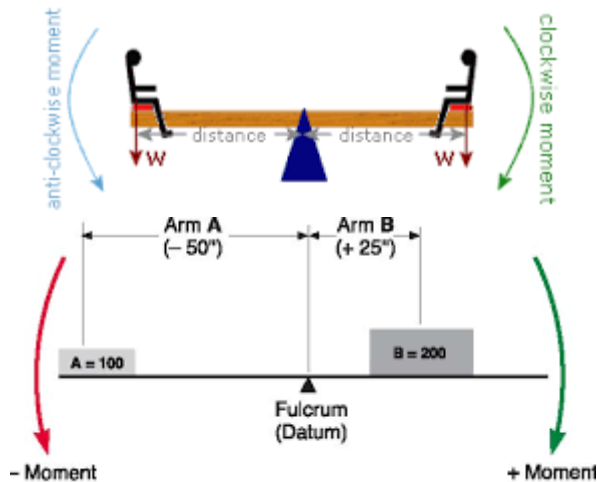
When a force acts on a body hinged at some point on it, two different types of motion can be observed. The body may rotate in the anticlockwise direction or clockwise direction. Accordingly they are called positive or negative moments.

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Positive moment: On application of a force if the body rotates in the anticlockwise direction, then it is called positive moment.

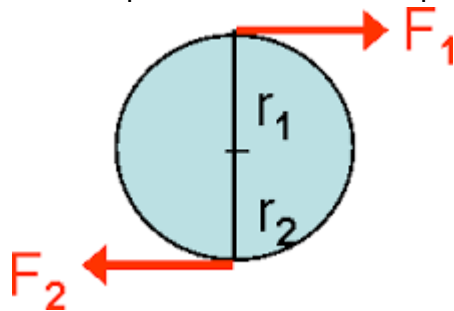
Negative moment: If the body rotates in the clockwise direction due to a force, then it is called negative moment.

Note: The moment of a force is zero, if the force acts on a body where it is hinged.



Couple

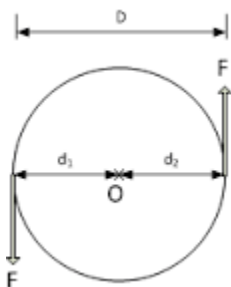
"Two unlike parallel forces equal in magnitude, opposite in direction and acting at two different points constitute a couple"



Moment of couple: (Torque due to couple)

The rotating effect of couple is called moment of couple.

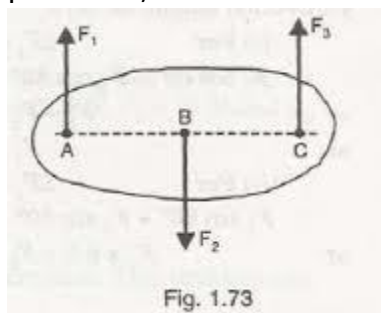
The moment of couple depends on two factors, the forces acting on the body and the perpendicular distance between the two forces which produce couple. Thus the moment of couple is measured as the product of either of the forces and the perpendicular distance between the lines of action of these two forces. Hence, moment of couple $C = FD$.



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Conditions of equilibrium

If a number of coplanar parallel forces act on a body at rest, translatory motion is observed in the direction of resultant force. Similarly, if the forces act on a body which is fixed at some point on it, rotator motion is observed.



A body acted upon by a number of coplanar parallel forces will be in equilibrium if,
Sum of the forces in one direction is equal to the sum of the forces in the opposite direction.

Or

Algebraic sum of the forces acting on a body must be zero.

$$F_1 + F_2 = F_3$$

$$F_1 + F_2 - F_3 = 0$$

Sum of anticlockwise moments (positive moments) must be equal to sum of clockwise moments (negative moments)

Or

Algebraic sum of moments, about a point must be zero. If the body is assumed to be hinged at A

$$F_2 AB = F_3 AC$$

$$F_2 AB - F_3 AC = 0$$

Note:

First condition indicates that the resultant force on the body is zero. So there is no translatory motion.

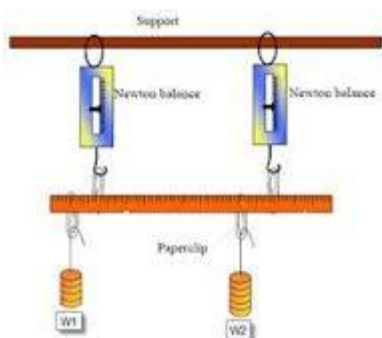
Second condition indicates that the resultant moment on the body is zero. So there is no rotatory motion.

Experimental verification of Conditions of equilibrium of coplanar parallel forces using moment bar and simple problems.

Aim: To verify two conditions of equilibrium of coplanar parallel forces.

Apparatus: Spring balances, stand, metre scale, weights and weight hangers.

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus



Procedure: Take a meter scale and find its weight (w) from a spring balance. Suspend the meter scale by means of loops of thread from two spring balances supported by suitable stands. A few more weights are also suspended by loops of thread.

The positions are so adjusted that meter scale remain horizontal and spring balances vertical. The readings of spring balances F_1 and F_2 are noted the downward forces F_3 and F_4 and w are noted. The experiment can be repeated by changing the weights, the results are tabulated :-

(i) The body will not have translator motion if the resultant of the forces acting on it is equal to zero.

Trial No.	F_1	F_2	F_3	F_4	Sum of Upward Forces $F_1 + F_2$	Sum of Downward Forces $F_3 + F_4 + W$

It will be found that sum of the upward forces is equal to sum of the downward forces.

(ii) The body will not have rotator motion if the algebraic sum of moment of forces acting on the body about any point in the plane must be equal to zero.

To verify F_1 , F_2 , F_3 , F_4 and W from end A of meter scale are noted and tabulated:-

Trial no.	$F_1 \times AF$	$F_2 \times AG$	$F_3 \times AD$	$W \times AC$	$F_4 \times AE$	Sum of Clockwise moments	Sum of Anticlockwise moments

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

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Result:

- (i) Algebraic sum of the forces are equal to zero or sum of the upward forces are equal to the sum of the downward forces.
- (ii) Algebraic sum of clockwise and anticlockwise moments about a point is equal to zero or sum of the clockwise moments are equal to the sum of the anticlockwise moments about a point.

Simple problems.

1. A painter stands on a uniform scaffold hung by its ends from two vertical ropes A and B 10m apart . The scaffold weighs 50 kg. The tension in A is 140 kg and that in B is 60 kg

Solution: The weight $w = 50 \text{ kg}$

Condition of equilibrium

Sum of upward forces = sum of downward forces

$$T_1 + T_2 = W + X$$

$$140 + 60 = 50 + X$$

Therefore $X = 100 \text{ kg wt.}$

Taking moments about point A

Sum of clockwise moments = sum of anticlockwise moments

$$X \times AC + 50 \times 5 = 0 + 60 \times AB$$

$$100 \times AC + 50 \times 5 = 60 \times 10$$




$$AC = 350 / 100$$

$$= 3.5 \text{ m}$$

Hence painter is standing at 3.5m from A.

UNIT II: PROPERTIES OF SOLIDS AND LIQUIDS

Most of the substances that exist in the world can be classified into one of three phases: solid, liquid or gas. These three phases of matter are governed by interatomic and intermolecular forces under ordinary conditions of temperature and pressure.

State	Solid	Liquid	Gas
Diagram			
Arrangement of particles	Regular arrangement	Randomly arranged	Randomly arranged
Movement of particles	Vibrate about a fixed position	Move around each other	Move quickly in all directions
Closeness of particles	Very close	Close	Far apart

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Properties of Solid:

Substances have definite shapes and volumes. Solid particles do move, but not very far. Solid particles have relatively little kinetic energy and vibrate in place. Because of this, they can't flow like liquids. Most solids are arranged in a tightly packed crystalline structure. The crystalline structure is an orderly, repeating arrangement of particles called a crystal lattice. The shape of the crystal shows the arrangement of the particles in the solid.

Properties of liquids:

They are fluid and they can flow. Liquids have definite volume, but not a definite shape. Liquids are said to have low compressibility; in other words, it's hard to pack liquid particles closer together. Compared to gases, there is relatively little space between particles. Compared to solids, however, liquids have some space between particles.

Deforming force:

The change in size and shape or both of a body by the application of external forces is called deforming force. Solids can be deformed in many ways.

There are three basic types of deformation, all others are combinations of these three types.

The deforming force causes a change in

- (i) Length of the object
- (ii) Volume
- (iii) Shape

Elasticity: -

The property of a body by virtue of which it tends to regain its original shape and size when deforming force is removed is called elasticity.

Example: All solids show the property of elasticity. The greater the elasticity of a body the greater its tendency to regain its original shape and size after the removal of the deforming force. The elastic property varies from solid to solid for example steel is very elastic(it means that steel closely returns to its original dimension even after being subjected to relatively large force)

**Plasticity:**

A body which does not have any tendency at all to regain its original shape and size after the removal of the slightest deforming force is called plasticity.

Example: when wet clay is deformed by a force it remains deformed.

(Note: In nature no body is perfectly elastic or plastic)

**Stress:**

When an external force is applied to a body changes the size or shape of the body an internal restoring force is developed in the body. "The internal restoring force acting per

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unit area of the deformed body is called stress." The restoring force is equal in magnitude to the external force.

$$\begin{aligned}\text{Stress} &= \text{External deforming force} / \text{Area} \\ &= F/A\end{aligned}$$

The S I unit of stress is newton per square metre (Nm^{-2})

Types of Stress:

Since the deforming force causes the change in length, volume and shape of the body depending on this there are three types of stress.

(i) Tensile stress (longitudinal stress): The deforming force which changes the length of the body is called tensile stress.

(ii) Volume stress (compressive stress): The deforming force which changes the volume of the body is called volume stress.

(iii) Shear stress (tangential stress): If the deforming force is applied parallel to the surface over the body which changes the shape of the body is called shear stress.

Strain:

The change in the size or shape of a body due to the deforming force is called strain. The strain is measured by the ratio of change in dimension to the original dimension.

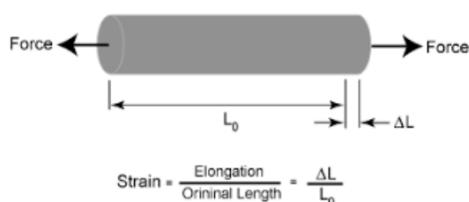
$$\text{Strain} = \text{change in dimension} / \text{original dimension}$$

Types of strain :

Since deforming forces can produce three types of deformations in a body there are three types of strain.

(i) Tensile strain or Longitudinal strain: The strain occurs whenever a change in length of a material takes place. It is defined as the ratio of change in length to the original length.

If a material of length L is increased in its length by ΔL then Tensile strain = $\Delta L / L$



(ii) Volume strain or compressive strain: The strain occurs due to the change in volume of a material. It is defined as the ratio of the change in volume to the original volume.

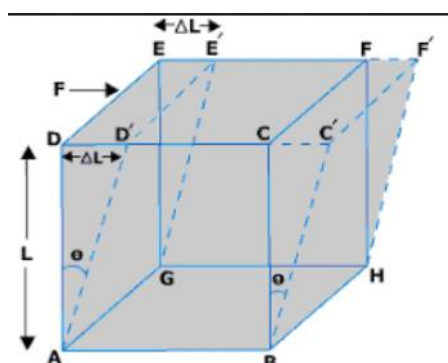
If the volume of the material is V , the change in volume is dv then volume strain = dv/V

(iii) Shear strain tangential strain : If the deforming force produces the change in the shape of the body without changing its volume, it is called shearing strain

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Consider one face ABCD rectangular block . A force F is applied to upper face and lower face is fixed ,now upper face is displaced and the new position of face is A1 , B1,C,D. There is change in shape without a change in volume. The shear strain is ratio lateral displacement between two layers to the distance between two layers.

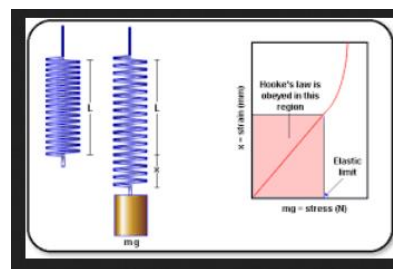
Shear strain = lateral displacement between two layers / distance between two layers



$$DD'/AD = \Delta L / L = \tan \theta = \theta \text{ for small angles in radian}$$

Elastic limit

On the removal of the deforming force, an elastic body will regain its original state only if the deforming force does not exceed a certain limit called elastic limit. "The maximum stress from which an elastic body will recover its original state after the removal of the deforming force is called elastic limit."



Hooke's law:

Robert Hooke studied the elastic behaviour of some objects such as coiled springs, metal rods, metallic wires etc., He enunciated a law known as Hooke's law

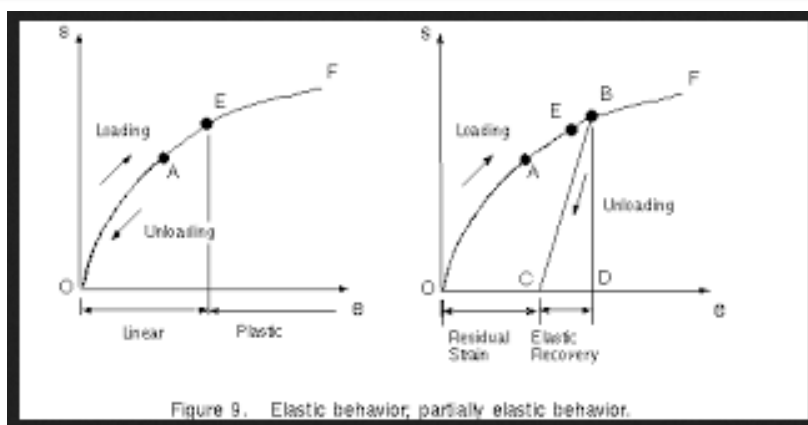
" Within elastic limit , the strain produced in an elastic body is directly proportional to the stress"

$$\text{Stress} \propto \text{Strain}$$

$$\text{Stress} / \text{Strain} = \text{constant} = \text{Modulus of elasticity}$$

Stress - strain graph with explanation:

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Suppose a metallic wire of uniform cross-section is suspended from a rigid support. When the load on the other end is gradually increased, the length of the wire goes on increasing. If the graph between stress and strain is plotted, the shape of the curve will be as shown in Fig1.

1. Portion OA: The portion OA of the graph is a straight line showing that up to point A strain produced in the wire is directly proportional to the stress. In this portion the material of the wire obeys Hooke's law. If the applied force is removed at any point between O and A the wire regains its original length.
2. Portion AB: The portion AB of the graph is not a straight line showing that in this region strain is not proportional to the stress, strain increases more rapidly with stress. Nevertheless, if the load is removed at any point between O and B the wire will return to its original length.
3. Portion BC: If the stress is increased beyond the elastic limit, a point C is reached at which there is marked increase in extension. This point is called yield point. Between B and C, the material becomes plastic if the wire is unloaded at any point between B and C the wire does not come back to original length.
4. Portion CD: If the stress is increased beyond point C, the wire lengthens rapidly until it reaches point D at the top of the curve. The point D is called the ultimate or breaking stress.

Moduli of elasticity and its types:

As there are three types of stress and strain, we have three moduli of elasticity.

1. Young's Modulus of Elasticity: It is defined as the ratio of Tensile stress to the Tensile strain within the elastic limit and it is considered in solids and denoted by 'Y'. If a wire of length L radius r is stretched by mass m (force $F=mg$) and if dl is the change in length produced in the wire of radius r.

$Y = \text{Tensile stress} / \text{Tensile strain}$

$$= \frac{\left[\frac{F}{A} \right]}{\left[\frac{\Delta l}{L} \right]}$$

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$$Y = \frac{\left[\frac{mg}{\pi r^2} \right]}{\left[\frac{\Delta l}{L} \right]} = \frac{mgL}{\pi r^2 \Delta l} = \frac{4mgL}{\pi d^2 \Delta l} \text{ N/m}^2$$

Where $A = \pi r^2$ sq meter is area of cross section and $F = mg$ in newton a stretching force .

2. Bulk Modulus of Elasticity (K): It is defined as the ratio of Volume stress to the Volume strain within elastic limit.

$$\text{Bulk modulus} = \frac{\text{Volume stress}}{\text{Volume strain}}$$

$$\text{Bulk modulus} = \frac{\frac{F}{A}}{\frac{\Delta V}{V}} = \frac{FV}{A \Delta V} \text{ N/m}^2$$

3. Modulus of Rigidity (Shear modulus) (η): It is defined as the ratio of Shear stress to Shear strain within elastic limit.

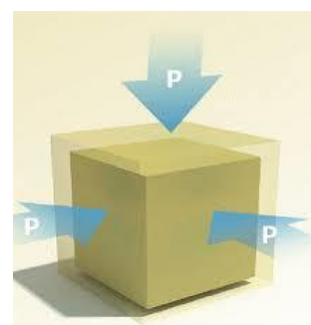
$$\text{Rigidity modulus} = \frac{\text{Shear stress}}{\text{Shear strain}}$$

$$\text{Rigidity modulus} = \frac{\frac{F}{A}}{\tan \theta}$$

Definition of Compressibility and factor of safety:

Compressibility:

It is the property by virtue of which a body can be compressed so as to occupy smallest volume by the application of external force. " It is defined as reciprocal of bulk modulus of elasticity (K)".



Note: Gases are highly compressible, Liquids are slightly compressible. The compressibility of solids varies from one material to another. The S I unit of compressibility is square meter per newton.

Factor of safety:

Stress in a material should not exceed the elastic limit, if exceeds there would be a permanent change in its physical dimension. Hence, factor of safety is used in common practice.

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It is defined as the ratio of ultimate stress to the working stress. Its value is decided by the experience with the material used and also the type of use. It may vary usually between 5 and 10.

Simple problems on stress, strain and Young's modulus:

1. A steel of rectangular cross section 0.05m x 0.025m supports a load of 2 tonnes. Calculate the stress.

$$\text{Solution: stress} = F/A = \frac{2 \times 1000}{0.05 \times 0.025} = 16 \times 10^5 \text{ N/m}^2$$

2) A metal wire is 2.5mm in diameter and 2m long. A force of 12N is applied on it and it stretches 0.3mm. Assume the material is elastic determine

i) Stress in wire

ii) Strain in the wire

Solution: Area of cross-section

$$A = \frac{\pi d^2}{4} = \frac{3.142 \times (2.5 \times 10^{-3})^2}{4} = 4.9093 \times 10^{-6} \text{ m}^2$$

$$\text{i) Stress} = F/A = \frac{12}{4.9093 \times 10^{-6}} = 2.444 \times 10^6$$

$$\text{ii) Strain} = \frac{\partial l}{L} = \frac{0.3 \times 10^{-3}}{2} = 1.5 \times 10^{-4}$$

3) A steel bar of length 6m and rectangular cross section 5cm x 2.5cm supports a load of 2tonnes. How much is change in length of the bar given Young's modulus for steel is $20 \times 10^{10} \text{ Nm}^{-2}$ and $g = 9.8 \text{ ms}^{-2}$

Solution:

$$L = 6\text{m},$$

$$A = 5\text{cm} \times 2.5\text{cm} = 12.5 \times 10^{-4} \text{ m}^2,$$

$$F = 2000 \times 9.8 = 19600\text{N},$$

$$Y = 20 \times 10^{10} \text{ Nm}^{-2}$$

$$\partial l = \frac{FL}{AY} = \frac{19600 \times 6}{12.5 \times 10^{-4} \times 20 \times 10^{10}} = 0.47 \text{ m}$$

Properties of liquids

Thrust:

Liquid at rest always exerts a force perpendicular to the surface of contact. The surface may be the bottom or walls of the containing vessels or a body immersed in the liquid. "The total

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perpendicular force exerted by a liquid at rest on a surface in contact with it is called thrust".

Since thrust is force its SI unit is newton.

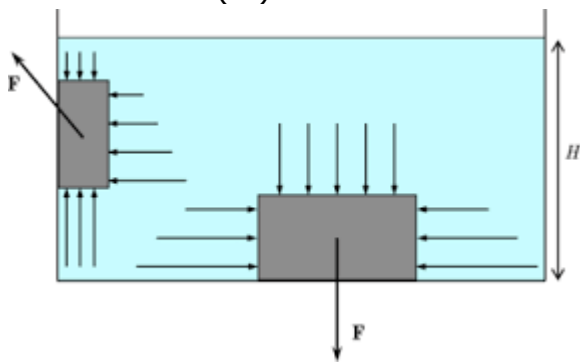
Pressure:

" The normal force (thrust) exerted by liquid at rest on a unit area of the surface in contact with it is called pressure of the liquid on the surface".

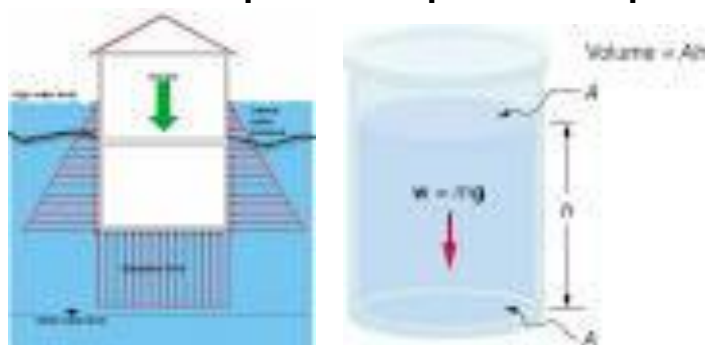
If F is the normal force exerted by a liquid on a surface of area A , then pressure of the liquid on the surface is,

$$\text{Pressure } P = \frac{\text{Thrust}}{\text{Area}} = \frac{F}{A} \text{ N/m}^2 \text{ or pascal}$$

The S I unit of pressure is N/m^2 . When we describe pressure sometimes give special name as Pascal (Pa) .



Derivation of expression for pressure at a point inside the liquid at rest:



Consider a cylinder of cross-sectional area A filled with a liquid of uniform density ρ to a height h as shown in fig(i) . A normal force acts on the bottom of the cylinder due to the weight of the liquid column inside. Therefore, pressure P exerted by the liquid column on the bottom of the cylinder is,

$$P = \frac{\text{Thrust}}{\text{Area}} = \frac{F}{A} \text{ N/m}^2 \text{ or pascal}$$

If m is the mass of the liquid in the cylinder , then $F = mg$

$$P = \frac{mg}{\pi r^2} = \frac{\rho v g}{\pi r^2} = \frac{\rho \pi r^2 h g}{\pi r^2} = \rho g h \text{ N/m}^2 \quad (m = \text{Volume} \times \text{density})$$

$$P = \rho g h \text{ N/m}^2$$

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Note:

1. the pressure exerted by a liquid at rest is independent of the size and shape of the container $P = \rho gh \text{ N/m}^2$
2. All the points at the same depth have the same pressure($\rho g h$). As depth increases pressure increases.

Simple problems:

1. Find the pressure at a point 10cm below the surface of liquid of density 0.8gm/cc

Solution:

$$\begin{aligned} h &= 10\text{cm} = 0.1\text{m} \\ \rho &= 0.8\text{gm/cc} = 800 \\ P &= \rho gh \\ P &= 0.1 \times 9.8 \times 800 \\ P &= 7840 \text{ N/m}^2 \end{aligned}$$

Energy of liquid in motion:

A moving liquid can possess the following types of energies

- (i) Kinetic energy due to its motion.
- (ii) Potential energy due to its position
- (iii) Pressure energy due to the pressure of the liquid.

Kinetic, Potential energies and Pressure energy in moving liquid :

1. When the liquid is under motion the energy possess is called kinetic energy.
2. When the liquid is under motion the energy possess due to its position is called potential energy.
3. When the liquid is under motion the energy possess due to its pressure is called pressure energy.

Bernoulli's theorem: statement and expression (No derivation):

Bernoulli's theorem is simply a statement of law of conservation of energy applied to a liquid in motion. " This theorem states that for the steady flow of an ideal liquid the total energy (ie sum of pressure energy , potential energy and kinetic energy) per unit volume remains constant throughout the flow".

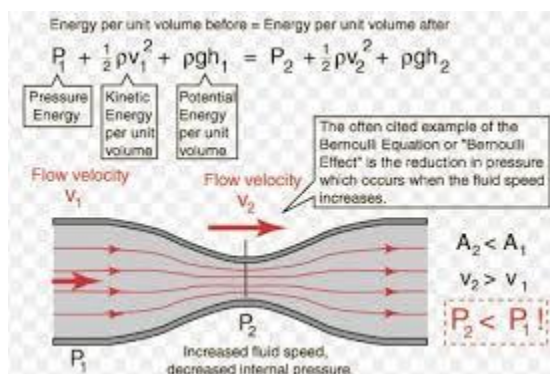
$$P + \rho gh + \frac{1}{2} \rho v^2 = \text{constant}$$

where p = pressure energy per unit volume

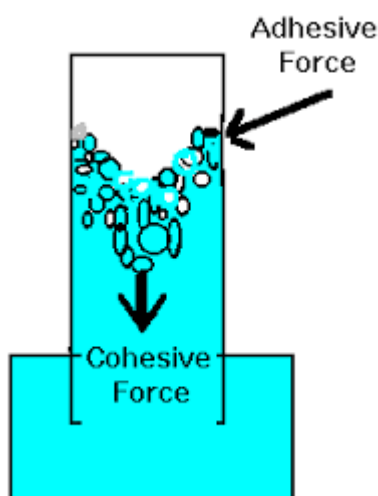
ρgh = potential energy per unit volume

$$\frac{1}{2} \rho v^2 = \text{kinetic energy per unit volume.}$$

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Cohesive and adhesive forces, angle of contact:



According to the molecular theory, matter is made up of minute particles called molecules which attract each other. The intermolecular forces may be classified as:-

- (i) Cohesive force
- (ii) Adhesive force

(i) Cohesive force: "The force of attraction between the molecules of the same substance is called force of cohesion or Cohesive force". The force of cohesion is maximum in solids, lesser in liquids and least in gases.

(ii) Adhesive force: "The force of attraction between the molecules of the different substances is called the force of adhesion or Adhesive force". The force of adhesion is different for different substances.

Note: some practical example of cohesive and adhesive forces:

1. The ink sticks on paper. It is because the adhesive force between ink and paper is greater than the cohesive force of ink molecules.
2. Water wets glass. Because the adhesive force between water molecules and glass molecules is greater than the force of cohesion between water molecules.

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

3. Mercury does not wet the glass because the adhesive force between mercury molecules and glass molecules is less than the cohesive force between mercury molecules.

Angle of contact:

The angle of contact between a liquid and a solid is defined as the angle () which the tangent to the liquid surface at the point of contact makes with the solid surface inside the liquid.

Note:

1. When angle of contact is acute, adhesive force is greater than the cohesive force then,
 - i) The liquid will wet the solid.
 - ii) Meniscus of the liquid will be concave.
 - iii) Liquid will rise in the capillary tube.
2. when the angle of contact is obtuse, cohesive force is greater than the adhesive force then
 - (i) Liquid will not wet the solid.
 - (ii) Meniscus of the liquid will be convex.
 - (iii) Liquid will get depressed in the capillary tube.

Surface Tension



The property of a liquid at rest by virtue of which its free surface behaves like a stretched membrane under tension and tries to occupy as small area as possible is called surface tension.

Observation:

(i) If a needle is slightly oiled so that the water cannot wet it, laid carefully on the surface of water so that the film is not broken, it floats. It can be observed that the surface is depressed under the needle.

“Surface tension of a liquid can be measured as the force per unit length in the plane of the liquid surface acting at right angles on either side of an imaginary line drawn on the liquid surface”.

Image:

$$\text{Surface tension} = \frac{\text{Tangential force}}{\text{length}} = \frac{F}{l} \text{ N/m}$$

The S I unit of surface tension is newton per metre.

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Factors affecting surface tension:

The surface tension of a liquid depends upon

1. Nature of liquid: Different liquids have different surface tensions
2. Contamination : Impurities in a liquid lower its surface tension .
3. Temperature: The surface tension of a liquid decreases with the increase in temperature.

Applications of surface tension:

1. Liquid drops will be perfectly spherical in the absence of gravity, this effect can be observed in the manufacture of lead shots. The freely falling metal temporarily loses its weight and spherical drops are formed due to surface tension.
2. Wetting agent or detergent such as aerosol or petro wet lowers the surface tension of water . Hence cloth becomes wet easily in such water.
3. Mosquitos hang their eggs from the surface of water .when a small amount of oil is poured on water the surface tension of water is reduced ,this breaks the elastic film of water surface and mosquitoes eggs are drowned.

Cohesion causes water to form drops, surface tension causes them to be nearly spherical, and adhesion keeps the drops in place.

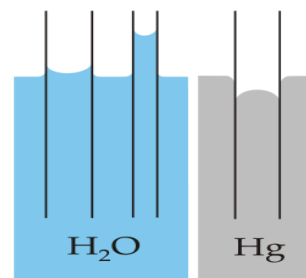
**Capillarity and its applications:**

When a glass capillary tube open at both ends is dipped vertically in water the water in the tube will rise above the level of water. In the case of mercury the liquid is depressed in the tube below the level of mercury in the vessel.

“ The rise or fall of a liquid in a narrow tube is called capillarity”.

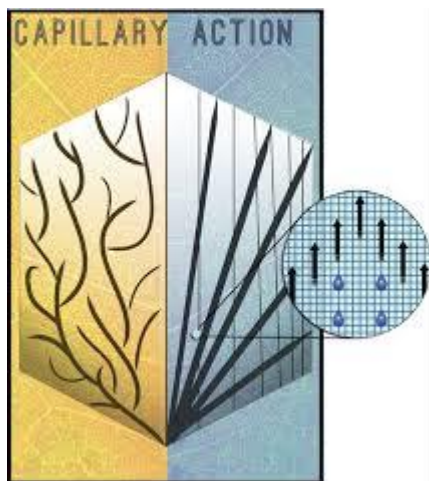
Applications:

1. Water rises in the plants up the leaves through fine pores of the fibres of wood.
2. Due to capillarity water rises to the surface of the fields and gets evaporated.
3. Oil rises in the cotton wicks of lamps through the small capillaries between the threads.



Note: This is only Basic Information for students. Please refer “Reference Books” prescribed as per syllabus

4. Coffee powder is easily soluble in water because water immediately wets the fine granules of coffee by capillary action.



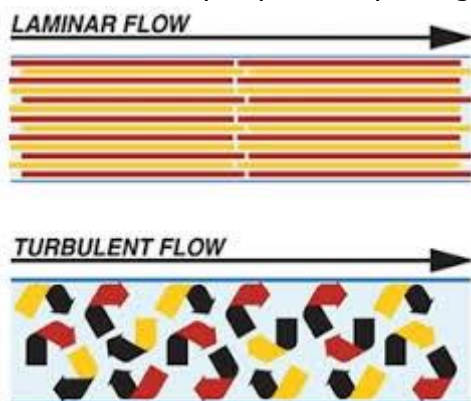
Viscosity

Types of flow of liquid:

The liquid flow is of two main types

(i) Stream line flow or steady flow: The flow of a liquid is said to be streamline flow if all the liquid particles that pass any given point follow the same path at the same speed (same velocity).

(ii) Turbulent flow : The flow of a liquid is said to be turbulent flow if the speed and direction of the liquid particles passing any point change with time



Definition of viscosity :

" The property of a moving fluid to oppose the relative motion between its layers is called viscosity" .

(Note: the viscosity is that property of a fluid that indicates its internal friction ,the greater the viscosity of a fluid the greater is the force required to cause one layer of fluid to slide another.)

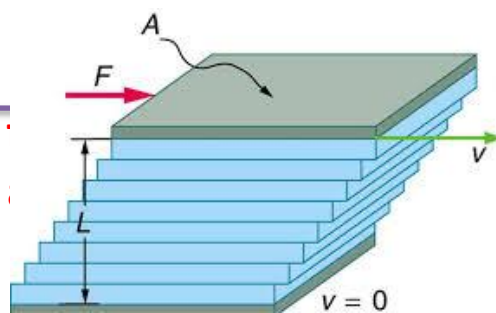
Expression for coefficient of viscosity:

When a fluid is set in motion, different layers of the fluid move with different velocities. Consider a



Viscosity of Water and Honey

Note: This is only Basic Information refer "Reference Books" prescribed



liquid flowing slowly over a fixed horizontal surface, the layer of liquid in contact with horizontal surface is at rest and velocity of layers increases with distance from the fixed surface. Considering any particular layer of the liquid, the layer below it moves slower than it and one above it moves faster than it. Because of this lower layer tends to retard the motion of upper layer which tends to accelerate it.

Newton showed that the viscous force acting tangentially on any liquid layer is:

1. Directly proportional to surface area A
2. Directly proportional to velocity V
3. Inversely proportional to its distance from stationary layer X

$$F \propto \frac{AV}{X}$$

$$F = \eta \frac{AV}{X} \quad \text{if } A = 1 \text{ sq cm, } V = 1 \text{ cm/s, } X = 1 \text{ cm}$$

$$F = \eta$$

Therefore the coefficient of viscosity (η) of a liquid is the tangential force required per unit area to maintain unit relative velocity between two layers unit distance apart.

Experimental determination of coefficient of viscosity of water:

Aim: To determine the coefficient of viscosity of water by poissolue's method.

Apparatus: aspirator bottle, beaker, capillary tube, stop watch water etc.,

Principle: According to poiseuille's equation, the volume of liquid flowing per second through a narrow tube of radius r and length L is given by : $V = \frac{\pi P r^4}{8 \eta L}$ Where P is the pressure difference between the two ends of the tube, where (η) is co-efficient of viscosity of liquid flowing through the narrow tube.



Procedure: The experiment consists of two parts:

- (i) The radius of capillary tube is first using travelling microscope, initially L.C of Travelling Microscope is obtained by knowing value of one main scale division and number of divisions

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on vernier. Capillary tube is fixed horizontally to the stand. The bore of capillary is focused and crosswire of T.M is set tangential on one side and reading R1 is taken, then cross wire is shifted to diametrically opposite tangential position and reading R2 taken. The difference between these two readings gives diameter. Hence radius is obtained.

Observation:

$$\text{Least count of T.M} = \frac{\text{Value of one MSD}}{\text{Total number of VSD}} \text{ cm}$$

Tabular column:

Trial no.	T.M reading for Capillary tube		Diameter d= R1- R2	Radius=d/2
	Left R1	Right R2		

(ii) Volume of water coming out per second from capillary is determined as below, fix the capillary tube horizontally at the bottom of reservoir, maintained with constant height h of liquid above the axis of the capillary tube. Collect the water coming out per second, measure length L of the capillary tube, thus knowing r and v , co-efficient of viscosity (η) can be calculated.

Observation:

Acceleration due to gravity (g):

Density of water : ρ

Length of capillary tube L :

Pressure P : $\rho g h$

Tabular column:

Trial No.	Pressure head		$h = \frac{h_1 + h_2}{2}$ cm	Volume V cc	T sec	$\frac{ht}{v}$	$\frac{ht}{v}$ Mean
	Initial height h_1	Final Height h_2					

$$\text{Co-efficient of Viscosity } \eta = \frac{\pi \rho g r^4}{8l} \left[\frac{ht}{v} \right]_{\text{mean}} \text{ poise}$$

Effect of temperature on viscosity:

- (i) The viscosity of ideal liquid is zero.
- (ii) The coefficient of viscosity of a liquid decreases with the increase in temperature and vice-versa.
- (iii) The coefficient of viscosity of gases increases with the increase in temperature.

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List of applications of viscosity:

1. Blood circulation through arteries depends upon the viscosity of blood.
2. The shapes of ships, cars, aeroplanes etc., are streamlined so as to overcome viscous resistance of water or air.
3. Oil used as a lubricant should have proper value of viscosity.
4. Viscosity of air or liquid is used in providing damping torque in measuring instruments.

**Simple problems:**

- 1) A plate of metal 200sqcm. In area rests on layer of castor oil 2mm, thick whose coefficient of viscosity is 15.5 poise. Calculate the horizontal force required to move the plate with a speed of 3cm/sec.

Solution: Horizontal force required $F = ?$

$$F = - \eta \frac{AV}{X}$$

$$= - 15.5 \times 200 \times (3/0.2) = 46500 \text{ dynes}$$

UNIT III: HEAT AND PROPERTIES OF GASES.**What is Heat?**

All matter is made up of molecules and atoms. These atoms are always in different types of motion (translation, rotational, vibrational). The motion of atoms and molecules

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creates heat or thermal energy. All matter has this thermal energy. If the motion the atoms or molecules is more then, they have more heat or thermal energy.

In day-to-day conversation talking about heat as if it's contained in something. This distinction between heat and temperature is subtle, but very important.

For Example: The iron is hot, so it's reasonable to say it must have a lot of heat in it. Reasonable, but wrong. It's more appropriate to say that it has a lot of energy in it (i.e. it has a high temperature), and touching it will cause that energy to transfer to your hand ... in the form of heat.

Heat is the total energy of molecular motion in a substance while temperature is a measure of the average energy of molecular motion in a substance. Heat energy depends on the speed of the particles, the number of particles (the size or mass) and the type of particles in an object.

If the heat energy is used to change the state of the substance, say by melting it, then the added energy is used to break the bonds between the molecules rather than changing their kinetic energy.

In physical equations, the amount of heat transferred is usually denoted with the symbol Q .

SI UNIT:

As a form of energy, the SI unit for heat is the joule (J).

Heat is frequently measured in calorie, which is defined as "the amount of heat required to raise the temperature of one gram of water from 14.5 degrees Celsius to 15.5 degrees Celsius."

Temperature is not energy, but a measure of heat energy. Temperature is a number that is related to the average kinetic energy of the molecules of a substance. It does not say that temperature is kinetic energy, nor does it state exactly what is the relation between temperature and kinetic energy.

Here is the relation: If temperature is measured in Kelvin degrees, then the value of temperature is directly proportional to the average kinetic energy of its molecules that means if you double the Kelvin temperature of a substance, you double the average kinetic energy of its molecules of a substance.

Temperature can be measured in a variety of units. Namely Kelvin, Centigrade and Fahrenheit. The SI unit of temperature is Kelvin.

Temperature does not depend on the size or type of object. For example, the temperature of a small cup of water might be the same as the temperature of a large tub of water, but the tub of water has more heat because it has more water and thus more total thermal energy.

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It is heat that will increase or decrease the temperature. If we add heat, the temperature will become higher. If we remove heat the temperature will become lower. Higher temperatures mean that the molecules are moving, vibrating and rotating with more energy.

If we take two objects which have the same temperature and bring them into contact, there will be no overall transfer of energy between them because the average energies of the particles in each object are the same. But if the temperature of one object is higher than that of the other object, there will be a transfer of energy from the hotter to the colder object until both objects reach the same temperature.

When heat energy goes into a substance one of two things can happen:

1. The substance can experience a rise in temperature.
2. The substance can change state (or phase). For example, if the substance is ice, it can melt into water. Perhaps surprisingly, this change does not cause a rise in temperature. At the exact moment before melting, the average kinetic energy of the ice molecules is the same as the average kinetic energy of the water molecules at the exact moment after melting. That is, the melting ice and the just melted water are at the same temperature. Although heat (energy) is absorbed by this change of state, the absorbed energy is not used to change the average kinetic energy of the molecules, and thus proportionally change the temperature.

Specific heat

Specific Heat Capacity Definition: Specific heat capacity is the amount of heat energy required to raise the temperature of unit of mass of a body by unit degree temperature.

In SI units, specific heat capacity (symbol: c) is the amount of heat in joules required to raise temperature of 1 kg of a substance by 1 kelvin.

Also Known As: specific heat, mass specific heat.

Examples: Water has a specific heat capacity of 4.18 J.

Copper has a specific heat capacity of 0.39 J.

Equation for specific heat of a substance (no derivation).

If Q amount of heat is required to raise the temperature of a body of mass m from temperature t_1 to temperature t_2 , so that the raise in temperature is $t_2 - t_1 = t$

then we have, amount of heat

Q is directly proportional to m (mass)

Q is directly proportional to t (raise in temperature)

ie., Q is directly proportional to mt .

To remove proportionality we introduce proportionality constant, c called Specific heat

Hence, $Q \propto mt$

$$Q = cmt$$

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$$c = \frac{Q}{m \times t}$$

SI unit of Specific heat is J per kg-s

Transmission of heat

Conduction

Transfer of heat from one place to another without the actual movement of heated medium particles is called conduction of heat.

Conduction is probably the most basic and intuitive way of achieving heat transfer. Conduction is the transfer of heat between substances that are in direct contact with each other. The better the conductor, the more rapidly heat will be transferred. Metal is a good conductor of heat.



When a hot body touches some cool body, the cool body heats up. Conduction occurs when a substance is heated. Particles will gain more energy, and vibrate more. These molecules then bump into nearby particles and transfer some of their energy to them. This then continues and passes the energy from the hot end down to the colder end of the substance.

For instance, if you drop an egg into that boiling water, the heat from the water is then transferred to the egg. As the outer parts of the egg heat up, that heat is transferred inward, so that it is the hotter parts of the egg that end up cooking the cooler, interior parts of itself. So the transfer of heat from one part of an object to another part of the same object is also considered conduction.

How efficiently heat is transferred in this way depends on the conductivity of the items involved. Copper is an extremely good conductor of heat, which means heat moves through copper cookware and is transferred to the food very quickly.

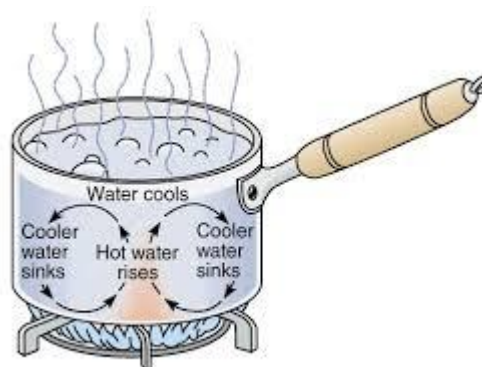
Applications of conduction

- Hot soup burning your tongue
- Burning your hand on holding hot objects
- Age of Earth

Convection

Transfer of heat from one place to another with the movement of heated medium particles is called convection of heat.

Whereas conduction is a static process, convection is a more efficient method of heat transfer because it adds the element of motion.



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Convection occurs when warmer areas of a liquid or gas rise to cooler areas in the liquid or gas because of decrease in density. Cooler liquid or gas then takes the place of the warmer areas which have risen higher. This results in a continuous circulation pattern.

Water boiling in a pan is a good example of these convection currents.

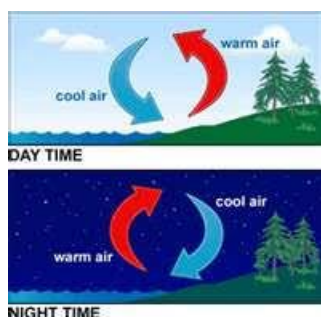
Stirring a pot of soup would be considered a form of convection, as it redistributes the heat from the bottom of a pot throughout the soup.

A convection oven heats food faster than an ordinary one because it has a fan that blows the hot air around, convection ovens can reduce cooking time by 25% or more compared with ordinary ovens.

Another good example of convection is in the atmosphere. The earth's surface is warmed by the sun, the warm air rises and cool air moves in.

Applications of convection

Land and sea breeze



Boiling water

Cooling system in automobiles.

Radiation

Transfer of heat from one place to another without the help of the medium.

Radiation is a method of heat transfer that does not depend upon any contact between the heat source and the heated object as in the case of conduction and convection. Heat can be transmitted through empty space by thermal radiation often called infrared radiation. This is a type electromagnetic radiation. No mass is exchanged and no medium is required in the process of radiation.

Examples of radiation are the heat from the sun reaching earth, Heat released from the filament of a light bulb.



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Applications of radiation

1. Buildings which are white-washed or painted in light colours keep cooler in summer, since the light surfaces reflect radiant heat from the sun.
2. Many factory roofs are aluminium-painted. The bright surface reduces the heat lost in winter, and keeps the interior cool in summer.
3. We choose light-colored clothing in summer for the same reason, and in very hot countries white clothing is generally the rule.
4. Brightly polished objects retain their heat for a long period. This is one reason why silver teapot is to be preferred to others.

Thermal conductivity

Definition: The rate at which heat is transferred by conduction through a unit cross-sectional area of material when a temperature gradient exists perpendicular to the area.

The coefficient of thermal conductivity, called the k-factor, is expressed as the quantity of heat that passes through a unit cube of the substance in unit time when the difference in temperature of the two faces is 1 °.

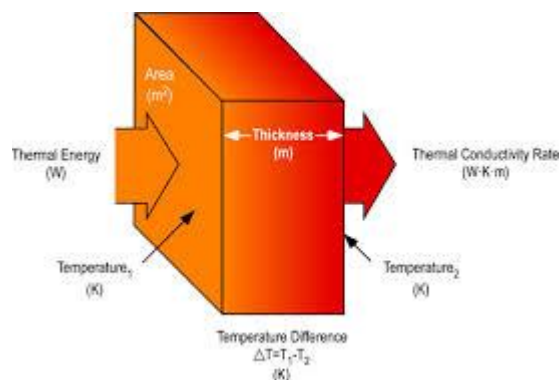
Derivation of co-efficient of thermal conductivity (k) and its S.I unit.

Consider a metallic rod of length 'l', cross sectional area A which is heated at one end. Heat flows to the other end by the method of conduction. If the temperature of first end is maintained at T_1 and the temperature at the other end is maintained at T_2 so that $T_1 > T_2$. The amount of heat Q conducted through the metallic rod for the time 'T' seconds is

1. Directly proportional to area A
2. Directly proportional to temperature difference
3. Directly proportional to the time for which heat is conducted T
4. Inversely proportional to the length of the rod 'l'

$$\text{Therefore } Q \propto \frac{A(t_1 - t_2)T}{l}$$

$$Q = k \cdot \frac{A(t_1 - t_2)T}{l}$$



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Where k is proportionality constant.

Thus the coefficient of thermal conductivity is defined as the quantity of heat (Q) transmitted through a unit thickness (l) in a direction normal to a surface of unit area (A) due to a unit temperature difference (ΔT) for unit time T under steady state conditions.

In equation form this becomes the following:

Thermal Conductivity k = Quantity of heat Q

In SI thermal conductivity is measured in joules per meter kelvin second or J/mKs.

Simple problem on thermal conductivity, k .

How much heat will be lost per square metre per hour from the body of a person, whose body temperature is 37 °C, wearing 1mm thick tight cloth when the atmospheric temperature is 26 °C ?

Given coefficient of thermal conductivity of the material of cloth is 0.04joule/second.metre.kelvin.

Given Data:

$k = 0.04\text{joule/second.metre.kelvin.}$

$A = 1 \text{ sq.metre}$

$t_1 = 37 + 273 = 310 \text{ K}$

$t_2 = 26 + 273 = 299 \text{ K}$

$t_1 - t_2 = 310 - 299 = 11 \text{ K}$

$T = 1\text{hour} = 3600 \text{ seconds}$

$l = 1\text{mm} = 0.001\text{m}$

We know that, amount of heat conducted

$Q = k. (A(t_1-t_2)T/l) \text{ joules}$

Substituting,

$Q = (0.04 \times 1 \times 11 \times 3600) / 0.001$

$Q = 1584000 \text{ joules}$

Gas laws

The gas laws were developed at the end of the 18th century, when scientists began to realize that relationships between pressure, volume and temperature of a sample of gas could be obtained which is approximately same for all gases. Gases behave in a similar way over a wide variety of conditions because they all have molecules which are widely spaced. The earlier gas laws are now considered as special cases of the ideal gas equation, with one or more of the variables held constant.

Boyle's Law, published in 1662. It states that, for a given mass of an ideal gas, in a closed system, at constant temperature, the product of the pressure and volume is always constant.

It can be verified experimentally using a pressure gauge and a variable volume container. It can also be derived from the kinetic theory of gases: if a container, with a fixed number of molecules inside, is reduced in volume, more molecules will strike a given area of the sides of the container per unit time, causing a greater pressure.

As a mathematical equation, Boyle's Law is written as either:

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$$P \propto \frac{1}{V}, \text{ or}$$

$$P \times V = \text{constant}, \text{ or}$$

$$P_1 V_1 = P_2 V_2$$

where P is the pressure, and V is the volume of a gas.

Charles' Law: or the law of volumes, was found in 1787 by Jacques Charles. It states that, for a given mass of an ideal gas at constant pressure, the volume is directly proportional to its absolute temperature assuming a closed system.

As a mathematical equation, Charles' Law is written as either:

$$V \propto T, \text{ or}$$

$$\frac{V}{T} = \text{constant}, \text{ or}$$

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

where V is the volume of a gas, T is the absolute temperature.

Gay-Lussac's Law, or the Pressure Law, was found by Joseph Louis Gay-Lussac in 1809. It states that, for a given mass of an ideal gas and at constant volume, the pressure exerted on the sides of its container is directly proportional to its absolute temperature.

As a mathematical equation, Gay-Lussac's Law is written as either:

$$P \propto T, \text{ or}$$

$$\frac{P}{T} = \text{constant}, \text{ or}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

where P is the pressure, T is the absolute temperature.

Derivation of the relation between them (PV= nRT)

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Charles's Law:	$V \propto T$ [P and n are held constant] As gas temperature increases, gas volume increases.	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Boyle's Law:	$V \propto 1/P$ [T and n are held constant] As gas pressure increases, gas volume decreases.	$P_1V_1 = P_2V_2$
Avogadro's Law:	$V \propto n$ [P and T are held constant] As the number of moles of gas increase, gas volume increases.	$\frac{V_1}{n_1} = \frac{V_2}{n_2}$
Combined Law:	$V \propto T/P$ [n is held constant] Obtained by combining Boyle's Law and Charles's Law.	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Derivation of perfect gas equation

Step 1: Write Boyle's Law:

$$P_1V_1 = P_2V_2$$

Step 2: Multiply by Charles Law:

$$P_1(V_1)^2 / T_1 = P_2(V_2)^2 / T_2$$

Step 3: Multiply by Gay-Lussac's Law:

$$(P_1)^2(V_1)^2 / (T_1)^2 = (P_2)^2(V_2)^2 / (T_2)^2$$

Step 4: Take the square root to get the combined gas law:

$$P_1V_1 / T_1 = P_2V_2 / T_2$$

$$\text{or, } \frac{PV}{T} = \text{constant} = R$$

Therefore, $PV = RT$

For n moles of gas, $PV = nRT$

Specific Heat Capacity in case of gases:

For solids and liquids we define the specific heat capacity as the quantity of energy that will raise the temperature of unit mass of the body by 1 K. For gases, however, it is necessary to specify the conditions under what condition the change of temperature takes place, since a change of temperature will also produce large changes in pressure and volume.

For solids and liquids we can neglect this pressure change and the specific heat capacity that we measure for them is essentially one where the pressure on the body is unaltered. We call this the specific heat capacity at constant pressure (C_p).

The specific heat capacity at constant volume (C_v) is defined as the quantity of heat required to raise the temperature of 1 kg of the gas by 1 °K if the volume of the gas remains constant.

The specific heat capacity at constant pressure (C_p) is defined as the quantity of heat required to raise the temperature of 1 kg of the gas by 1 °K if the pressure of the gas remains constant.

The specific heat capacity at constant pressure (C_p) is always greater than that at constant volume (C_v). Since if the volume of the gas increases work must be done by the gas to push back the surroundings.

Relation between C_p and C_v

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1. $C_p - C_v = R$, where R is Universal gas constant.
This equation is called Mayer's equation.

2. $\frac{C_p}{C_v} = \gamma$

The value of this ratio depends on the atomicity of the gas – in other words how many atoms there are in one molecule.

Problems on Gas laws

Boyle's law

A container holds 500ml of Carbon-di-oxide at C and 742 mm of mercury. What will be the volume of Carbon-di-oxide if the pressure is increased to 795 mm of mercury?

Given Data:

$$V_1 = 500 \text{ ml}$$

$$P_1 = 742 \text{ mm of Hg.}$$

$$P_2 = 795 \text{ mm of Hg.}$$

$$T = 20^\circ\text{C}$$

WE know that,

$$P_1 \cdot V_1 = P_2 \cdot V_2$$

$$V_2 = ?$$

$$V_2 = (P_1 \cdot V_1) / P_2$$

$$V_2 = (742 \times 500) / 795$$

$$V_2 = 466.66 \text{ ml of Carbon-di-oxide}$$

Charles' law

A container holds 100ml of nitrogen at C and a pressure of 736 mm of mercury. What will be its volume if the temperature is increased by C

Given Data:

$$V_1 = 100 \text{ ml}$$

$$T_1 = 25 + 273 = 298 \text{ }^\circ\text{K}$$

$$P_1 = 736 \text{ mm of Hg.}$$

$$T_2 = (25 + 35) + 273 = 333 \text{ K}$$

$$V_2 = ?$$

WE know that,

$$V_1 / T_1 = V_2 / T_2$$

$$V_2 = (V_1 \cdot T_2) / T_1$$

$$V_2 = (100 \times 333) / 298$$

$$V_2 = 111.744967 \text{ ml of nitrogen}$$

Thermodynamics:

It is a branch of physics concerned with heat and temperature and their relation to energy and work. It defines macroscopic variables, such as internal energy, entropy, and pressure that partly describe a body of matter or radiation.

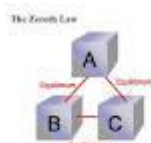
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The field of thermodynamics deals with systems that are able to transfer thermal energy into at least one other form of energy (mechanical, electrical, etc.) or into work. The laws of thermodynamics were developed over the years as some of the most fundamental rules which are followed when a thermodynamic system goes through some way of energy change.

Zeroeth law of thermodynamics:

If two systems are in thermal equilibrium respectively with a third system, then they must be in thermal equilibrium with respect to each other.

This zeroeth law is sort of a transitive property of thermal equilibrium. The transitive property of mathematics says that if $A = B$ and $B = C$, then $A = C$. The same is true of thermodynamic systems that are in thermal equilibrium.



In order to measure a temperature, thermal equilibrium must be reached between the thermometer as a whole, the mercury inside the thermometer, and the substance being measured. This, in turn, results in being able to accurately tell what the temperature of the substance is.

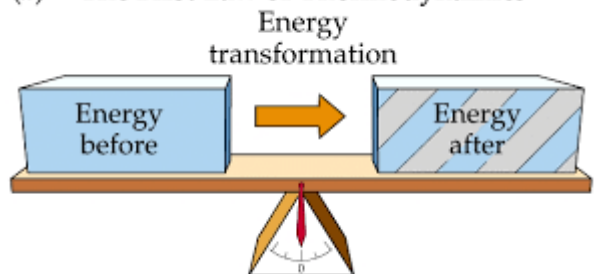
This law was understood without being explicitly stated through much of the history of thermodynamics study. British physicist Ralph H. Fowler first coined the term "zeroeth law," based on a belief that it was more fundamental even than the other laws.

First law of thermodynamics:

When energy passes, (as work, as heat or with matter,) into a system or out from a system, its internal energy changes in accordance with the law of conservation of energy. The change in a system's internal energy is equal to the difference between heat added to the system from its surroundings and work done by the system on its surroundings.

The first law of thermodynamics is seen by many as the foundation of the concept of conservation of energy. It basically says that the energy that goes into a system is used either to change internal energy or to perform work or both.

(a) The First Law of Thermodynamics



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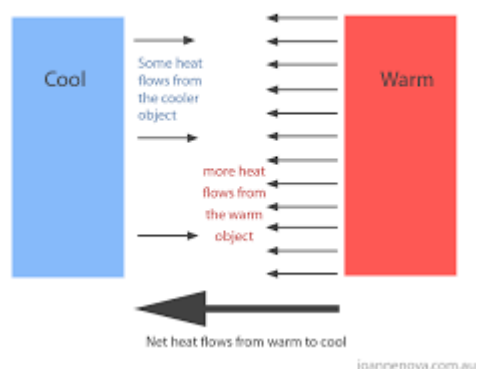
Second law of thermodynamics:

In a natural thermodynamic process, the sum of the entropies of the interacting thermodynamic system increases. It is impossible for a process to transfer heat from a cooler body to a hotter one.

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Each time a system goes through a thermodynamic process, the system can never completely return to the same state it was in before. This is one definition used for the arrow of time, since entropy of the universe will always increase over time according to the second law of thermodynamics.

A cooler body can reduce net heat loss from a warmer one



Types of thermodynamics process

Isothermal Process

An isothermal process is a thermodynamic process in which the temperature of the system remains constant, the heat transfer into the system or out of the system must happen at such a slow rate that the thermal equilibrium is maintained.

Other Factors in an Isothermal Process

An isothermal process is a change of a system, in which the temperature remains constant: $\Delta T = 0$.

In general, during an isothermal process there is a change in internal energy, heat energy and work.

The internal energy of an ideal gas, however, depends solely on the temperature, so the change in internal energy during an isothermal process for an ideal gas is also 0.

Adiabatic Process

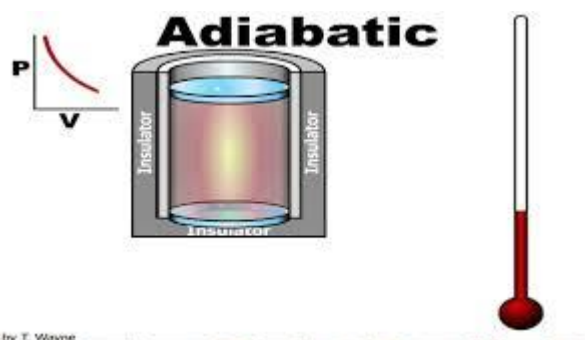
An adiabatic process is one that occurs without transfer of heat or matter between a system and its surroundings. Here no heat is gained or lost by the system.

An adiabatic process is generally obtained by surrounding the entire system with a strongly insulating material or by carrying out the process so quickly that there is no time for a significant heat transfer to take place.

Other Factors in an Adiabatic Process

A system that expands under adiabatic conditions does positive work, so the internal energy decreases.

A system that contracts under adiabatic conditions does negative work, so the internal energy increases.



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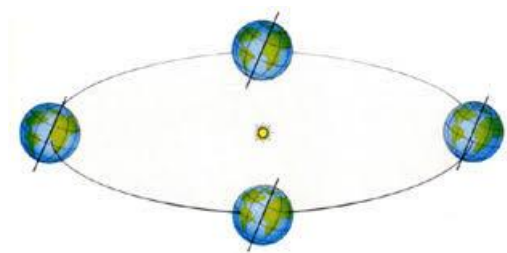
Eg. The compression and expansion strokes in an internal-combustion engine are both approximately adiabatic processes

UNIT IV: WAVE MOTION

Introduction and simple harmonic motion

Periodic motion: A motion that repeats itself in equal intervals of time is called Periodic motion.

Example: A rocking chair, a bouncing ball, a vibrating tuning fork, a swing in motion, the Earth in its orbit around the Sun, and a water wave.

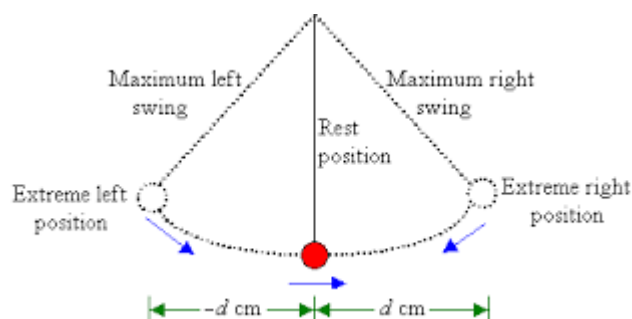


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Simple harmonic motion

Simple harmonic motion is a type of periodic motion where the restoring force is directly proportional to the displacement and acts in the direction opposite to that of displacement.

Example: A rocking chair, a vibrating tuning fork, a swing in motion, pendulums, springs



Derivation of displacement of a particle executing Simple Harmonic Motion.

Definitions of period, frequency, amplitude, in case of vibrating particle. Definition of wave, wave period (T), wave frequency (n or f), wave amplitude (a), wave length (λ) and wave velocity (v) in case of wave motion.

Derive the relation between v , n and λ .

Vibratory motion can be defined as to and fro motion or oscillatory motion about a mean position.

VIBRATORY MOTION

- Vibratory motion is the back and forth (to and fro) motion of an object.
- For example, a swing set. It vibrates back and forth as you swing it. Motion of the pendulum of a clock is also the example of vibratory motion.




Vibrating Tuning fork

A weight on a spring

A boy on a swing

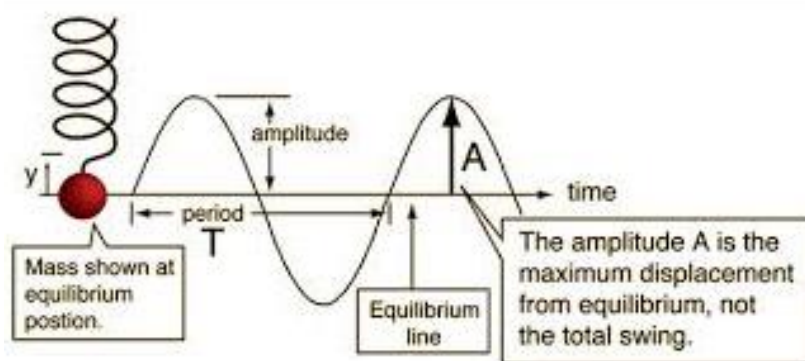




Some Common Examples of Vibratory Motion

Definitions of period, frequency, amplitude, in case of vibrating particle

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Period: Time required to complete one cycle or one to and fro motion is called period. Denoted by 'T' and its SI unit is second.

Frequency: Total number of cycles completed by the body in one second. Denoted by 'n' or 'f' and its SI unit is hertz.

Amplitude: Maximum displacement of the particle from the mean position is amplitude. Denoted by 'a' and its SI unit is meter.

Wave: A wave is a vibratory disturbance in a medium which carries energy from one point to another without any direct contact between the two points.

In other words a wave is an oscillation accompanied by the transfer of energy that travels through space or mass. Wave motion transfers energy from one point to another, which may or may not displace particles of the medium with little or no associated mass transport. Waves consist of oscillation or vibrations (of a physical quantity), around fixed locations.



Wave period (T): The period of a wave is the time required for a particle on a medium to make one complete vibrational cycle. Period, being a time, is measured in units of time such as seconds, hours, days or years. Its SI unit is seconds.

Wave frequency (n or f): The frequency of a wave refers to how many times the particles of the medium vibrate in unit time when a wave passes through the medium. Its SI unit is hertz.

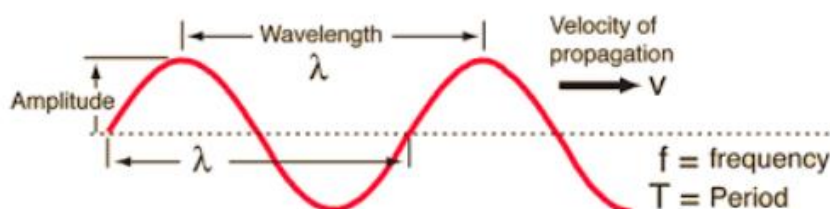
Wave amplitude (a): The amplitude of a wave refers to the maximum amount of displacement of a particle on the medium from its rest position. Its SI unit is metre.

For example in transverse wave, the amplitude is the distance from rest to crest. Similarly, the amplitude can be measured from the rest position to the trough position.

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Wave length (λ): The wave length of a wave is simply the length of one complete wave cycle. Its SI unit is metre.

Wave velocity (v): The distance travelled by the wave or disturbance in unit time is called wave velocity. Its SI unit is metre/second.



Derive the relation between v , n and λ .

Consider a wave of wave length ' λ ', wave period ' T ' and frequency ' n ' travelling in a medium with wave velocity ' v '. During one oscillation of the medium particle the distance travelled by the wave is one wave length λ and time taken for this is one wave period T .

We know that wave velocity is distance travelled by the wave/time taken Therefore, wave velocity $v = \text{wave length } \lambda / \text{wave period } T$

$$\text{Velocity} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{\text{wave length}}{\text{time period}}$$

$$= \frac{\lambda}{T}$$

$$\text{But wave period } T = \frac{1}{\text{Frequency}} = \frac{1}{n}$$

Substituting we get $v = n \lambda$

Simple problems.

1. Sound wave travelling in air with frequency 12 kHz has a velocity of 332 m/s. Find the wavelength of this wave in air.

Solution:

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

data:

$$v = 332 \text{ m/s}$$

$$n = 12 \text{ kHz} = 12 \times 10^3 \text{ Hz}$$

$$\lambda = ?$$

$$v = n\lambda$$

$$\lambda = \frac{v}{n} = \frac{332}{12 \times 10^3} = 0.0276 \text{ m} = 27.6 \text{ mm}$$

2. A radio station broadcasts programs on a wavelength of 300 m. Find the frequency of broadcasting.

Solution:

Data:

$$\lambda = 300 \text{ m}$$

$$\text{Velocity of radio wave} = \text{Velocity of Electromagnetic wave} = 3 \times 10^8 \text{ m/s}$$

$$v = n\lambda$$


$$n = \frac{v}{\lambda} = \frac{3 \times 10^8}{300} = 1 \times 10^6 \text{ Hz} = 1 \text{ MHz}$$

Mechanical Waves and NonMechanical Waves or Electromagnetic waves.

Mechanical Waves are waves which propagate through a material medium (solid, liquid, or gas) at a wave speed which depends on the elastic and inertial properties of that medium. Mechanical waves propagate through a medium, and the substance of this medium is deformed. The deformation reverses itself owing to restoring forces resulting from its deformation. For example, sound waves propagate via air molecules colliding with their neighbours. When air molecules collide, they also bounce away from each other (a restoring force). This keeps the molecules from continuing to travel in the direction of the wave.

Examples for this type of waves are water waves, sound waves.

Mechanical Waves



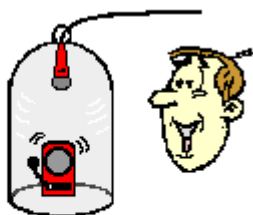
Mechanical waves are the most familiar type of waves to us because they can be most readily seen in action. They also have the following properties:

- Mechanical waves must have a material to travel through (known as a medium). This can be water, air, dirt, basically anything made of matter.
- Mechanical waves are governed by Newton's Laws.

Water waves and sound waves are examples of mechanical waves.

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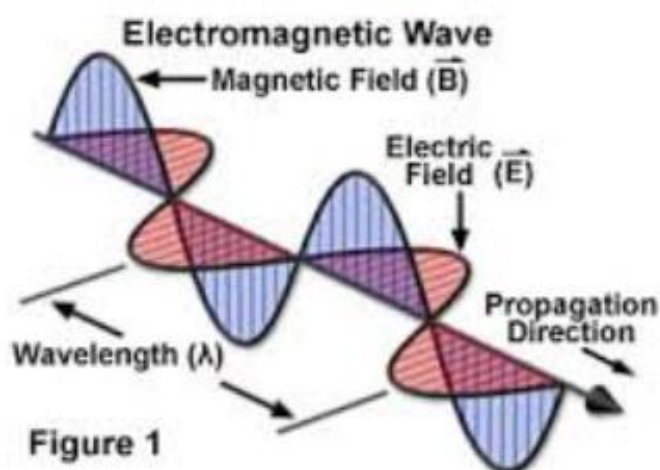
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The sound produced by the bell cannot be heard since sound cannot travel through a vacuum.

Let an electric bell be enclosed within a bell jar which is placed over a disc. we hear sound, transmitted through the air when it is rung. On gradually removing the air, the sound of the bell becomes feebler and becomes almost inaudible when the limit of exhaustion is reached. In air, sound is propagated in the form of compressions and rarefactions i.e., longitudinal waves. Unlike light, sound cannot pass through vacuum.

The second main type of wave is Non Mechanical Waves or Electromagnetic waves, which do not require a medium. Instead, they consist of periodic oscillations of electrical and magnetic fields generated by charged particles, and can therefore travel through vacuum. Examples for this type of waves are radio waves, microwaves infrared waves, visible light etc.

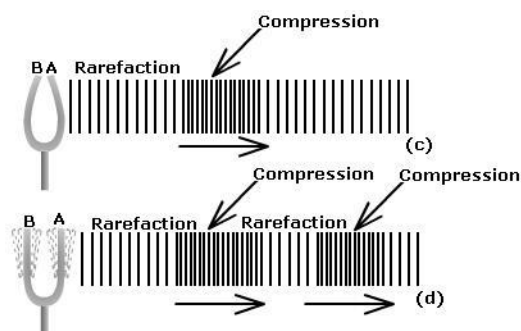


There are two types of mechanical waves:

Longitudinal waves and transverse waves

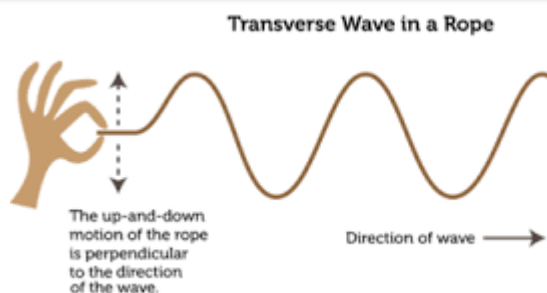
Longitudinal wave:

A wave in which the particles of the medium vibrate back and forth (oscillate) in the same direction in which the wave is moving, is called a longitudinal wave. Longitudinal wave can be produced in all the three medium solids, liquids, and gases.



Transverse wave:

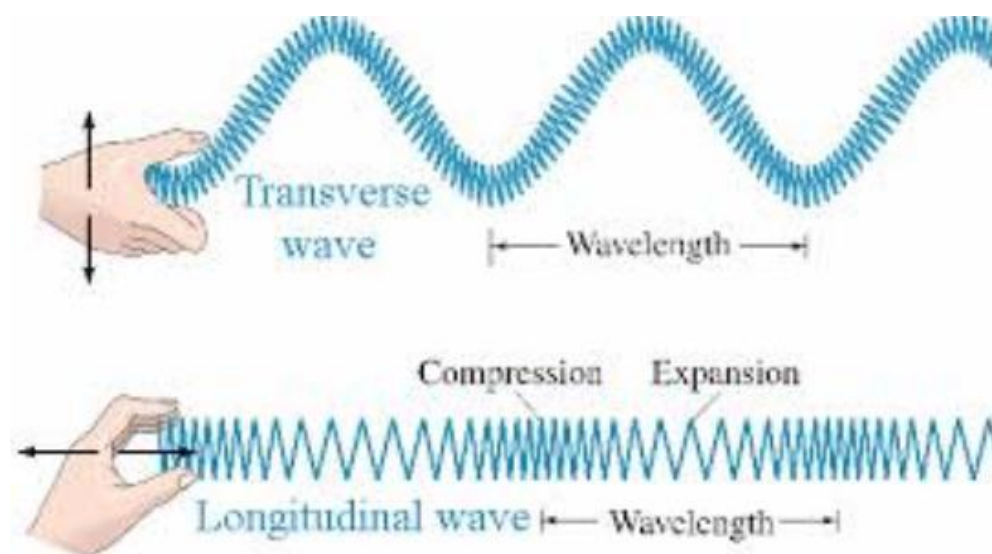
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A wave in which the particles of the medium vibrate back and forth (oscillate) in the direction perpendicular to the direction in which the wave is moving, is called a transverse wave. Transverse wave can be produced in medium

solids, and liquid surfaces.

Differences between longitudinal waves and transverse waves



Longitudinal waves	Transverse waves
1. The particle displacement is parallel to the direction of wave propagation.	1. The particle displacement is perpendicular to the direction of wave propagation.
2. Sound waves in air is an example	2. Ripples on water surface is an example
3. Compression and rarefaction are formed	3. Crest and trough are formed
4. Longitudinal waves cannot be polarised	4. Transverse waves can be polarised
5. Pressure and density changes as the longitudinal wave propagates	5. Pressure and density remains same as the transverse wave propagates
6. Longitudinal waves can propagate through solids, liquids and gases	6. Transverse waves can propagate through solids and liquid surfaces.

Sound: A form of energy produced by vibrating objects. When sound travels through a material such as air, molecules in the material vibrate and bump into the molecules, passing on their energy.

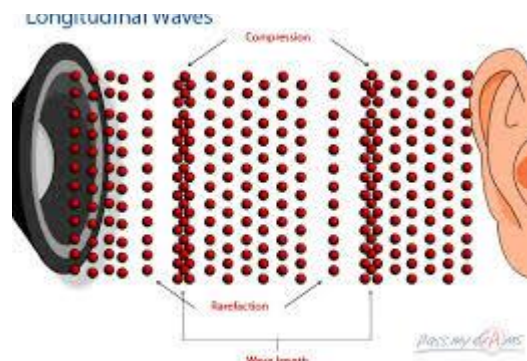
Wave: A wave is a vibratory disturbance in a medium which carries energy from one point to another without any direct contact between the two points.

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Longitudinal wave: A wave in which the particles of the medium vibrate back and forth in the same direction, in which the wave is moving is called a longitudinal wave. Longitudinal wave can be produced in all the three medium solids, liquids and gases.

Sound waves are longitudinal waves:

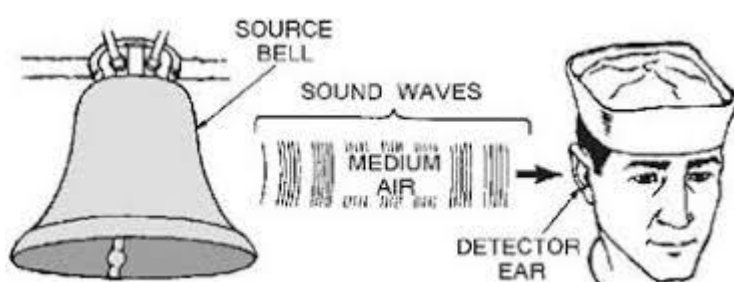
When a sound wave passes through air, the particles of air vibrate back and forth parallel to the direction of sound wave. Thus, when a sound wave travels in the horizontal direction, then the particles of the medium also vibrate back and forth in the horizontal direction but parallel to the direction of sound



Newton's formula for the velocity of sound in air and Laplace's correction to it, various factors affecting velocity of sound in air

Sound is a mechanical wave that results from the back and forth vibration of the particles of the medium through which the sound wave is moving. If a sound wave is moving from left to right through air, then particles of air will be displaced both rightward and leftward as the energy of the sound wave passes through it. The motion of the particles is parallel to the direction of the energy transport. This is what characterizes sound waves in air as longitudinal wave.

A vibrating tuning fork is capable of creating such a longitudinal wave. As the prongs of the fork vibrate back and forth, they push on neighbouring air particles. The forward motion of a prong pushes air molecules horizontally to the right and the backward retraction of the prong creates a low-pressure area allowing the air particles to move back to the left.



Because of the longitudinal motion of the air particles, there are regions in the air where the air particles are compressed together and other regions where the air particles are spread apart. These regions are known as compressions and rarefactions respectively. The compressions are regions of high air pressure while the rarefactions are regions of low air pressure.

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Sir Issac Newton assumed this process of propagation of sound through air takes place under isothermal conditions (constant temperature) hence obeying Boyle's law

We know that, Velocity of longitudinal waves in a homogeneous medium is given by,

$$v = \sqrt{\frac{E}{\rho}},$$

Where, E is elasticity of the medium and

ρ is density of the medium

In air or gaseous medium, $E = B$, where B is bulk modulus of the medium

But for a perfect gas under isothermal conditions,

Bulk modulus of the medium = Pressure of the medium

i.e., $B = P$

Hence, Velocity of longitudinal waves or sound waves in a homogeneous medium becomes

$$v = \sqrt{\frac{P}{\rho}}$$

This equation is called Newton's formula for the velocity of sound in air.

At normal temperature and pressure,

Normal pressure, $P = 1.013 \times 10^5 \text{ N/m}^2$

Density of air, $\rho = 1.293 \text{ kg/m}^3$

Substituting these values in the Newton's formula we get the

theoretical value of velocity of sound in air = 280 m/s

but the experimental value of velocity of sound in air at normal temperature and pressure is equal to 332 m/s

There is a large difference between theoretical value and experimental value of velocity of sound in air which could not be explained.

Hence Newton's formula for the velocity of sound in air requires correction.

This correction was done by a scientist called Laplace.

Because of the longitudinal motion of the air particles, there are regions in the air where the air particles are compressed together known as compressions and other regions where the air particles are spread apart known as rarefactions. The compressions are regions of high air pressure hence there will be slight rise in temperature while the rarefactions are regions of low air pressure hence there will be slight decrease in temperature. Compressions and rarefactions occur very rapidly that heat exchange to and from the surroundings is not

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possible .(do not take place.) So this process of propagation of sound through air takes place under adiabatic conditions and not under isothermal conditions.

For a perfect gas under adiabatic conditions,

Bulk modulus of the medium is γP of the medium

where,
$$\gamma = \frac{C_p}{C_v}$$

i.e., $B = \gamma P$

Hence, Velocity of longitudinal waves or sound waves in a homogeneous medium becomes

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

This equation is called Newton Laplace formula for the velocity of sound in air.

At normal temperature and pressure,

Normal pressure, $P = 1.013 \times 10^5 \text{ N/m}^2$

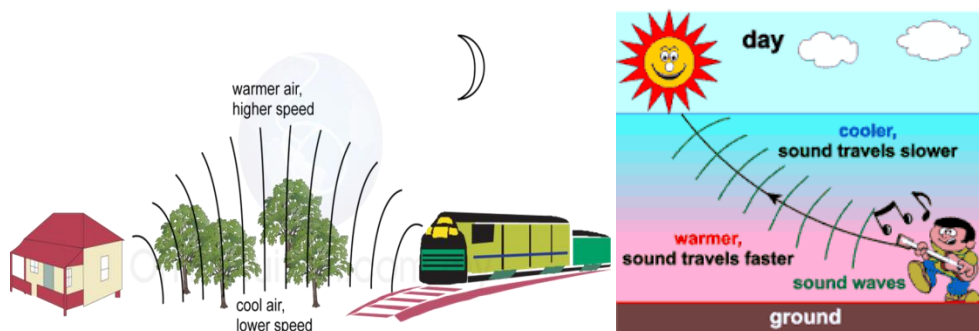
Density of air, $\rho = 1.293 \text{ kg/m}^3$

Substituting these values in the Newton Laplace formula we get the

theoretical value of velocity of sound in air = 331.6 m/s which is in close agreement with the experimental value of velocity of sound in air at normal temperature and pressure is equal to 332 m/s

Factors affecting velocity of sound in air

1. Effect of Pressure : As the pressure changes there will be corresponding change in density such that P/ρ remains constant. Hence velocity of sound in air is independent of pressure variations when the temperature remains same.
2. Effect of Temperature: Velocity of sound in air is directly proportional to the square root of its absolute temperature when density is constant.



3. Effect of Density: Velocity of sound in air is inversely proportional to the square root of density.

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4. Effect of Humidity: Velocity of sound in air increases with humidity of air.

Problems:

1. Velocity of sound in air at 0°C is 330 m/s. Find its velocity at 25°C .

Solution:

Data:

$$v_0 = 330 \text{ m/s}$$

$$t = 25^{\circ}\text{C}$$

$$v_t = ?$$

$$v \propto \sqrt{T}$$

$$\frac{v_t}{v_0} = \sqrt{\frac{273 + t}{273}}$$

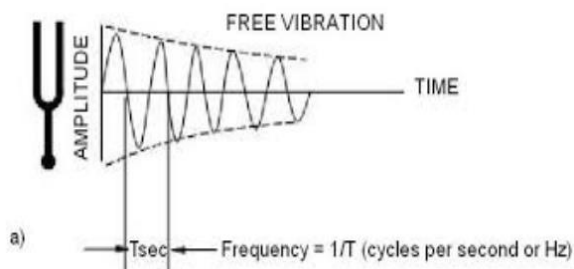
$$v_t = v_0 \sqrt{\frac{273 + t}{273}} = 330 \sqrt{\frac{273 + 25}{273}} = 330 \sqrt{1.092} = 344.85 \text{ m/s}$$

Free vibration occurs when a mechanical system is set off with an initial input and then allowed to vibrate freely. Examples of this type of vibration are pulling a child back on a swing and then letting go or hitting a tuning fork and letting it ring. The mechanical system will then vibrate at one or more times of its natural frequency and damp down to zero.

Examples:

Oscillations of pendulum

Vibrations of tuning fork **Forced vibration** occurs when a mechanical system is set off with time-varying disturbance applied to it. The disturbance can be a periodic, steady-state input, a transient input, or a random input.



Forced vibrations occur when the object is forced to vibrate at a particular frequency by a periodic input of force.

The tendency of one object to force another adjoining or interconnected object into vibrational motion is referred to as a Forced vibration.

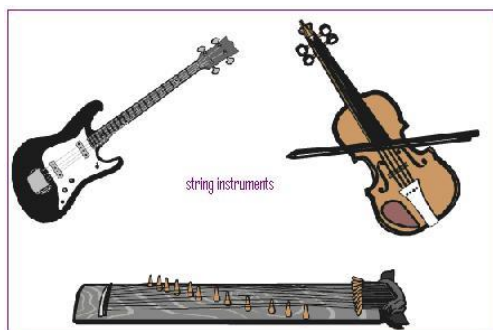
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Examples:

A tightly-stretched string is made to vibrate using an electromagnet, which is a periodic force.

Melody of stringed musical instruments is due to forced vibrations of their sounding boxes.



Damped vibrations:

Any oscillation in which the amplitude of the oscillating material decreases with time is called damped vibration.

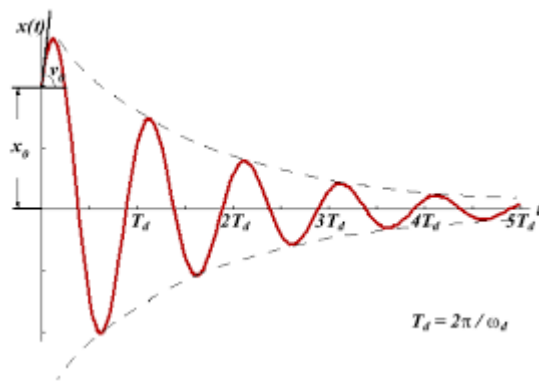
Frictional forces will diminish the amplitude of oscillation until eventually the system is at rest. Damped oscillations are clearly shown in the figure given below. In such a case, during each oscillation, some energy is lost. The amplitude of the oscillation will be reduced to zero as no compensating arrangement is provided. The only parameters that will remain unchanged are the frequency or time period.

Examples:

A swing once pulled and left.

An ordinary pendulum which is not isolated from other forces.

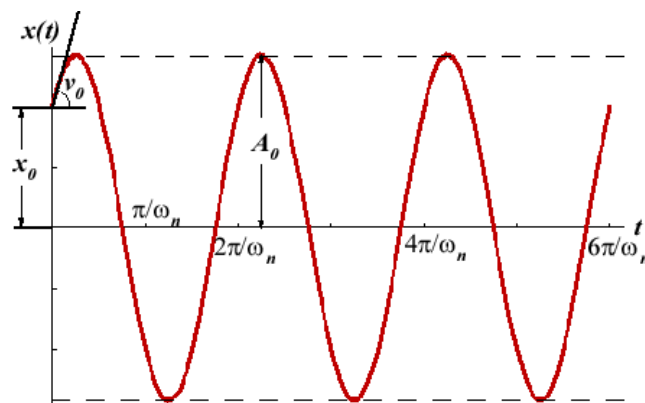
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Undamped vibrations:

Any oscillation in which the amplitude of the oscillating material remain constant with respect to time is called undamped vibration.

The correct amount of undamped oscillations will be obtained only if the correct amount of energy is supplied to overcome the losses at the right time in each cycle. The resulting “undamped oscillations” are also called sustained oscillations or continuous waves. Undamped oscillations is clearly shown in the figure given below.



Examples:

Pendulum in a clock to which energy is supplied using a battery

Resonance:

When one object vibrating at the same natural frequency of a second object forces that second object into vibrational motion, resonance occurs.

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1. Soldiers are asked to break the steps while marching across bridge.



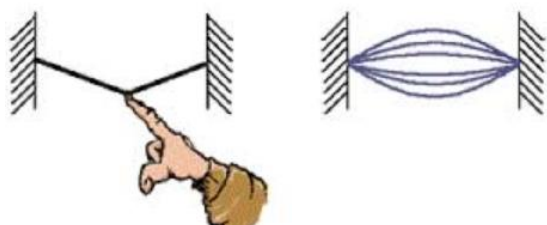
2. Tuning a Radio receiver

Laws of transverse vibrations of stretched string.

A string is tightly-stretched between two points. If the centre of the string is plucked vibrations move out in opposite directions along the string. This causes a transverse wave to travel along the string. The pulses travel outwards along the string and when they reach end of the string they are reflected back. The two travelling waves then interfere with each other to produce a standing wave in the string. In the fundamental mode of vibration there are points of no vibration or nodes at each end of the string and a point of maximum vibration or antinode at the centre.

The fundamental frequency (n) of vibration produced by a stretched string depends on the:

- (i) Vibrating length (l) of the string
- (ii) Its tension (T)
- (iii) Its mass per unit length (m) - which effectively means its thickness



1. **Law of Lengths:** - The fundamental frequency of transverse vibration of a stretched string " n " is inversely proportional to its vibrating length l , when the tension in the string T and mass per unit length m are kept constant.

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$$n \propto \frac{1}{l}, \text{ if } T \text{ and } m \text{ are kept constant}$$

2. **Law of Tension:** - The fundamental frequency of transverse vibration of a stretched string "n" is directly proportional to the square root of the tension T when its vibrating length l and mass per unit length m are kept constant.

$$n \propto \sqrt{T}, \text{ if } l \text{ and } m \text{ are constant}$$

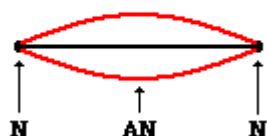
3. **Law of mass:** - The fundamental frequency of transverse vibration of a stretched string "n" is inversely proportional to the square root of its mass per unit length m when the tension in the string T and vibrating length l are kept constant.

$$n \propto \frac{1}{\sqrt{m}}, \text{ if } T \text{ and } l \text{ are constant}$$

Derivation for the fundamental frequency of transverse vibration of a stretched string "n"

Consider a string of length l, linear density m vibrating with one loop under the tension T. When the string vibrates in fundamental mode, the two ends become two adjacent nodes. The length between two adjacent nodes is $\lambda/2$.

**Fundamental Frequency
or 1st Harmonic**



$$l = \lambda/2$$

$$\lambda = 2l$$

$$v = n\lambda = n \times (2l)$$

$$v = \sqrt{\frac{T}{m}}$$

$$n \times (2l) = \sqrt{\frac{T}{m}}$$

$$\text{Therefore, } n = \frac{1}{2l} \sqrt{\frac{T}{m}} \text{ Hz}$$

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Problems:

1. A wire of length 1.5 m and mass 0.5 mg is stretched by a load of 15 kg. Find the frequency of vibration of wire.

Solution:

Data:

$$l = 1.5 \text{ m}$$

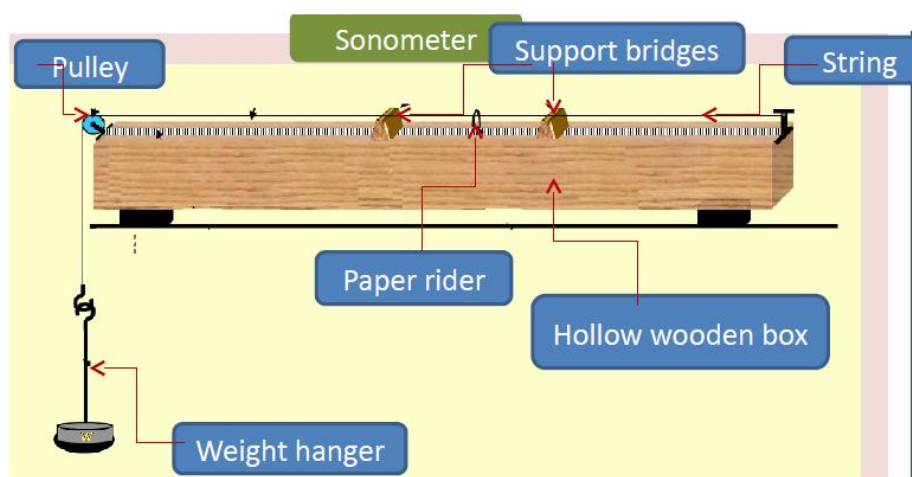
$$w = 0.5 \text{ mg} = 5 \times 10^{-4} \text{ kg}$$

$$T = 15 \times 9.8 \text{ N} = 147 \text{ N}$$

$$\text{linear density } m = \frac{w}{l} = \frac{5 \times 10^{-4}}{1.5} = 3.33 \times 10^{-4} \text{ kg/m}$$

$$n = \frac{1}{2l} \sqrt{\frac{T}{m}} = \frac{1}{2 \times 1.5} \sqrt{\frac{147}{3.33 \times 10^{-4}}} = 221.47 \text{ Hz}$$

Experiment to determine the unknown frequency of a given tuning fork by absolute and comparison methods using sonometer.

Sonometer.**Apparatus:**

The sonometer consists of a wire stretched between two supports or bridges on a wooden sounding box. The tension of the string may be varied by hanging weights on one end of it. The length of the vibrating wire can be changed using a small wooden support that can be moved along under the wire.

The purpose of the sounding box is to make a larger mass of air vibrate and so amplify the

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very small sounds produced by the vibrating string itself. The frequency at which the string is vibrating can be found by using a tuning fork of known frequency, which is made to vibrate and held with its base on the sounding box. The string is then tuned by adjusting the distance between two bridges to give the same note. A small piece of paper may be placed on the center of the wire and when the frequency of the wire is tuned to that of the fork resonance occurs and the wire will vibrate with maximum amplitude, throwing the piece of paper off. The distance between two bridges gives the resonating length corresponding to the tuning fork that is being used.

Absolute method:

Procedure:

1. The mass per unit length of the string is kept constant.
2. Resonating lengths corresponding to different tensions in the string is found.
3. Readings are tabulated as below.

Observations:

Mass per unit length of the wire, $m =$ kg/m

Tabular column:

Sl. No.	Mass attached in weight hanger M kg	Tension (T) in newton $T = Mg$	Resonating length l in m.			$\sqrt{\frac{T}{l}}$
			L1	L2	Mean length l	

Mean $\sqrt{\frac{T}{l}}$ is calculated

Calculations:

The unknown frequency of a given tuning fork by absolute method using sonometer is determined using the

$$\text{formula } n = \frac{1}{2\sqrt{m}} \frac{\sqrt{T}}{l} \text{ Hz}$$

Result: The unknown frequency of a given tuning fork determined using sonometer by absolute method is ----- Hz

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Comparison method:**Procedure:**

1. The tension, and mass per unit length of the string are kept constant.
2. Resonating length corresponding to different tuning forks is found.
3. Repeat the experiment with tuning forks of different frequencies.
4. Readings are tabulated as below.

Tabular column:

Sl. No.	Frequency of tuning fork n in Hz	Resonating length l in m.			nl	Mean nl
		L1	L2	Mean length l		
1.						
2.						
3.						

Mean nl is calculated

Calculations:

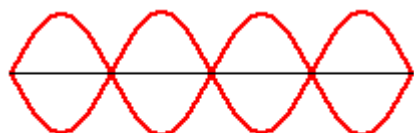
The unknown frequency of a given tuning fork by Comparison method using sonometer is

determined using the formula
$$n_x = \frac{(n \times l)_{\text{mean}}}{l_x} \text{ Hz}$$

Where, l_x is the resonating length of unknown frequency tuning fork.

Result: The unknown frequency of a given tuning fork determined using sonometer by comparison method is Hz

Stationary waves: A stationary wave is formed when two travelling waves moving in opposite directions along a same straight line superimpose on one another.



A standing wave pattern for a string

Stationary waves are created within a medium when the reflected waves from one end of the medium interfere with incident waves from the source. The result of the interference is

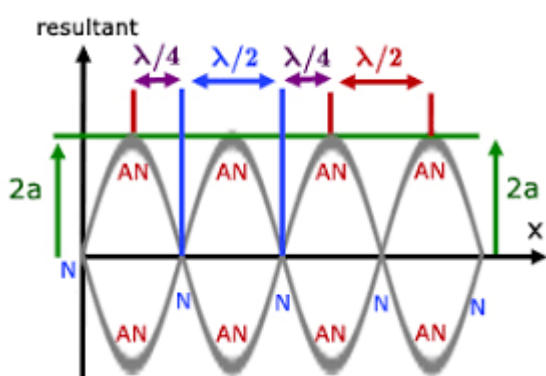
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that specific points along the medium appear to be standing still while other points vibrated back and forth.

The points in the pattern that are standing still are referred to as nodal points or node, which has zero amplitude. These positions occur as the result of the destructive interference of incident and reflected waves. Between two nodal points is a point, which has maximum amplitude called antinode or antinodal points creating an alternating pattern of nodal and antinodal points.

Fundamental frequency: This would be the harmonic with the longest wavelength and the lowest frequency. The lowest frequency produced by any particular instrument is known as the fundamental frequency. The fundamental frequency is also called the first harmonic of the instrument.

Characteristics of Stationary waves:



1. Stationary waves are localised means disturbance does not travel from one place to another.
2. Nodes and Antinodes are equally spaced. The distance between two consecutive nodes or two consecutive antinodes is equal to $\lambda/2$
3. Anode exist between two consecutive antinodes and viceversa. The distance between a node and the very next antinode is equal to $\lambda/4$
4. The period of oscillation of all the particles in the medium is equal.
5. There is no transfer of energy in the medium.
6. The amplitude of vibration varies from zero at node to maximum at antinode.

Experiment to determination of velocity of sound in air by using resonance air column apparatus.

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Apparatus: Resonance tube apparatus, tuning fork, and rubber pad.

Procedure:

1. Strike a tuning fork of frequency n Hz with a rubber pad and hold it at about an inch above the open end of the resonance tube with its prongs horizontal. Adjust the water level starting from its highest level.
2. Gradually increase the length of the air column by lowering the can to find the first position of resonance, where the sound coming out of the air column is loudest. You may have to strike the fork several times and move the water column up and down to precisely locate the resonance position.
3. Continue this procedure to find second (and if possible, the third) position of resonance. Record these lengths.
4. Repeat the experiment with a tuning fork of different frequency.
5. calculate the speed of sound from the formula

$$V = 2n(l_2 - l_1) \text{ m/s}$$

If you get only the first resonance, and not the second resonance then, to calculate the speed of the sound, use

$$V = 4nl \text{ m/s}$$

OBSERVATION:

Inner diameter of the pipe $d = \dots\dots\dots\text{m}$

End correction $e = 0.3 d = \dots\dots\dots\text{m}$

Room temperature $t = \dots\dots\dots^\circ\text{C}$

Tabular column:

Sl. No.	Frequency in Hz	Resonating length in cm.			Corrected Resonating length $l = (L + e)$ in m.	Velocity of sound $V_t = 4nl$ in m/s	Mean Velocity of sound V_t in m/s
		L1	L2	Mean L			
1							
2							
3							

Calculations:

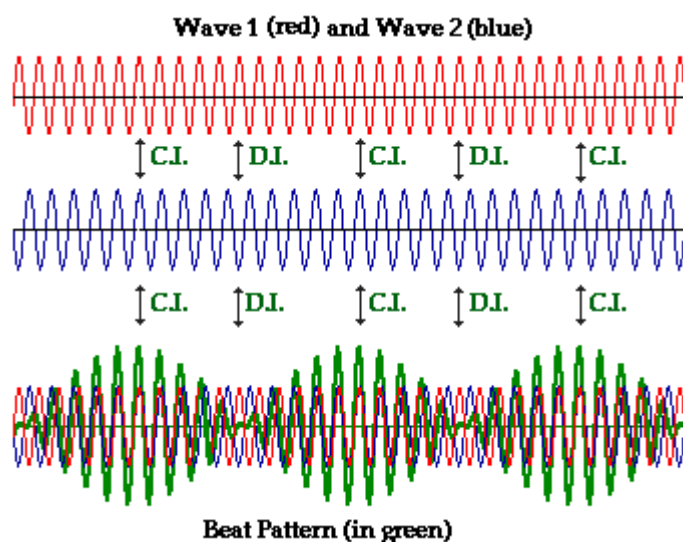
$$V_t = 4nl \text{ m/s}$$

2. To calculate the speed of sound at 0°C

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

$$V_0 = V_t \sqrt{\frac{273}{(273 + t)}} \text{ m/s}$$

Beats are the periodic and repeating fluctuations heard in the intensity of a sound when two sound waves of very similar frequencies interfere with one another.



The beat frequency is always equal to the difference in frequency of the two notes that interfere to produce the beats.

EXAMPLE:

If two sound waves with frequencies of 256 Hz and 254 Hz are played simultaneously, a beat frequency of 2 Hz will be detected. A common physics demonstration involves producing beats using two tuning forks with very similar frequencies. If the prongs of one of two identical tuning forks is wrapped with a rubber band, then that tuning fork's frequency will be lowered. If both tuning forks are vibrated together, then they produce sounds with slightly different frequencies. These sounds will interfere to produce detectable beats. The human ear is capable of detecting beats with frequencies of 7 Hz and below.

If two frequencies f_1 and f_2 interfere to produce the beats, then

Beat frequency = difference in frequency

Beat frequency = $f_1 - f_2$

Applications of Beats.

1. Tuning of musical instruments
2. Detection of harmful gases
3. Determination of frequency of tuning fork
4. To avoid music becoming monotonous in orchestra

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UNIT V: MODERN PHYSICS

ELECTROMAGNETIC WAVES

Introduction:

Waves are generally classified into two types based on the medium of propagation, as mechanical and non-mechanical waves. A mechanical wave needs a medium for propagation, example: water ripple, a vibrating string. A non-mechanical wave does not require a medium for propagation, example: light wave, radio waves etc.

Definition of electromagnetic wave

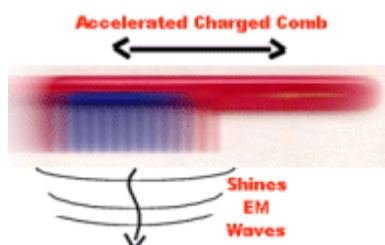
A wave of energy consisting of oscillating electric and magnetic fields is an electromagnetic wave. Radio waves, light waves, and x-rays are electromagnetic waves. These waves propagate with the speed of light by the periodic variations of electric and magnetic fields.

Generation of electromagnetic wave

It is a fact taken from observation of nature that any object that carries charge and moves with a nonzero acceleration radiates EM waves. Of course, the properties of the radiated EM waves strongly depend on HOW the source moved, what its acceleration was.



As a simple example, let's consider your comb, after you combed your hair. The comb is made of plastic, and it becomes charged after you brush your hair (your hair, of course, becomes charged with the equal, but opposite, charge). If one starts to wave the comb up and down, the charge on the comb moves with a nonzero acceleration, and therefore shines EM waves.



It should be emphasized that a charged object has to have a nonzero acceleration to be able to radiate. Steadily moving objects DO NOT radiate

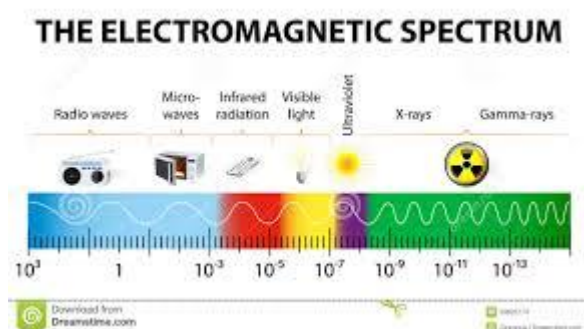
Some other methods of generation of electromagnetic waves

In an LC circuit, the charge oscillates (i.e., undergoing acceleration) across the capacitance plates. Therefore, an LC circuit emits electromagnetic waves which have the same frequency as that of the oscillating charge.

The emission of visible light is associated with electrons jumping from higher energy orbit to lower energy orbit.

X-rays are produced when fast moving electrons abruptly decelerate as they collide with a metal target of high atomic number.

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Electromagnetic spectrum:

Definition: The orderly classification of electromagnetic waves according to their wavelength or frequency is called the electromagnetic spectrum.

The entire range of electromagnetic radiation, which includes radiations, in order of increasing frequency and decreasing wavelength is known as electromagnetic spectrum. For example: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays, and gamma rays. The complete range of electromagnetic spectrum consists of the longest wavelength e.m wave radio waves (wavelength 105 meters) to the shortest gamma radiation (wavelength 10-13 meter).

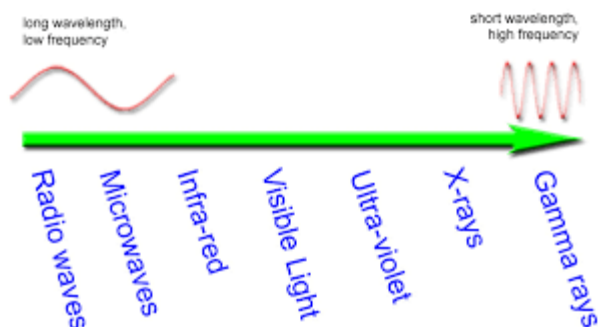
The electromagnetic spectrum can be measured in frequencies or in wavelengths. Visible light, which is a band of colors from red to violet, is the only portion of spectrum that can be seen by human eye.

Classification of electromagnetic spectrum:

Region	Wavelength (centimeters)	Frequency (Hz)
Radio	> 10	$< 3 \times 10^9$
Microwave	$10 - 0.01$	$3 \times 10^9 - 3 \times 10^{12}$
Infrared	$0.01 - 7 \times 10^{-5}$	$3 \times 10^{12} - 4.3 \times 10^{14}$
Visible	$7 \times 10^{-5} - 4 \times 10^{-5}$	$4.3 \times 10^{14} - 7.5 \times 10^{14}$
Ultraviolet	$4 \times 10^{-5} - 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{17}$
X-Rays	$10^{-7} - 10^{-9}$	$3 \times 10^{17} - 3 \times 10^{19}$
Gamma Rays	$< 10^{-9}$	$> 3 \times 10^{19}$

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Applications of electromagnetic spectrum



For convenience, the electromagnetic spectrum is divided into following regions:

Gamma rays
X-rays
Ultraviolet rays
Visible light
Infra-red rays
Microwaves
Radio waves.

Applications of gamma rays:

They are used to kill cancerous cells in humans but care is needed in their use because they also attack and kill healthy cells.

They are used to produce nuclear reactions.

They are used for detecting flaws in metal castings.

Applications of x-rays:

They are used to produce pictures of the internal organs of the body.

They are used to kill dangerous cells and tumors in the body.

They are used to study the structure of crystals and arrangement of atoms and molecules in a complex substance.

Applications of ultraviolet rays:

They are used for checking the mineral samples for fluorescence under ultraviolet radiation.

Ultraviolet radiation destroys bacteria and is used to sterilize surgical equipment.

They are used to study the molecular structure.

Applications of visible light:

They are used in photography.

They are used in photocells.

They are used in imaging.

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Applications of infra-red rays:

They are used for cooking, heating and drying.

They are used by earth resource satellites to detect healthy crops.

They are used to treat muscular strains.

Applications of microwaves

They are used in radar and telemetry.

They are used in the study of atomic and molecular structure.

Microwave ovens are useful because they reduce cooking time considerably.

Applications of radio waves:

They are used in radio and television communication system.

They are used for ground wave propagation.

It is used for sky wave propagation.

LASERS

LASER: L - Light

A - Amplification by

S - Stimulated

E - Emission of

R - Radiation.

Principle of laser:

Laser is the abbreviation of Light Amplification by the Stimulated Emission of Radiation. It is a device that creates a narrow and low-divergent beam of coherent light, while most other light sources emit incoherent light, which has a phase that varies randomly with time and position. Most lasers emit nearly "monochromatic" light with a narrow wavelength spectrum.

The principle of a laser is based on three separate features: a) stimulated emission within an amplifying medium, b) population inversion of electronics and c) an optical resonator.

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Spontaneous Emission and Stimulated Emission

According to the quantum mechanics, an electron within an atom can have only certain values of energy, or energy levels. There are many energy levels that an electron can occupy, but here we will only consider two. If an electron is in the excited state with the energy E_2 it may spontaneously decay to the ground state, with energy E_1 , releasing the difference in energy between the two states as a photon as shown in the figure (a) below. This process is called spontaneous emission, producing fluorescent light. The phase and direction of the photon in spontaneous emission are completely random due to Uncertainty Principle. The angular frequency ω and energy of the photon is:

(1)

$$E_2 - E_1 = \hbar\omega$$

Where \hbar is the reduced plank constant.

Conversely, a photon with a particular frequency satisfying the above equation would be absorbed by an electron in the ground state. The electron remains in this excited state for a period of time typically less than 10^{-6} second. Then it returns to the lower state spontaneously by a photon or a phonon. These common processes of absorption and spontaneous emission cannot give rise to the amplification of light. The best that can be achieved is that for every photon absorbed, another is emitted.

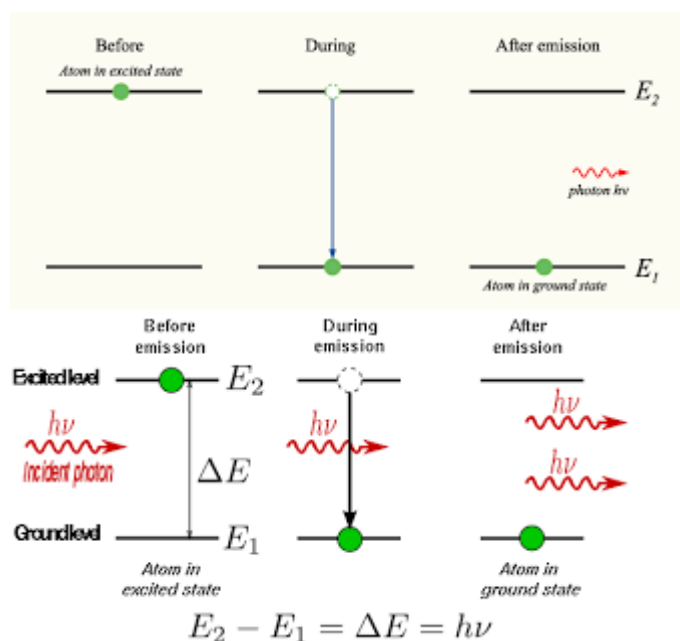


Diagram of (a) spontaneous Emission; and (b) stimulated Emission

Alternatively, if the excited-state atom is perturbed by the electric field of a photon with frequency ω , it may release a second photon of the same frequency, in phase with the first photon. The atom will again decay into the ground state. This process is known as stimulated emission as shown in fig (b).

The emitted photon is identical to the stimulating photon with the same frequency, polarization, and direction of propagation. And there is a fixed phase relationship between light radiated from different atoms. The photons, as a result, are totally coherent. This is the critical property that allows optical amplification to take place.

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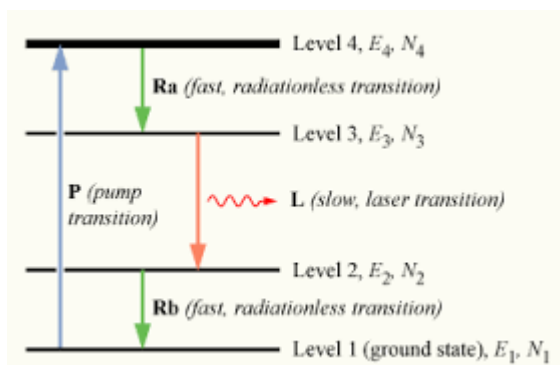
All the three processes occur simultaneously within a medium. However, in thermal equilibrium, stimulated emission does not account to a significant extent. The reason is there are far more electrons in the ground state than in the excited states. And the rates of absorption and emission are proportional to the number of electrons in ground state and excited states, respectively, so absorption process dominates.

Population Inversion

If the higher energy state has a greater population than the lower energy state, then the light in the system undergoes a net increase in intensity. And this is called population inversion. But this process cannot be achieved by only two states, because the electrons will eventually reach equilibrium with the de-exciting processes of spontaneous and stimulated emission.

Instead, an indirect way is adopted, with three energy levels ($E_1 < E_2 < E_3$) and energy population N_1 , N_2 and N_3 respectively. (See Fig. below) Initially, the system is at thermal equilibrium, and the majority of electrons stay in the ground state. Then external energy is provided to excite them to level 3, referred as pumping. The source of pumping energy varies with different laser medium, such as electrical discharge and chemical reaction, etc.

In a medium suitable for laser operation, we require these excited atoms to quickly decay to level 2, transferring the energy to the phonons of the lattice of the host material. This wouldn't generate a photon, and labeled as R, meaning radiation less. Then electrons on level 2 will decay by spontaneous emission to level 1, labeled as L, meaning laser. If the life time of L is much longer than that of R, the population of the E_3 will be essentially zero and a population of excited state atoms will accumulate in level 2. When level 2 hosts over half of the total electrons, a population inversion be achieved.



(b) Electron Transitions within (a) 3-level gain medium; and (b) 4-level gain medium

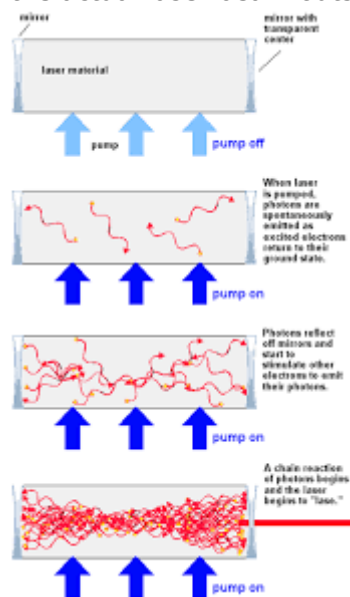
Because half of the electrons must be excited, the pump system needs to be very strong. This makes three-level lasers rather inefficient. Most of the present lasers are 4-level lasers, see Fig. below. The population of level 2 and 4 are 0 and electrons just accumulate in level 3. Laser transition takes place between level 3 and 2, so the population is easily inverted.

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Optical Resonator

Stimulated emission on axis. The "back" mirror is made as close to 100% reflective as possible, while the "front" Although with a population inversion we have the ability to amplify a signal via stimulated emission, the overall gain is quite small, and most of the excited atoms in the population emit spontaneously and do not contribute to the overall output. Then the resonator is applied to make a positive feedback mechanism.

An optical resonator usually has two flat or concave mirrors, one on either end, that reflect lasing photons back and forth so that stimulated emission continues to build up more and more laser light. Photons produced by spontaneous decay in other directions are off axis so that they won't be amplified to compete with mirror typically is made only 95 - 99% reflective so that the rest of the light is transmitted by this mirror and leaks out to make up the actual laser beam outside the laser device.



Schematic Diagram of Laser Operation

The output of a laser may be a continuous constant-amplitude output (known as CW or continuous wave); or pulsed, by using the techniques of Q-switching, model-locking, or gain-switching. In many applications of pulsed lasers, one aims to deposit as much energy as possible at a given place in as short time as possible. Some dye lasers and vibronic solid-state lasers can produce light over a broad range of wavelengths; this property makes them suitable for generating extremely short pulses of light, on the order of a few femtoseconds (10⁻¹⁵ s).[1] The peak power of pulsed laser can achieve 10¹² Watts.

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Properties of lasers:**Types of Lasers and Applications**

According to the gain material, lasers can be divided into the following types. Several common used lasers are listed in each type.

Gas Lasers:

Laser Type	Applications
Helium-neon laser	Interferometry, holography, spectroscopy, barcode scanning, alignment, optical demonstrations
Argon laser	Retinal phototherapy (for diabetes), lithography, confocal microscopy, spectroscopy pumping other lasers
Carbon dioxide laser	Material processing (cutting, welding, etc.), surgery
Excimer laser	Ultraviolet lithography for semiconductor manufacturing, laser surgery

Solid State Lasers:

Laser type	Applications
Ruby laser	Holography, tattoo removal. The first type of visible light laser invented; May 1960.
Nd:YAG laser	Material processing, laser target designation, surgery, research, pumping other lasers. One of the most common high power lasers.
Erbium doped glass lasers	Um doped fibers are commonly used as optical amplifiers for telecommunications.
F-center laser	Research

Metal-vapour Lasers:

Laser type	Applications
Helium-cadmium (HeCd) metal-vapor laser	Printing and typesetting applications, fluorescence excitation examination (i.e. in U.S. paper currency printing)
Copper vapour laser	Dermatological uses, high speed photography, pump for dye lasers

Other types of lasers:

Laser type	Applications
Dye lasers	Research, spectroscopy, birthmark removal, isotope separation.
Free electron laser	Atmospheric research, material science, medical applications

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Nanotechnology

Definition of nano technology:

Nanotechnology is science, engineering, and technology conducted at the nano-scale, which is about 1 to 100 nano-meters. Physicist Richard Feynman, the father of nanotechnology.

Advantages of Nanotechnology

1. Nanotechnology can actually revolutionize a lot of electronic products, procedures, and applications using nano transistors, nano diodes, OLED, plasma displays, quantum computers, and many more.
2. Nanotechnology is also beneficial in the energy sector. The development of more effective energy-producing, energy-absorbing, and energy storage products in smaller and more efficient devices is possible with this technology.
3. Another industry that can benefit from nanotechnology is the manufacturing sector because materials like nanotubes, aerogels, nano particles, and other similar items can be used to produce their products. These materials are often stronger, more durable, and lighter than those that are not produced with the help of nanotechnology.
4. In the medical world, nanotechnology is also seen as a boon since these can help with creating what is called smart drugs. These help cure people faster and without the side effects that other traditional drugs have.
5. It also found that the research of nanotechnology in medicine is now focusing on areas like tissue regeneration, bone repair, immunity and even cures for such ailments like cancer, diabetes, and other life threatening diseases.

Disadvantages of nanotechnology

1. One of the biggest disadvantages that world is facing because of nanotechnology is the lack of employment in the fields of traditional farming and manufacturing and industrial sector because of the vast development in the nanotechnology.
2. Increasing development and instant performance has also increased the fall of certain markets like diamond and oil because of the low value of diamond and oil .Presence of alternative has decreased the demand because alternates are more efficient and do not require the use of fossil fuels. Diamonds have lost its value because it is now produced massively with the help of nanotechnology.
3. Another big threat, which is born with the advent of nanotechnology, is the easy accessibility of atomic weapons. Nanotechnology has made these weapons more powerful and more destructive.
4. Nanotechnology has increased risk to the health also, nano-particles due to there their small size can cause inhalation problem and many other fatal diseases.
5. At present nanotechnology is on the most expensive technologies and its cost is increasing day by day.
6. Working with nanotechnology is quite risky also; Manufacturers have to invest huge money for starting nano tech plants and if products produced fail to satisfy the customer then manufacturer bear a lot of loss.

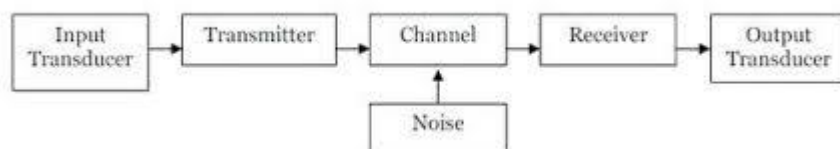
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7. Nanotechnology also raised some practical problems. Practical problems can include everything which is to be produced from masses like coal, petroleum.

Advanced communication systems

Introduction:

Communication is the act of transmission of information. Every living creature in the world experiences the need to impart or receive information almost continuously with others in the surrounding world. For communication to be successful, it is essential that the sender and the receiver understand a common language. The pace of development seems to have increased dramatically after the first half of the 20th century. We can hope to see many more accomplishments in the coming decades. The aim of this chapter is to introduce the concepts of communication, namely the mode of communication, the need for modulation, production and deduction of amplitude modulation.



Elements of a communication system:

Every communication system has three essential elements-

1. The transmitter is located at one place: The purpose of the transmitter is to convert the message signal produced by the source of information into a form suitable for transmission through the channel. If the output of the information source is a non-electrical signal like a voice signal, a transducer converts it to electrical form before giving it as an input to the transmitter.
2. The receiver is located at some other place (far or near) separate from the transmitter: Moreover, noise adds to the transmitted signal and the receiver receives a corrupted version of the transmitted signal. The receiver has the task of operating on the received signal. It reconstructs a recognizable form of the original message signal for delivering it to the user of information.
3. The channel is the physical medium that connects them: Depending upon the type of communication system, a channel may be in the form of wires or cables connecting the transmitter and the receiver or it may be wireless.

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Basic terminology used in electronic communication systems

(i) Transducer: Any device that converts one form of energy into another can be termed as a transducer. In electronic communication systems, we usually come across devices that have either their inputs or outputs in the electrical form. An electrical transducer may be defined as a device that converts some physical variable (pressure, displacement, force, temperature, etc.) into corresponding variations in the electrical signal at its output.

(ii) Signal: Information converted in electrical form and suitable for transmission is called a signal. Signals can be either analog or digital.

Analog signals are continuous variations of voltage or current.

Digital signals are those which can take only discrete stepwise values. Binary system that is extensively used in digital electronics employs just two levels of a signal. '0' corresponds to a low level and '1' corresponds to a high level of voltage/ current.

(iii) Noise: Noise refers to the unwanted signals that tend to disturb the transmission and processing of message signals in a communication system. The source generating the noise may be located inside or outside the system.

(iv) Transmitter: A transmitter processes the incoming message signal so as to make it suitable for transmission through a channel and subsequent reception.

(v) Receiver: A receiver extracts the desired message signals from the received signals at the channel output.

(vi) Attenuation: The loss of strength of a signal while propagating through a medium is known as attenuation.

vii) Amplification: It is the process of increasing the amplitude (and consequently the strength) of a signal using an electronic circuit called the amplifier. Amplification is necessary to compensate for the attenuation of the signal in communication systems.

(viii) Range: It is the largest distance between a source and a destination up to which the signal is received with sufficient strength.

(ix) Bandwidth: Bandwidth refers to the frequency range over which equipment operates or the portion of the spectrum occupied by the signal.

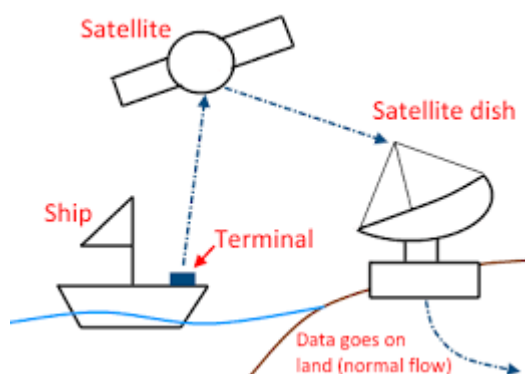
(x) Modulation: The original low frequency message/information signal cannot be transmitted to long distances because of various reasons. Therefore, at the transmitter, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information. This process is known as modulation.

(xi) Demodulation: The process of retrieval of information from the carrier wave at the receiver is termed demodulation. This is the reverse process of modulation.

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(xii) Repeater: A repeater is a combination of a receiver and a transmitter. A repeater, picks up the signal from the transmitter, amplifies and retransmits it to the receiver sometimes with a change in carrier frequency. Repeaters are used to extend the range of a communication system. A communication satellite is essentially a repeater station in space.

Satellite communication



In satellite communication, signal transferring between the sender and receiver is done with the help of satellite. In this process, the signal which is basically a beam of modulated microwaves is sent towards the satellite. Then the satellite amplifies the signal and sent it back to the receiver's antenna present on the earth's surface. So, all the signal transferring is happening in space. Thus this type of communication is known as space communication.

Advantages of Satellite Communication:

Because of its unique geometry and it's inherently a broadcast medium with an ability to transmit simultaneously from one point to an arbitrary number of other points within its coverage area. Thus satellite Communication possesses several advantages which are as follows:

1. Point to multipoint communication is possible whereas terrestrial relay are point to point, this is why satellite relay are wide area broadcast.
2. Circuits for the satellite can be installed rapidly. Once the satellite is in position, Earth Station can be installed and communication may be established within some days or even hours.
3. During critical condition each Earth Station may be removed relatively quickly from a location and reinstalled somewhere else.
4. Mobile communication cab be easily achieved by satellite communication because of its flexibility in interconnecting mobile vehicles.
5. As compared to fiber cable, the satellite communication has the advantage of the quality of transmitted signals and the location of Earth Stations. The sending and receiving information independent of distance.

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Disadvantages of Satellite Communication:

Apart from advantages Satellite Communication also has some disadvantages that are as follows:-

1. With the Satellite in position the communication path between the terrestrial transmitter and receiver is approximately 75000 km long.
2. There is a delay of $\frac{1}{4}$ sec between the transmission and reception of a signal because the velocity of electromagnetic wave is 3×10^5 Km/second.
3. The time delay reduces the efficiency of satellite in data transmission and long file transfer, which carried out over the satellites.
4. Overcrowding of available bandwidth due to low antenna gains is occurred.
5. High atmosphere losses occur above 30 GHz, limit the carrier frequency.

Optical fibre

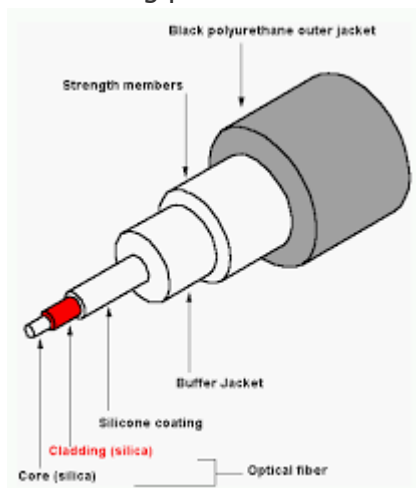
It refers to the medium and the technology associated with the transmission of information as light pulses along a glass or plastic strand or fibre. Optical fibre carries much more information than conventional copper wire and is in general not subject to electromagnetic interference and the need to retransmit signals. Most telephone company long-distance lines are now made of optical fibre.

An optical fibre is made of three sections:

The core carries the light signals

The cladding keeps the light in the core

The coating protects the cladding

**Principle of optical fibre:**

An Optical Fibre works on the principle of Total Internal Reflection Light rays are reflected and guided down the length of an optical fibre. The acceptance angle of the fibre determines which light rays will be guided down the fibre.

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Applications of optical fibres:

Telecommunication applications are widespread, ranging from global networks to desktop computers. These involve the transmission of voice, data, or video over distances of less than a meter to hundreds of kilometres, using one of a few standard fibre designs in one of several cable designs.

Carriers use optical fibre to carry plain old telephone service (POTS) across their nationwide networks. Local exchange carriers (LECs) use fibre to carry this same service between central office switches at local levels, and sometimes as far as the neighbourhood or individual home.

Optical fibre is also used extensively for transmission of data. Multinational firms need secure reliable systems to transfer data and information between buildings to the desktop terminals or computers and to transfer data around the world. Cable television companies also using fibre for delivery of digital video and data services. The high bandwidth provided by fibre makes it the perfect choice for transmitting broadband signals, such as high-definition television (HDTV) telecasts.

Intelligent transportation systems, such as smart highways with intelligent traffic lights, automated tollbooths, and changeable message signs, also use fibre-optic-based telemetry systems.

Another important application for optical fibre is the biomedical industry. Fibre-optic systems are used in most modern telemedicine devices for transmission of digital diagnostic images.

Other applications for optical fibre include space, military, automotive, and the industrial sector.

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UNIT VI: INDUSTRIAL CHEMISTRY

Electrolysis:

It is an electro-chemical process in which current is passed between two electrodes through an ionized solution (electrolyte) to deposit positive ions (anions) on the negative electrode (cathode) and negative ions (cations) on the positive electrode (anode).

Basic principles of electrolysis were discovered by the UK scientist Michael Faraday (1791-1867) and were developed by the Swedish scientist Svante Arrhenius (1859-1927) winner of the 1903 Nobel Prize in chemistry.

The entire system is called electrolytic cell which is used in several industries such as electroplating, refining bauxite into aluminium, producing chlorine and caustic soda from table salt (sodium chloride), and in analytical techniques such as palaeography.

Electrolyte:

Electrolytes are non-metallic liquid or solid substance which (when melted or dissolved in water or a solvent disassociates into ions and can transmit electric current through positively and negatively charged ions. Common electrolytes include salts such as aluminium sulphate, ammonium chloride, copper sulphate, sodium chloride (table salt), and acids such as hydrochloric and sulphuric.

Types of electrolytes

Electrolytes are generally classified into Strong, Weak, and Non Electrolytes

Strong electrolytes:

Strong electrolytes completely ionize in water. This means 100% of the dissolved chemical breaks into cat ions and anions. However, it does not mean the chemical completely dissolves in water! For example, some species are only slightly soluble in water, yet are strong electrolytes. An example is the strong base Strontium hydroxide, $\text{Sr}(\text{OH})$. It has a low solubility in water, but dissociates completely into Sr^{2+} and OH^- Ions.

Examples: Strong acids, strong bases, and salts are strong electrolytes.

Weak electrolytes:

Weak electrolytes partially ionize in water. Around 1% to 10% of a weak electrolyte breaks into ions.

Examples: Weak acids and weak bases are weak electrolytes. Most nitrogen- containing molecules are weak electrolytes.

Non electrolytes:

If a substance doesn't ionize in water at all, it's a non-electrolyte.

Examples: Most carbon compounds are non-electrolytes. Fats, sugars, and alcohols are largely non electrolytes.

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Arrhenius postulates of electrolytic dissociation or ionization:

In 1887, Svanta Arrhenius, a Swedish chemist put forward a theory to explain the behaviour of electrolytes during electrolysis. This theory is known as theory of electrolytic dissociation. Following are the postulates of Arrhenius theory.

The splitting up of an electrolyte in solution into ions is called ionization or electrolytic dissociation. The positively charged particles are called cations and negatively charged particles are called anions.

Examples: sodium chloride when dissolved in water dissociates into sodium (Na^+) and chloride (Cl^-) ions.



The charge carried by an ion is equal to the valence of its atom or radical.

Example: The valence of copper is 2. An ion of copper (Cu^{+2}) carries 2 units of positive charge. The total number of positive and negative charges or the ions produced is equal. Therefore the solution as whole is electrically neutral. Whole amount of the electrolyte is not ionised. Only a part of the electrolyte is ionized. There is equilibrium between the ionised and unionised components of the solution. Movement of ions causes current in the solution.

Mechanism of electrolysis:

The mechanism of electrolyte can be explained on the basis of Arrhenius theory.

Example: electrolysis of NaCl. Formation of NaCl: During the formation of NaCl, sodium loses an electron and becomes positively charged and chlorine gains this electron and becomes negatively charged.



Sodium chloride when dissolved in water dissociates into sodium (Na^+) and chloride (Cl^-) ions.

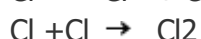
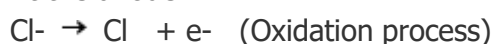


Suppose an electric current is passed through the solution by dipping two carbon electrodes in the solution. Then, the positively charged Na^+ ions are attracted towards the cathode or negative electrode and their charges are neutralised.

At the cathode: $\text{Na}^{++} \text{e}^- \rightarrow \text{Na}$ (Reduction process)

Simultaneously, the negatively charged chloride ions are attracted towards the anode or positive electrode and their charges are neutralised. Neutral atoms of chlorine combine to form chlorine molecules.

At the anode:



Thus the mechanism of electrolysis can be explained on the basis of ionic theory.

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Faraday's laws of electrolysis:

After careful study of the phenomenon of electrolysis from quantitative point of view, Faraday formulated the following two laws of electrolysis.

1st law: The mass of a substance liberated during electrolysis is directly proportional to the quantity of electricity passed.

If "m" is the mass of the substance liberated during electrolysis due to passing of a quantity of electricity Q then

$$m \propto Q$$

$$m = ZQ$$

Where 'Z' is a constant depending on the nature of the substance liberated and called the electro chemical equivalent of the substance (ECE).

But $Q = i \times t$

"i" being the strength of the current flowing for "t" seconds.

$$m = Z \times i \times t$$

If $i = 1\text{A}$, $t = 1\text{ second}$ then,

$$m = Z \text{ or } Z = m.$$

Definition of electrochemical equivalent: (ece)

Electro-chemical equivalent of a substance is the mass of the substance liberated during electrolysis due to passing of 1 ampere current for 1 second or 1 coulomb of electricity.

$$\text{Now } m = \frac{Z \times i \times t}{i \times t} \text{ or } Z = \frac{m}{i \times t} \text{ gm/amp/sec or Kg/A/S}$$

FARADAY'S 2nd LAW: When the same quantity of electricity is passed through different electrolytes, the masses of the substances liberated are proportional to their chemical equivalent weights. Whose equivalent weights are e_1, e_2, e_3, \dots respectively (due to same quantity of electricity) then

$$m_1 \propto e_1, \quad m_2 \propto e_2, \quad m_3 \propto e_3, \dots$$

Equivalent weight of a substance: Compounds are formed due to the combining of the elements in definite weights. Combining weights of the elements are called equivalent weights.

Example: In the formation of NaCl 23 grams of sodium combines with 35.5 grams of chlorine. Hence equivalent weight of sodium=23 g.

Corrosion

Corrosion is the deterioration of a metal as a result of chemical reactions between it and the surrounding environment.

Corrosion is the degradation of materials from either a chemical or electrochemical reaction. Chemical corrosion is typical of polymer materials, such as coatings and laminate films. Electrochemical corrosion is typical of metals and involves removal of electrons from the



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metal with a corresponding change of chemical state for atoms at the corrosion site.

An often asked question is: what basic factors are necessary for spray package corrosion? There are three basic factors needed to initiate and propagate corrosion:

- Environment
- Materials
- Surface

Electrochemical Corrosion Theory:

Electrochemical corrosion involves two half-cell reactions; an oxidation reaction at the anode and a reduction reaction at the cathode. For iron corroding in water with a near neutral pH, these half-cell reactions can be represented as:

<https://youtu.be/T4pSufIO9fk>

Anode reaction: $2\text{Fe} \Rightarrow 2\text{Fe}^{2+} + 4\text{e}^-$

Cathode reaction: $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \Rightarrow 4\text{OH}^-$

There are obviously different anodic and cathodic reactions for different alloys exposed to various environments. These half-cell reactions are thought to occur (at least initially) at microscopic anodes and cathodes covering a corroding surface. Macroscopic anodes and cathodes can develop as corrosion damage progresses with time.

Schematic representation of electrochemical corrosion process
(aqueous corrosion of iron under near neutral pH conditions)

http://www.corrosion-club.com/images/corrosioncell_small.gif

click on image to enlarge

Schematic representation of current flow (conventional current direction)
in a simple corrosion cell

From the above theory it should be apparent that there are four fundamental components in an electrochemical corrosion cell:

An anode.

A cathode.

A conducting environment for ionic movement (electrolyte).

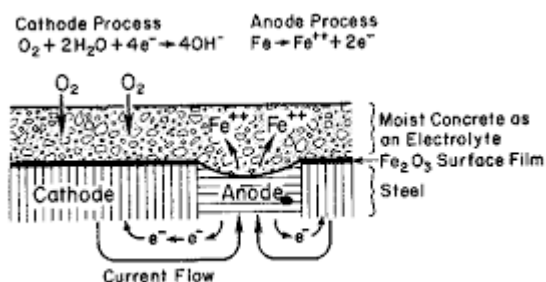
An electrical connection between the anode and cathode for the flow of electron current

If any of the above components is missing or disabled, the electrochemical corrosion process will be stopped. Clearly, these elements are thus fundamentally important for corrosion control.

Types of cells enabling corrosion

Composition cell: This cell is being usually set up between two dissimilar metals in contact. One metal acts as anode and the other acts as cathode and a cell is established. In the electrochemical series of metals, the lesser atomic number metal acts as cathode and higher atomic number metal acts as anode. The anode undergoes corrosion. In the series if the two metals are farther away, potential difference of the cell is more and effects in more corrosion.

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Stress cell: This type of galvanic cell is established between stressed and unstressed areas of the metal. The stressed area having higher energy serves as anode and unstressed areas serve as cathode.



Concentration cell: This cell is established between the clean surfaces and surface of contamination. The surface with dirt or contamination has less oxygen supply and behaves like anode. Whereas clean surface acts as cathode.

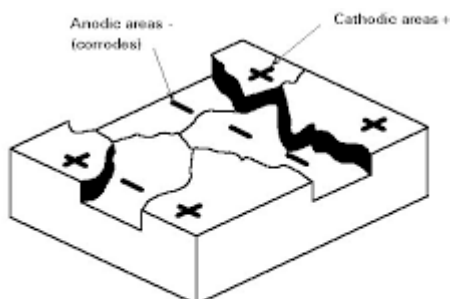


Figure 1 Local electro-chemical action on wet steel surface

Methods of prevention of corrosion:

- Alloying.
- Protection by paints.
- Protection by metals.
- Protection by organic coating.
- Cathode or galvanic protection.
- Sacrificial anodic method.

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Batteries



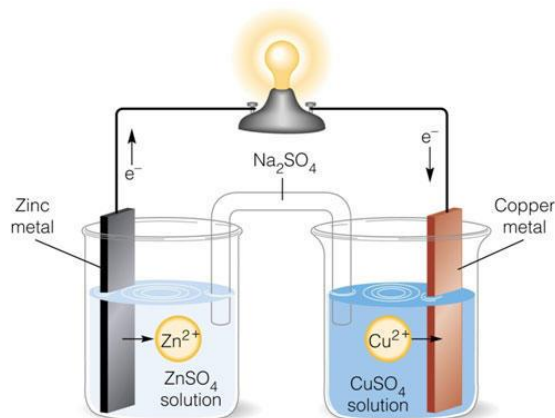
Humphrey Davy discovered the phenomenon of chemical decomposition (Electrolysis) on passing electricity through substances. In 1802, William Cruickshank designed the first electrical battery for mass production which resembled the flooded battery we still use. In 1859, Gaston Plante invented the first rechargeable battery based on lead acid system which is still very popular and hence came the first secondary cell. In 1899, Waldmar Jungner invented the Nickel-Cadmium battery using Nickel for cathode and Cadmium for anode. It was further improved by many people like Thomas Edison, Shlecht, Ackermann and Georg Nuemann. It remained popular for many years to come until

environmentalists became concerned about contamination, if NiCd were disposed off carelessly. This led to the development of Nickel Metal Hydrides and later the popular Lithium Ion batteries.

Basics of a battery

So what actually is a Battery?

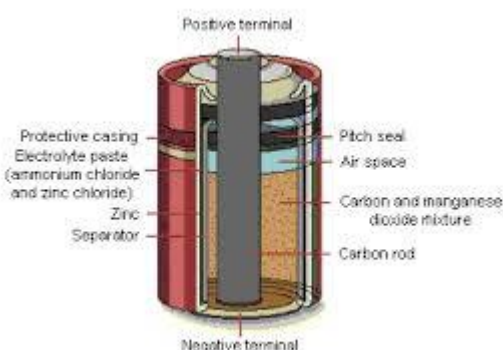
It is a collection of one or more electrochemical cells in which stored chemical energy is converted into electrical energy. The principles of operation haven't changed much since the time of Volta. Each cell consists of two half cells connected in series through an electrolytic solution. One half cell houses the Anode to which the positive ions migrate from the Electrolyte and the other houses the Cathode to which the negative ones drift. The two cells may be connected via a semi permeable membranous structure allowing ions to flow but not the mixing of electrolytes as in the case of most primary cells or in the same solution as in secondary cells.



Different amounts of voltages are built up according to the separation between the ions in the electrochemical series which results in the flow of ions in the solution and electrons in the external circuitry in the form of current. The performance of the cell continues to dip gradually as the concentration of ions in the solutions decrease, marked by an increase in internal resistance eventually leading to the exhaustion of the battery. The reversibility of this condition classifies the battery into two major categories, Primary and Secondary. Electrochemical batteries are classified into 4 broad categories.

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A primary cell or battery is one that cannot easily be recharged after one use, and are discarded following discharge. Most primary cells utilize electrolytes that are contained within absorbent material or a separator (i.e. no free or liquid electrolyte), and are thus termed dry cells.



A secondary cell or battery is one that can be electrically recharged after use to their original pre-discharge condition, by passing current through the circuit in the opposite direction to the current during discharge. The following graphic evidences the recharging process.

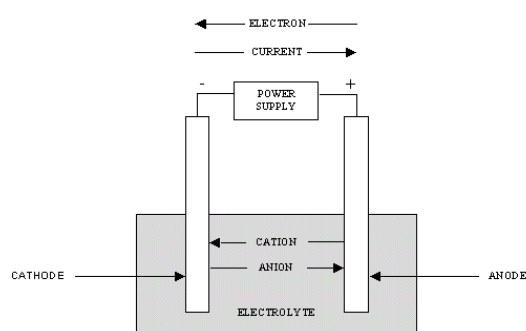


Figure 3: Recharging a Cell

Secondary batteries fall into two sub-categories depending on their intended applications.

Cells that are utilized as energy storage devices, delivering energy on demand. Such cells are typically connected to primary power sources so as to be fully charged on demand. Examples of these type of secondary cells include emergency no-fail and standby power sources, aircraft systems and stationary energy storage systems for load-levelling.

Cells that are essentially utilized as primary cells, but are recharged after use rather than being discarded. Examples of these types of secondary cells primarily include portable consumer electronics and electric vehicles.

A third battery category is commonly referred to as the reserve cell. What differentiates the reserve cell from primary and secondary cells is the fact that a key component of the cell is separated from the remaining components, until just prior to activation. The component most often isolated is the electrolyte. This battery structure is commonly observed in thermal batteries, whereby the electrolyte remains inactive in a solid state until the melting point of the electrolyte is reached, allowing for ionic conduction, thus activating the battery. Reserve batteries effectively eliminate the possibility of self-discharge and minimize chemical deterioration. Most reserve batteries are used only once and then

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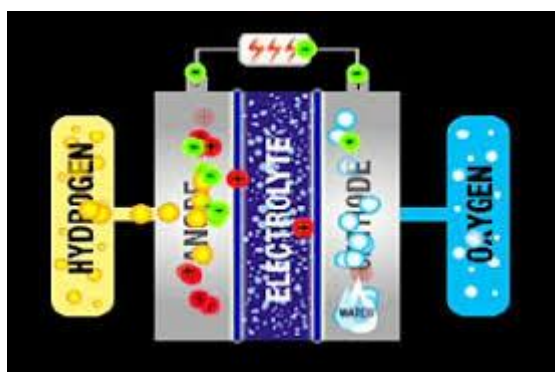
discarded. Reserve batteries are used in timing, temperature and pressure sensitive detonation devices in missiles, torpedoes, and other weapon systems.

Reserve cells are typically classified into the following 4 categories.

- Water activated batteries.
- Electrolyte activated batteries.
- Gas activated batteries.
- Heat activated batteries.

The fuel cell represents the fourth category of batteries. Fuel cells are similar to batteries except for the fact that all active materials are not an integral part of the device (as in a battery). In fuel cells, active materials are fed into batteries from an outside source. The fuel cell differs from a battery in that it possesses the capability to produce electrical energy as long as active materials are fed to the electrodes, but stop operating in the absence of such materials. A well-known application of fuel cells has been in cryogenic fuels used in space vehicles. Use of fuel cell technology for terrestrial applications has been slow to develop, although recent advances have generated a revitalized interest in a variety of systems with applications such as utility power, load-levelling, on-site generators and electric vehicles.

Fuel cells



An electrochemical cell in which the energy of a reaction between a fuel, such as liquid hydrogen, and an oxidant, such as liquid oxygen, is converted directly and continuously into electrical energy.

Types of fuel cells

- Polymer electrolyte membrane (PEM) fuel cells
- Direct methanol fuel cells
- Alkaline fuel cells
- Phosphoric acid fuel cells
- Molten carbonate fuel cells
- Solid oxide fuel cells
- Reversible fuel cells.

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Advantages of fuel cells

Fuel cells have various advantages compared to conventional power sources, such as internal combustion engines or batteries. Although some of the fuel cells' attributes are only valid for some applications, most advantages are more general.

Benefits include:

Fuel cells have a higher efficiency than diesel or gas engines.

Most fuel cells operate silently, compared to internal combustion engines. They are therefore ideally suited for use within buildings such as hospitals.

Fuel cells can eliminate pollution caused by burning fossil fuels; for hydrogen fuelled fuel cells, the only by-product at point of use are water.

If the hydrogen comes from the electrolysis of water driven by renewable energy, then using fuel cells eliminates greenhouse gases over the whole cycle.

Fuel cells do not need conventional fuels such as oil or gas and can therefore reduce economic dependence on oil producing countries, creating greater energy security for the user nation.

Since hydrogen can be produced anywhere where there is water and a source of power, generation of fuel can be distributed and does not have to be grid dependent.

The use of stationary fuel cells to generate power at the point of use allows for a decentralized power grid that is potentially more stable.

Low temperature fuel cells (PEMFC, DMFC) have low heat transmission which makes them ideal for military applications.

Higher temperature fuel cells produce high-grade process heat along with electricity and are well suited to cogeneration applications (such as combined heat and power for residential use).

Metallurgy

The Science and technology of recovery, refining, properties, and uses of metals and formulation of metal alloys is known as metallurgy.

Metallurgy also includes

The technique or science of working or heating metals so as to give them certain desired shapes or properties.

The technique or science of making and compounding alloys.

The technique or science of separating metals from their ores.

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Mineral:

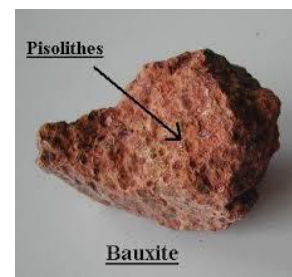
A mineral is the native form in which the metal exists. Example magnetite is a mineral of Iron of the formula Fe_3O_4 , which is extracted from the soil which is rich in it.

**Ore:**

An ore is a mineral from which the metal can be extracted economically. If you scoop a little mud from your garden it might contain traces of iron. But it cannot be called an ore because you cannot extract iron out of it in a profitable way.

Bauxite:

It is the chief source of Aluminum, generally considered as Al_2O_3 but is more complex than that.

**Flux:**

A substance used to refine metals by combining with impurities to form a molten mixture that can be readily removed.

**Slag:**

Slag consists mostly of mixed oxides of elements such as silicon, sulfur, phosphorus, and aluminum; ash; and products formed in their reactions with furnace linings and fluxing substances such as limestone.

**Alloys:**

Alloys are metallic materials consisting of two or more elements combined in such a way that they cannot be readily separated by physical means. More than 90% of metals used are in the form of alloys. They represent an enormous family of engineering materials that provide a wide range of products with useful properties.



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Purpose of Making Alloys

Pure metals possess few important physical and metallic properties, such as melting point, boiling point, density, specific gravity, high malleability, ductility, and heat and electrical conductivity. These properties can be modified and enhanced by alloying it with some other metal or non-metal, according to the need.

Alloys are made to:

Enhance the hardness of a metal: An alloy is harder than its components. Pure metals are generally soft. The hardness of a metal can be enhanced by alloying it with another metal or non-metal.

Lower the melting point: Pure metals have a high melting point. The melting point lowers when pure metals are alloyed with other metals or non-metals. This makes the metals easily fusible. This property is utilized to make useful alloys called solders.

Enhance tensile strength: Alloy formation increases the tensile strength of the parent metal.

Enhance corrosion resistance: Alloys are more resistant to corrosion than pure metals. Metals in pure form are chemically reactive and can be easily corroded by the surrounding atmospheric gases and moisture. Alloying a metal increases the inertness of the metal, which, in turn, increases corrosion resistance.

Modify colour: The colour of pure metal can be modified by alloying it with other metals or non-metals containing suitable colour pigments.

Provide better cast ability: One of the most essential requirements of getting good castings is the expansion of the metal on solidification. Pure molten metals undergo contraction on solidification. Metals need to be alloyed to obtain good castings because alloys expand...

Composition and uses of some alloys

Alloy	Components	Typical uses
Amalgam	Mercury (45–55%), plus silver, tin, copper, and zinc.	Dental fillings.
Brass	Copper (65–90%), zinc (10–35%).	Door locks and bolts, brass musical instruments, central heating pipes.
Bronze	Copper (78–95%), tin (5–22%), plus manganese, phosphorus, aluminium, or silicon.	Decorative statues, musical instruments.
Cast iron	Iron (96–98%), carbon (2–4%), plus	Metal structures such

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	silicon.	as bridges and heavy-duty cookware.
Duralumin	Aluminium (94%), copper (4.5–5%), magnesium (0.5–1.5%), manganese (0.5–1.5%).	Automobile and aircraft body parts, military equipment.
Gunmetal	Copper (80–90%), tin (3–10%), zinc (2–3%), and phosphorus.	Guns, decorative items.
Nichrome	Nickel (80%), chromium (20%).	Firework ignition devices, heating elements in electrical appliances.
Steel (general)	Iron (80–98%), carbon (0.2–2%), plus other metals such as chromium, manganese, and vanadium.	Metal structures, car and airplane parts, and many other uses.
Steel (stainless)	Iron (50 %+), chromium (10–30%), plus smaller amounts of carbon, nickel, manganese, molybdenum, and other metals.	Jewellery, medical tools, tableware.

Polymers:

Any of various chemical compounds made of smaller, identical molecules (called monomers) linked together is called a polymer. Some polymers, like cellulose are naturally occurring polymer, while others, like nylon, are artificial or manmade polymers. Polymers have extremely high molecular weights, make up many of the tissues of organisms, and are used to make such materials as plastics, concrete, glass, and rubber. The process by which molecules are linked together to form polymers is called polymerization.



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Classification of Polymers

Classification of Polymers can be done on various factors such as listed below:

Classification Based on Source

Classification Based on Structure of Polymers

Classification Based on Mode of Polymerisation

Classification Based on Molecular Forces

Classification Based on Source

Natural polymers: The polymers which obtain by nature or natural sources like plants and animals are called natural polymers.

Ex: - Proteins, Cellulose, Starch, Rubber etc.

Synthetic polymers: The polymers which found by laboratories or industries are called synthetic polymers.

Ex: - Polythene.

Semi Synthetic polymers: These types of polymers formed by chemical reaction with neutral polymers.

Ex: - Rayon.

Classification Based on Structure of Polymers

Based on structure polymers have three types.

(i) Linear polymers: In this type of polymers, monomers are joined with each other and formed long and straight chain.

These polymers have high melting points.

These polymers have high density.

Ex: - Polythene, Polyvinyl chloride, High density polythene (HDPE) etc.

(ii) Branch chain polymers: In this type of polymers, monomers are joined with each other and formed long and straight chain having some branches.

These polymers have low melting points.

These polymers have low density.

Ex: - Low density polythene (LDPE) etc.

(iii) Cross linked or Network polymers: In this type of polymers, monomers are formed from bi-functional and tri-functional monomers and contain strong covalent bonds between various linear polymer chains. These polymers are brittle in nature.

Ex: - Bakelite, Melamine etc.

Based on Mode of Polymerisation

Based on polymerization polymers have two types.

(i) Addition polymers (ii) Condensation polymers

Addition polymers: This type of polymers is formed by the repeated addition of monomer molecules.

In this reaction small particles are not eliminated like water, HCl, NH₃ etc.

In this type of polymers monomers are unsaturated hydrocarbons.

Ex: – Vinyl chloride to Poly vinyl chloride.

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2) Condensation polymers: This type of polymers is formed by repeated Condensation between two different bi-functional or tri-functional monomeric units.

In this reaction small particles are eliminated like water, HCl, NH₃ etc.

Ex: - Nylon – 66 is formed by condensation of Hexamethelenediamine and adipic acid.

Classification Based on Molecular Forces

Elastomers: The polymers that have elastic character like rubber are called elastomers.

In elastomers, the polymer chains are held together by weak inter-molecular forces.

Cause of these weak forces, the polymers can be easily stretched by applying small stress and regain their original shape when the stress is removed.

Ex: - Vulcanised rubber

In this rubber polymers chains are held by sulphur cross bond.

Cause of these cross bond it can be stretched by small stress.

Thermoplastics: The polymers in which inter-molecules forces are between the elastomer polymers and fibre polymers.

These polymers are softened when it heated and hardened when it cooled.

These polymers do not have any cross bond.

These polymers can easily convert into any shape by heating.

Ex: -Polyethene, Polystyrene, PVC etc.

Thermosetting: Theses polymers are made by low molecular mass semi fluid substance.

These polymers cannot convert in other shape by heating.

On heating, they become hard and in-fusible because these polymers have cross bond.

Ex: -Bakelite, Melamine formaldehyde, Resin etc.

Fibres: These polymers have strong inter-molecules forces between the chains.

These forces are either hydrogen bonds or dipole – dipole interaction.

Cause of these strong forces, the chains is closely packed giving high tensile strength and less elasticity.

Therefore these polymers have high melting points.

Ex: - Nylon 66, Dacron, silk etc.



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Composite materials

Composite: Two or more chemically different constituents combined macroscopically to yield a useful material are called a composite material.

Examples of naturally occurring composites are

Wood Cellulose: Cellulose fibers bound by lignin matrix

Bone: Stiff mineral "fibers" in a soft organic matrix permeated with holes filled with liquids.

Granite: Granular composite of quartz, feldspar, and mica

Some examples of manmade composites are

Concrete: Particulate composite of aggregates (limestone or granite), sand, cement and water.

Plywood: Plywood: Several layers of wood veneer glued together.

Fiberglass: Fiberglass: Plastic matrix reinforced by glass fibers

Cements: Ceramic and metal composites

Fibrous composites: Variety of fibers (glass, Kevlar, graphite, nylon, etc.) bound together by a polymeric matrix.

**Types of composite materials:**

Light weight composite: Used in automotive industry. Lighter, stronger, wear resistance, rust, free and aesthetics.

- Car body
- Brake pads
- Drive shafts
- Fuel tanks etc.

Aerospace composite: Used in aerospace industry. Lighter, stronger, temperature resistance, smart structures, wear resistance.

Aircraft: Nose, doors, struts, trunnion, fairings, cowlings, cowlings, ailerons, ailerons, outboard and inboard flaps, stabilizers, elevators, rudders, fin tips, spoilers, edges

Rockets & missiles: Nose, body, pressure tanks, frame and fuel tanks, turbo-motor stators etc.

Satellites: Antennae, frames, structural parts.

Unidirectional composites: Used in sports. Lighter, stronger, toughness, better aesthetics, higher damping properties.

Tennis

Bicycles

Badminton

Boats

Hockey

Golfing

Motorcycles etc.

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Fibre reinforced composite: Used in transportation & Infrastructure.

Lighter, stronger, toughness, damping

Railway coaches

Bridges

Ships and boats

Dams

Truck bodies and floors

RV bodies. Etc.

Composite FRP: Used in many more industrial sectors.

Biomedical industry

Consumer goods

Agricultural equipment

Heavy machinery

Computers

Healthcare. etc

Advantages and disadvantages of composite

Advantages of Composites

Light Weight.

High Strength

Strength Related to Weight - Strength-to-weight ratio is a material's strength in relation to how much it weighs. Some materials are very strong and heavy, such as steel. Other materials can be strong and light, such as bamboo poles. Composite materials can be designed to be both strong and light

Corrosion Resistance - Composites resist damage from the weather and from harsh chemicals that can eat away at other materials.

High-Impact Strength - Composites can be made to absorb impacts such as the sudden force of a bullet, for instance, or the blast from an explosion. Because of this property, composites are used in bulletproof vests and panels, and to shield airplanes, buildings, and military vehicles from explosions.

Design Flexibility - Composites can be moulded into complicated shapes more easily than most other materials. This gives designers the freedom to create almost any shape or form.
Part Consolidation - A single piece made of composite materials can replace an entire assembly of metal parts. Reducing the number of parts in a machine or a structure saves time and cuts down on the maintenance needed over the life of the item.

Dimensional Stability - Composites retain their shape and size when they are hot or cool, wet or dry. Wood, on the other hand, swells and shrinks as the humidity changes.

Nonconductive - Composites are nonconductive, meaning they do not conduct electricity. This property makes them suitable for such items as electrical utility poles and the circuit boards in electronics. If electrical conductivity is needed, it is possible to make some composites conductive.

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Nonmagnetic - Composites contain no metals; therefore, they are not magnetic. They can be used around sensitive electronic equipment. The lack of magnetic interference allows large magnets used in MRI (magnetic resonance imaging) equipment to perform better.

Radar Transparent - Radar signals pass right through composites, a property that makes composites ideal materials for use anywhere radar equipment is operating, whether on the ground or in the air.

Low Thermal Conductivity - Composites are good insulators, they do not easily conduct heat or cold. They are used in buildings for doors, panels, and windows where extra protection is needed from severe weather.

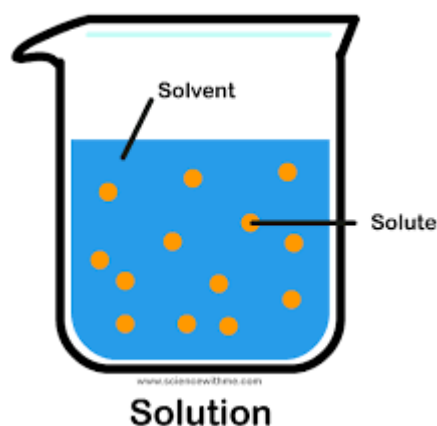
Disadvantages of composites

High costs.

Complex repair.

Mechanical characterization.

Solution



Solute:

A substance dissolved in another substance. Usually the component of a solution present in the lesser amount.

Example: In sugar solution, sugar is the solute.

Solute concentration is amount of solutes or particles dissolved in the solution.

Solvent:

A solvent is the solution, liquid, or gas part of the solution which dissolves the solvent.

Example: In sugar solution, water is the solvent.

Solution:

A homogeneous mixture of two or more substance.

Solute + solvent = solution

Sugar + water = sugar solution.

A solution can exist any phase.

Example; Brass is the solid solution.

Aqueous hydrochloric acid is liquid solution.

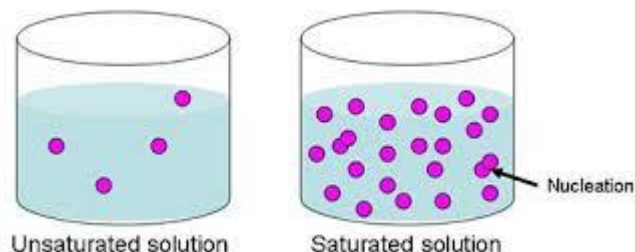
Air is gaseous solution.

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Saturated solution:

Is a solution containing the maximum concentration of a solute. Additional solute will not dissolve in a saturated solution.

Example: If we go on adding sugar in tumbler of water, the sugar gets dissolved up to certain limit. Further addition of sugar, the sugar does not get dissolved.

**Unsaturated solution:**

Is a chemical solution in which the solute concentration is lower than its equilibrium solubility.

OR

When there are fewer particles or solutes than solvent in the solution, then we call such a solution as unsaturated solution.

Example: Lime water, aqueous hydrochloric acid, etc

Concentration of a solution:

The amount of solute dissolved in a specific (fixed) amount of solvent.

Units of concentration of a solution: Molarity, Molality, Normality.

Molar solution or molarity:

Is defined as the number of moles of solute dissolved in 1 liter of solution.

Example: If 2 moles of a solute are present in 1 liter of solution, then the molarity of solution will be 2moles/ltr

Molarity = Number of moles of solute/volume of solution in liter
 = Mass of solute (in gram)/molecular mass X volume of solution in liter

Molal solution or molality:

Also called molal concentration of a solute in a solution.

Molality = the number of solute/kg of solvent

The unit for molality is expressed as m or mol/kg

Normal solution or normality:

The equivalent concentration or normality is defined as the molar concentration (c_i) divided by an equivalence factor (f_{eq}).

Normality = c_i/f_{eq}

Simple problems on concentration of solution:

The molecular weight (mw) of HCl is 36, calculate: i) the grams of HCl contained in 0.2 moles; ii) the grams of HCl needed to prepare 500 ml of a solution 1 M.

moles are given by grams/molecular weight, thus

(moles) (mw) = (36) (0.2) = 7.2 grams

a solution 1 M contain 1 mole/litre thus 36 grams/litres. It follows that for 500 ml we need:

$36/2 = 18$ grams

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2. 500 ml of a solution contains 20 grams of NaOH (mw = 40). Calculate the molarity of the solution.

20 gr of NaOH correspond to 0.5 moles which are contained in 0.5 litre of solution. In one litre of solution there will be $(2)(0.5) = 1$ mole and thus the solution is 1 M.

Calculate the ml of a 1 M solution of NaCl needed to prepare 100 ml of a 0.2 M solution.

By remembering that $M_i V_i = M_f V_f$ we have that

$(x)(1) = (100)(0.2)$; $x = 20$ ml

pH value

Concentration of Hydrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH = 0	Battery acid, Strong Hydrofluoric Acid
1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
100,000	pH = 2	Lemon Juice, Battery Acid, Vinegar
10,000	pH = 3	Orange Juice, Soda
1,000	pH = 4	Tomato Juice
100	pH = 5	Acid rain
10	pH = 6	Soft drinking water, Black Coffee
1	pH = 7	Urine, Saliva
1/10	pH = 8	"Pure" water
1/100	pH = 9	Sea water
1/1,000	pH = 10	Baking soda
1/10,000	pH = 11	Greasy salt lake, Milk of Magnesia
1/100,000	pH = 12	Ammonia solution
1/1,000,000	pH = 13	Soapy water
1/10,000,000	pH = 14	Bleaches, Oven cleaner, Liquid drain cleaner

Acids and Bases:

Usually chemical compounds are classified into two types as acids and bases.

Acids are the substances which contain H^+ (Hydrogen positive) ions in their solutions. In other words they give protons in the solution. Acids have following properties.

They are sour to taste.

They turn blue litmus to red.

They donate protons.

They are corrosive in their action.

Active metals replace hydrogen atoms of the acids.

Example: $Zn + 2HCl \rightarrow ZnCl_2 + H_2$.

They react with bases producing salt and water.

Examples of acids are HCl, H_2SO_4 , H_2CO_3 , H_3PO_4 etc.

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Bases

A base usually accepts H^+ ions. It can be also defined as the substance which produces hydroxyl ions (OH^-) when dissolved in water. Bases have following properties.

They are soapy to touch.

They turn red litmus to blue.

They are bitter to taste.

They react with acids to give salt and water.

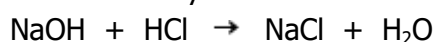
When dissolved in water they produce (OH^-) ions.

The soluble bases are called alkalies. Hence all alkakies are bases but not all bases are alkalies.

Examples: $NaOH$, KOH , $Ca(OH)_2$ etc

Neutralisation: A reaction between an acid and base to produce salt and water is called neutralization.

The sodium hydroxide reacts with hydrochloric acid to give sodium chloride and water.



During this reaction (OH^-) ion of the base combines with H^+ ion of the acid to give water.

Thus the acid and basic properties vanish. This results in a neutral salt. However sometimes acidic salts or basic salts are produced.

pH scale in terms of hydrogen ion concentrations.

In the water, which is neutral solution the number of ions per litre is equal to number of hydroxyl ions per litre. It is found to be equivalent to 10^{-7} gm ions per litre.

Number of H^+ ions = Number of OH^- ions = 10^{-7} gm ions per litre at $25^\circ C$

Therefore $H^+ \times OH^- = 10^{-14}$ gm ions per litre.

This product is known as ionic product of water. In any solution this product always remains constant. If H^+ ion concentration is increased, it results in the decrease of OH^- ion concentration and vice versa.

If in a solution concentration of H^+ ions and OH^- ions are equal it is called a neutral solution. If the concentration of H^+ ions is more than 10^{-7} gm ions per litre, the solution is acidic and if it is less than 10^{-7} gm ions per litre the solution is alkaline. Thus the acidic or alkaline nature of a solution depends on the concentration of hydrogen ion in the solution. Instead of expressing hydrogen ion concentration, Sorensen suggests the use of term pH meaning hydrogen powder.

The pH of the solution is defined as negative logarithm to base 10 of hydrogen ion concentration expressed in gram per litre.

$$pH = -\log_{10} (H^+)$$

For water $H^+ = 10^{-7}$ gm ions per litre

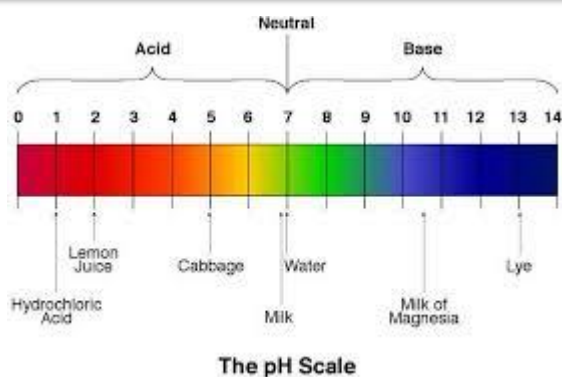
$$\text{Therefore } pH = -\log_{10} 10^{-7} = 7$$

By the definition it is clear that in case of acid, the value of pH is less than 7

(Concentration of hydrogen positive ion is more than 10^{-7} gm ions per litre)

In case of bases, the pH value is more than 7 (concentration of hydrogen positive ion is less than 10^{-7} gm ions per litre). Lower the value of pH stronger the acidity, higher the value of pH stronger the alkaline nature.

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**Application of pH in industry:**

In sugar industry, the sugarcane juice is always maintained neutral pH 7 to yield good quality sugar.

In chemical processes pH of solution is controlled by adding buffer solutions.

In the choice of the fertilizers for the soils, their acidity or alkalinity is tested initially

A healthy human must have pH of urine between 5 & 7 and that of blood is 7.4 . Variations in pH can cause serious problems.

The boiler feed water must have a pH of 10, so that the effect of acids produced due to hydrolysis is reduced.

The Sewage water is treated by coagulation , the coagulants must have pH between 8.5 to 10.0

Milk has the normal pH value between 6-7. pH less than 6 converts milk to curds.

In electroplating the pH of electrolyte is maintained using buffer solutions.

In the textile industry for dyeing proper control of pH is necessary, if not the dyeing will be non-uniform and temporary. It can also affect the strength of the fibre.

In leather industry proper pH value reduces the bad odour during the tanning of the leather.

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