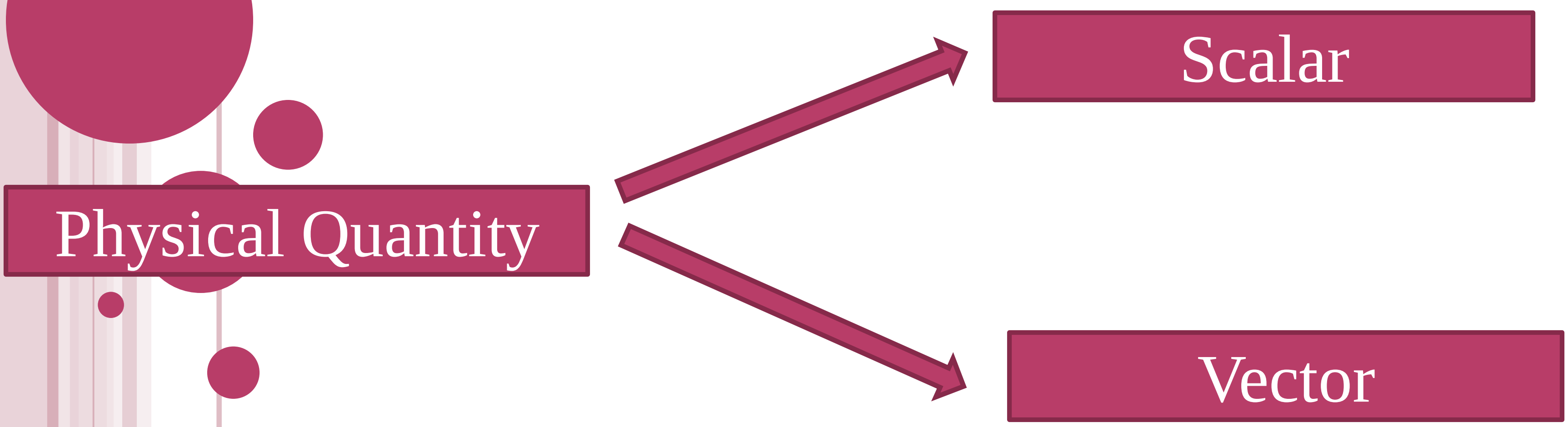
WELCOME

PRESENTED BY :DR. DOND G. R.

SCALARS AND VECTORS

<u>Physical Quantity</u> : Any Quantity which can be measured is called as physical quantity.

Classification of physical Quantity



Scalar Quantity :

A *scalar quantity* has only *magnitude* and is completely specified by a number and a unit. Examples are: mass (2 kg), volume (1.5 L), and frequency (60 Hz).

Vector Quantity :

A *vector quantity* has both *magnitude* and *direction*. Examples are displacement (an airplane has flown 200 km to the southwest), velocity (a car is moving at 60 km/h to the north), and force (a person applies an upward force of 25 N to a package). When vector quantities are added, their directions must be taken into account.

Vector notation

1. A vector is denoted either by an arrow on top or by **bold** print.

Example: The vector of acceleration a is

written either as: $\vec{a}$ or as: **a** Both methods are used

2. The magnitude of a vector is denoted either by the symbol: | | or by the symbol of the vector written with regular type. **Example:** the magnitude of the

acceleration vector can be written either as: $|\vec{a}|$ or as: a

3. Displacement of a body from P to Q is represented by as P—›Q where the starting point is P and the tail and Q is head of vector symbolically represented as $\overrightarrow{PQ}$

Zero vector

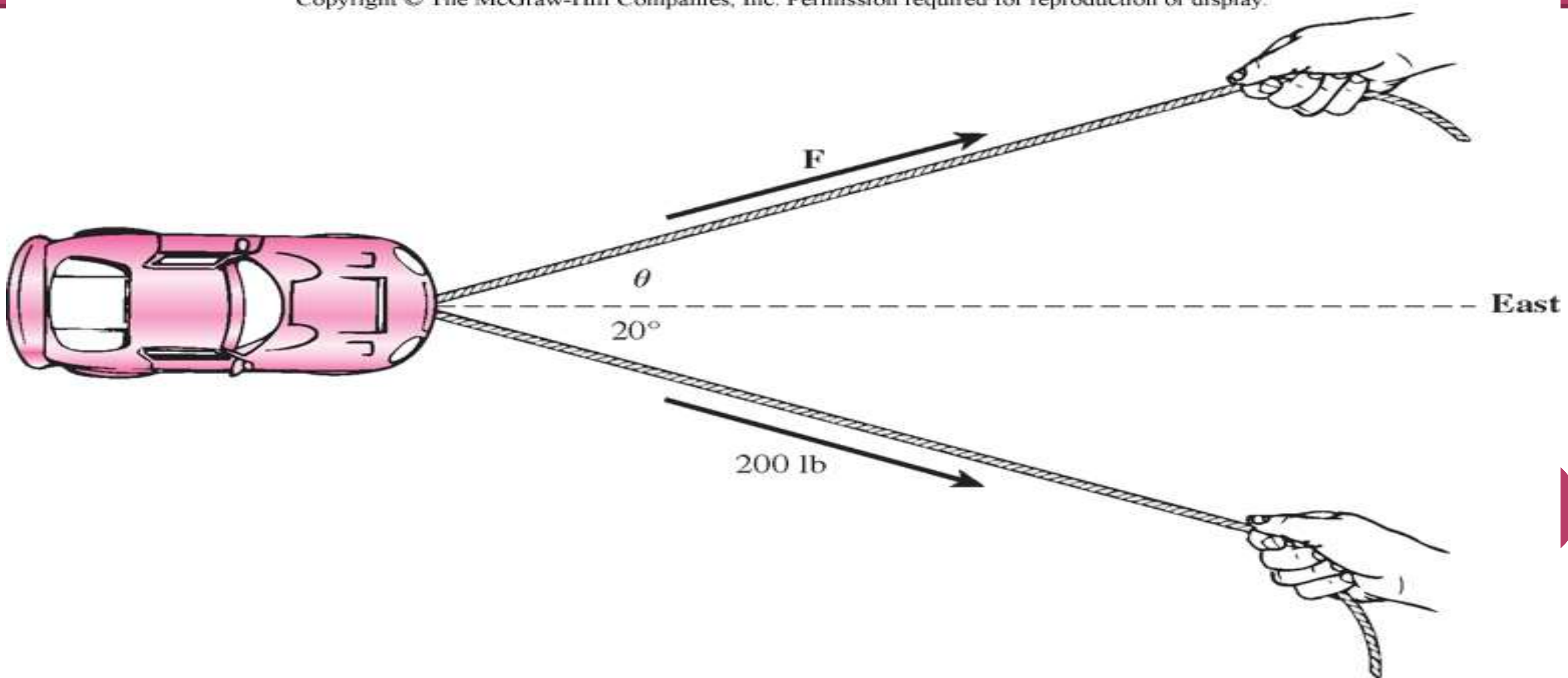
Consider , two vectors A and–A . Their sum is A + (–A).Since the magnitudes of the two vectors are the same, but the directions are opposite, the resultant vector has zero magnitude and is represented by 0 called a null vector or a zero vector :

Eg 1) $\vec{A} - \vec{A} = 0$, $|0| = 0$

2) velocity vector of stationary particle is zero vector

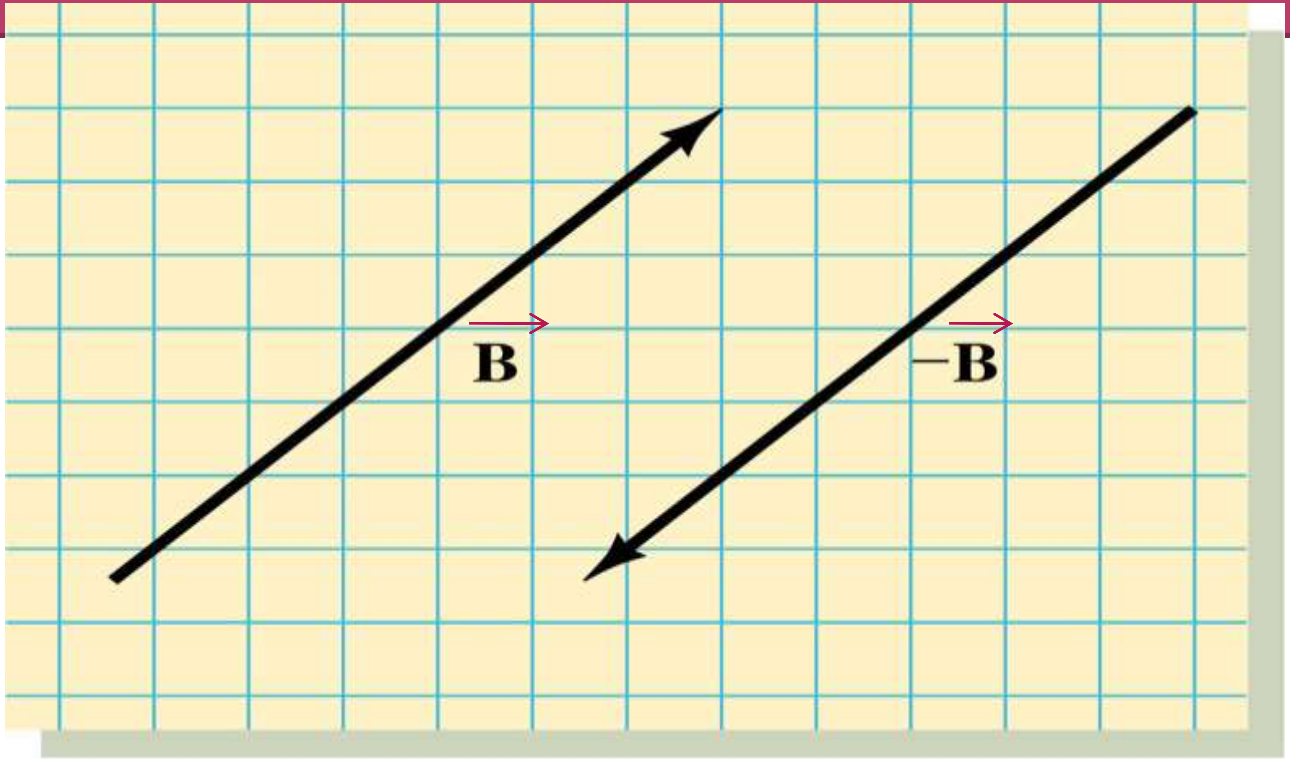
Resultant Vector :

The *resultant*, or sum, of a number of vectors of a particular type (force vectors, for example) is that single vector that would have the same effect as all the original vectors taken together.



Negative of a vector :

A negative vector of a given is a vector of the same magnitude but in the opposite direction to that of the given vector .



Equality of Vectors

Two vectors **A** and **B** are said to be equal if, and only if, they have the same magnitude and the same direction.**

Unit Vector

A vector having unit magnitude in a given direction is called unit vector .

Ex .if $\vec{A}$ is a vector of magnitude A and $\vec{u}$ is a vector of unit magnitude in the direction of $\vec{A}$ The unit vector gives the direction of a given vector

Ex we use i , j and k as unit vectors along the X , Y and Z direction resp.

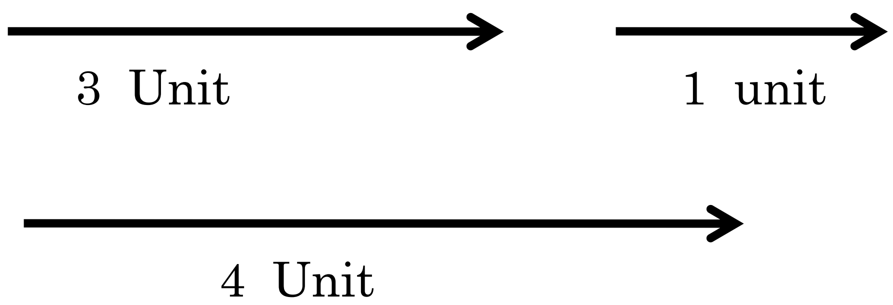
Ex . $\vec{P} = \vec{u}$ P

Addition and subtraction of vectors

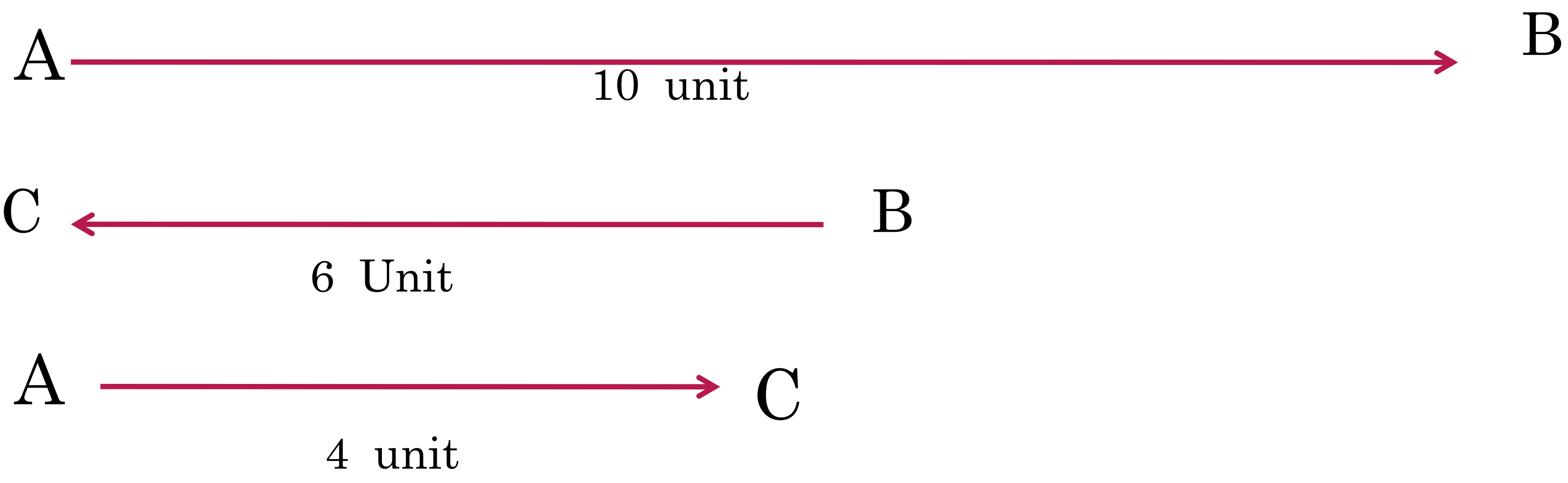
The process of finding the resultant of two or more vectors is called composition of vector .
Eg . Velocity $\vec{V1}$ and $\vec{V2}$ added to give the resultant velocity $\vec{V} = \vec{V1} + \vec{V2}$
Similarly Force $\vec{F1}$ and Force $\vec{F2}$ added to give the resultant force $\vec{F} = \vec{F1} + \vec{F2}$

Case 1)

If two vectors are acting along the same direction



If two vectors are acting along the opposite direction they are subtracted .

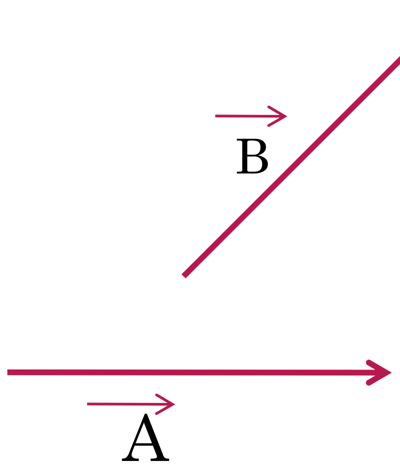


Case 2)

When the vectors are not along the same direction or apposite direction , we have to the use triangle law of vector addition

Triangle law

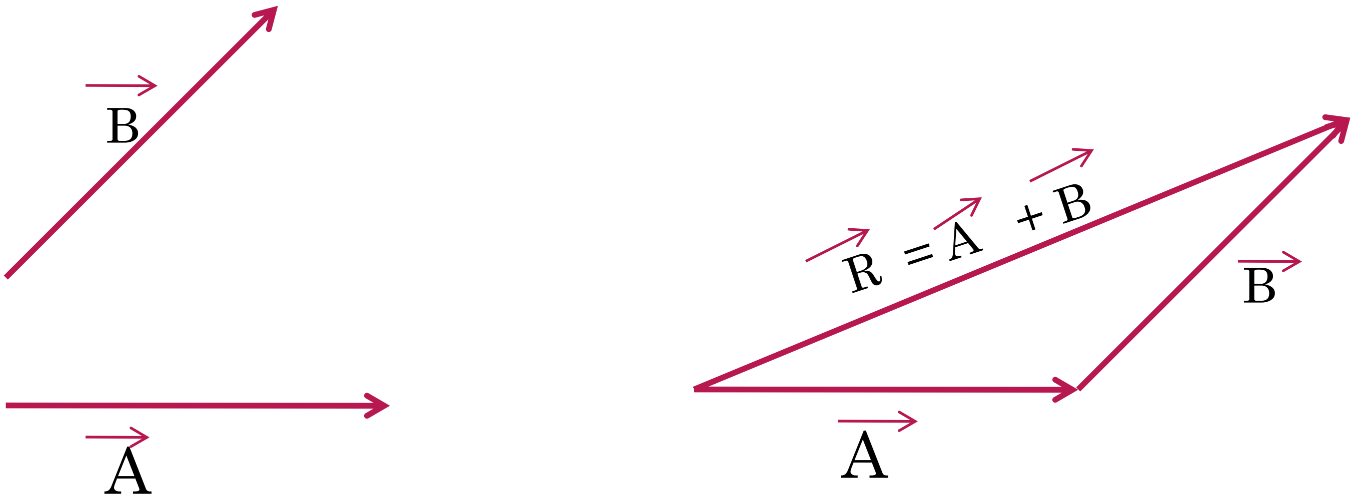
If two vectors of the same type are represented in magnitude and direction by The two sides of a triangle taken in order , then their resultant is is represented by the side of the triangle of the triangle drown from starting point of the first Vector to the end of the point of the second vector .



for determining $\vec{\mathbf{R}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$

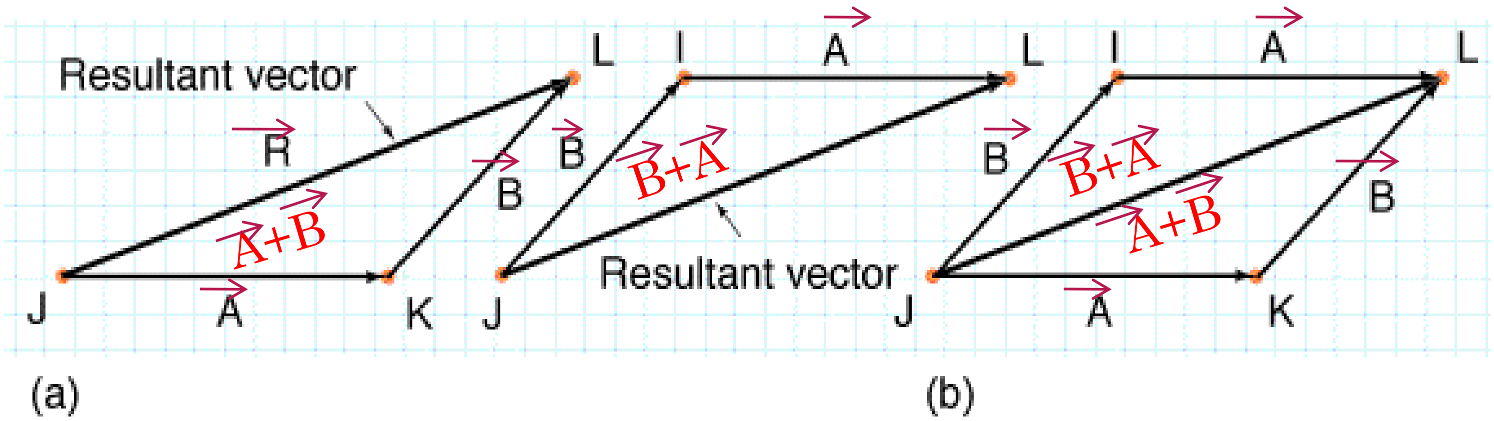
1. At the tip of the first vector (**A**) place the tail of the second vector (**B**)

2. Join the tail of the first vector (**A**) with the tip of the second (**B**

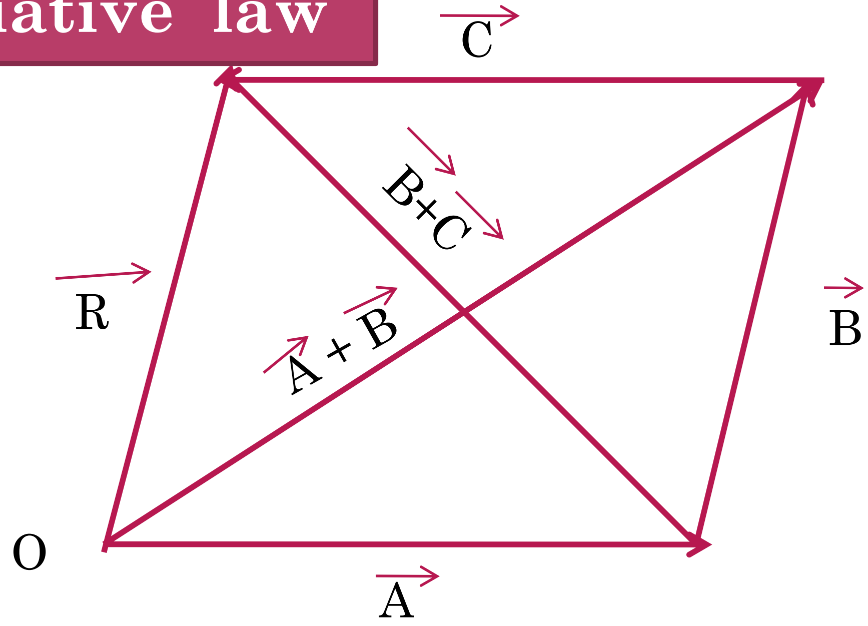


Commutative law

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



Associative law

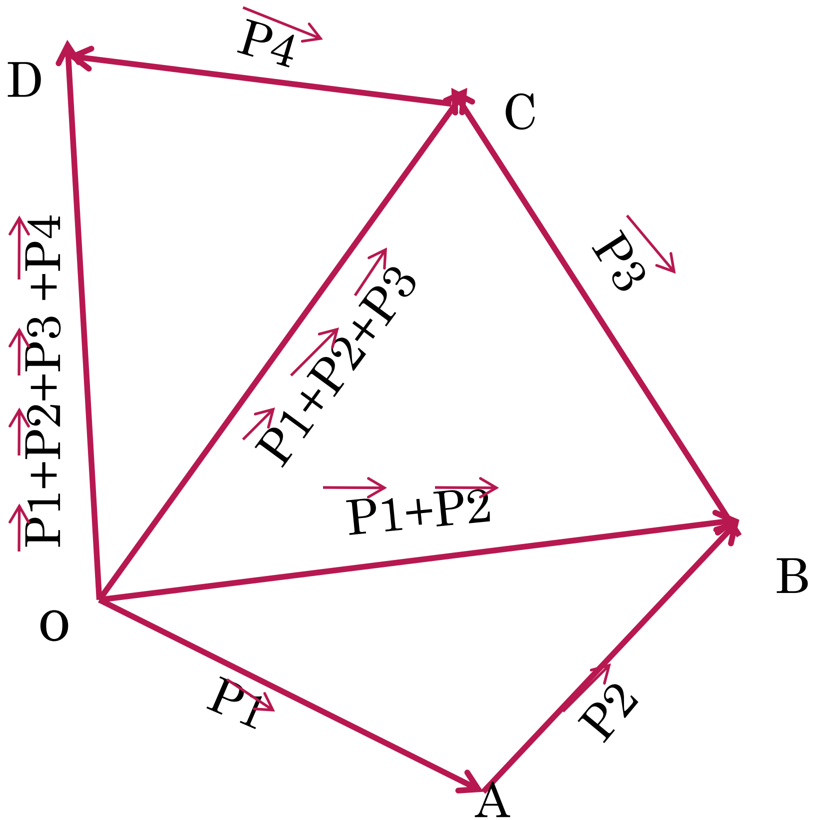


$\vec{A} + \vec{B}) + \vec{C} = \vec{R}$ and $\vec{A} + (\vec{B} + \vec{C}) = \vec{R}$

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

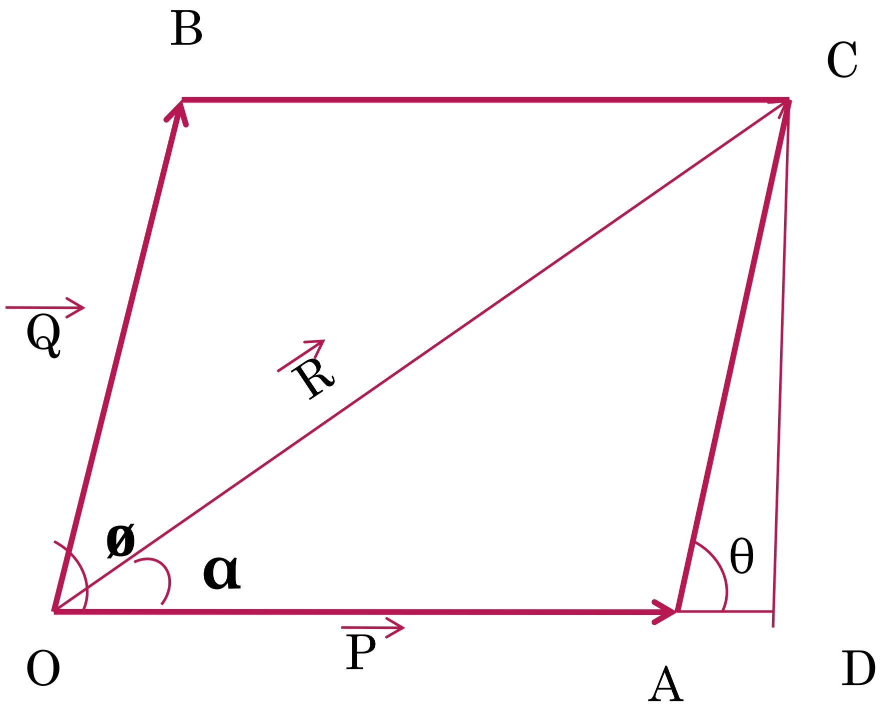
Case 3)

If a number of vectors are represented in magnitude and direction by sides of an Incomplete polygon in order, then resultant is represented in magnitude and Direction by remaining side of polygon directed from the starting point of the first vector to the end point of last vector .



Case 4) : Parallelogram law of vector addition

If two vectors of the same type are starting from the same point , are represented in magnitude and direction by two adjacent sides of a parallelogram , then their resultant vector is given in magnitude and direction of the parallelogram starting from the same point .



Proof : Two vectors $\vec{P}$ and $\vec{Q}$ at the point O and inclined at an angle θ .join BC and AC to complete Parallelogram OACB , as OA = $\vec{P}$ with OB = $\vec{Q}$ as the adjacent sides we have to prove the diagonal OC = $\vec{R}$ is the resultant of sum of the two given vectors .

By the triangle law of vector addition

$\vec{OA} + \vec{AC} = \vec{OC}$ ....(1)

AC is parallel to OB Where $|\vec{AC}|$ =AC

$\vec{AC} = \vec{OB} = \vec{Q}$ ....(2)

Substituting (2) in (1) we get

$\vec{P} + \vec{Q} = \vec{OC} = \vec{R}$

$\vec{P} + \vec{Q} = \vec{R}$ ....hence the proof

Now to find the magnitude and direction of the resultant vector

$\vec{R} = \vec{OC}$,draw a perpandicular from C to meet OA extended at D .

Therefore $\angle$ CAD = $\angle$ BOA =θ and AC =OB = Q

In the right angle triangle ADC cos θ = AD/AC

AD = AC cosθ = Qcos θ ....(3)

And sinθ = DC /AC

DC = AC sin θ = Q sin θ ....(4)

Using pythagorous thm in ◣ ODC

$(OC)^2 = (OD)^2 + (DC)^2$

$(OC)^2 = (OA + AD)^2 + (DC)^2$

$= (OA)^2 + 2OA \, . \, AD + (AD)^2 + (DC)^2$ ....(5)

But from right angle triangle ADC

$(AD)^2 + (DC)^2 = (AC)^2$ ....(6)

Using (5) and (6) , we get

$(OC)^2 = (OA)^2 + 2 \, OA \, . \, AD + (AC)^2$ ....(7) 1111

Using eqn 3 and 7 , we get

$(OC)^2 \quad (OA)^2 + 2 \, OA \, . \, AC \cos\theta + (AC)^2$

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

$R = \sqrt{P^2 + 2PQ\cos\theta + Q^2}$ ....(8)

This eqn gives the magnitude of resultant vector $\vec{R}$.

To find the direction of resultant vector $\vec{R}$.

Let $\vec{R}$ makes an angle α with $\vec{P}$, $\tan\alpha = DC/OD$, $\tan\alpha = DC/OA + AD$

From eqn 3 and 4 we get , $\tan\alpha = \dfrac{Q\sin\theta}{P + Q\cos\theta}$ ....(9)

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

Special cases :

(1) If $\vec{P}$ and $\vec{Q}$ are mutually perpandicular to each other then $\theta = 90°$ $\cos 90° = 0$

Eqn 8 bcom $R = \sqrt{P^2 + Q^2}$

And eqn 9 becomes $\tan\alpha = \dfrac{Q \sin 90°}{P + Q\cos 90°} = \dfrac{Q}{P}$ i.e . $\alpha = \tan^{-1}\dfrac{Q}{P}$

(2) $\theta = 0°$, i.e $\vec{P}$ and $\vec{Q}$ are parallel or having same direction then eqn 8 bcom

$R = \sqrt{P^2+Q^2+2PQ\cos 0°}$

$R = \sqrt{P^2 + Q^2+2PQ}$ ($\cos 0° = 1$)

$R = \sqrt{(P + Q)^2}$

$R = P+Q$

Eqn 9 becomes $\tan\alpha = \dfrac{Q \sin 0°}{P+Q\cos 0°}$ $\sin 0° = 0$

$\alpha = 0$

(3) If $\theta = 180°$, i.e. $\vec{P}$ and $\vec{Q}$ are antiparallel then

$R = \sqrt{P^2 + Q^2 + 2PQ\cos 180°}$

$R = \sqrt{P^2 + Q^2 - 2PQ}$ ($\cos 180° = 1$)

$R = \sqrt{(P-Q)^2}$

$R = P-Q$

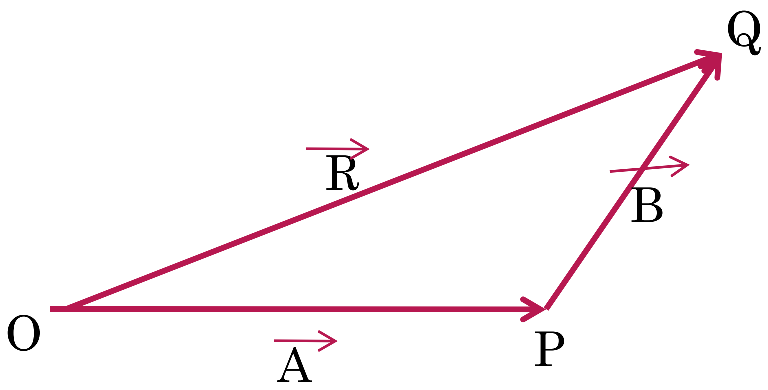
Eqn 9 becomes $\tan\alpha = \dfrac{Q\sin 180°}{P + Q\cos 180°}$ ($\sin 180° = 0$)

$\alpha = 0$

Resolution of Vector

The process of splitting of a single vector into two or more vectors in different direction which together produce the same effect as the single vector is called resolution of vector .

The vectors into which single vector is split are called components of vector .



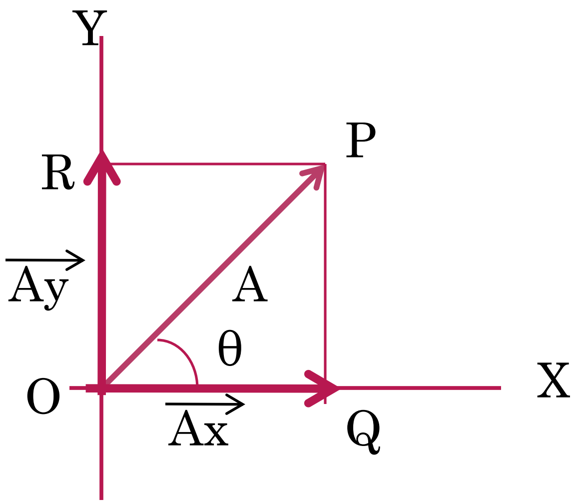
$\vec{R} = \vec{A} + \vec{B}$

Vector $\vec{R}$ can be resolved into two vectors $\vec{A}$ and $\vec{B}$.

The vectors $\vec{A}$ and $\vec{B}$ are called components of the Vector $\vec{R}$.

Rectangular components of a vector

When a vector is split into two components which are mutually perpandicular to each other then these components are called as rectangular components of a vector .



Let $\vec{A}$ be vector , draw an arrow OP from origin O to represent vector $\vec{A}$ in magnitude and direction .draw perpandicular PQ and PR on the X-axis & Y-axis resp. Then intercepts $\vec{OQ}$ and $\vec{OR}$ represent the components $\vec{Ax}$ and $\vec{Ay}$ 0f a vector $\vec{A}$ along the X & Y axes resp .

$\vec{A} = \vec{OP} = \vec{OQ} + \vec{QP} = \vec{OQ} + \vec{OR}$ $(\vec{OP} = \vec{OR})$

$\vec{A} = \vec{Ax} + \vec{Ay}$, $\vec{A} = i\vec{Ax} + jAy$,(i&j areunit vector

From fig.Ax =Acos θ and Ay =Asinθ

$A^2x + A^2y = A^2\cos^2\theta + A^2\sin^2\theta = A^2(\cos^2\theta + \sin^2\theta) = A^2$

$A^2 = A^2x + A^2y$, $A = \sqrt{A^2x + A^2y}$

From this eqn magnitude of the vector $\vec{A}$ can be calculated .

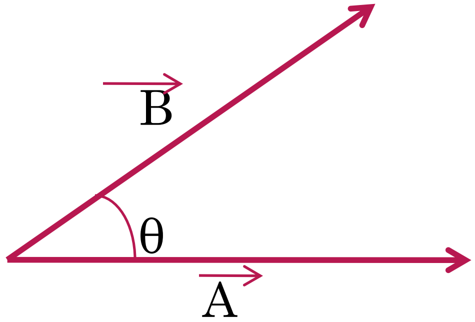
$\tan\theta = Ay / Ax$

This eqn gives the direction of the vector $\vec{A}$.

Scalar product of two vectors

The product of magnitude of the two vectors and cosine of the angle between them is called scalar product of two vectors . It is also known as dot product . It is scalar quantity .

Let $\vec{A}$ and $\vec{B}$ are two vectors and θ is the angle between them .



Then their scalar product is given as

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

Characteristics of Scalar Product

1)It obeys commutative law $\vec{A}.B = B.A$

2) It obeys distrubutive law . Let A,B & C are three vectors then $A.(B+C)=A.B + A.C$

3)Scalar product of two perpandicular vectors is zero .

$A.B = AB \cos 90$, $A.B = 0$

4) Scalar product of a vector with itsself is equal to the squar of its magnitude. $A.A = A\cos 0$, $A.A = A^2$

5) Scalar product of rectangular unit vectors

$$i.i = j.j = k.k = 1$$

$$i.j = j.k = k.i = 0$$

6) Scalar product of two vectors in terms of magnitude of their rectangular components

$A = iA_x + jA_y + kA_z$ and $B = iB_x + jB_y + kB_z$

$A.B = (iA_x + jA_y + kA_z).(iB_x + jB_y + kB_z)$

$= (i.i)A_xB_x + (i.j)A_xB_y + (i.k)A_xB_z + (j.i)A_yB_x + (j.j)A_yB_y + (j.k)A_yB_z + (k.i)A_zB_x + (k.i)A_zB_y + (k.k)A_zB_z$

$$A.B = A_xB_x + A_yB_y + A_zB_z \qquad \left[\begin{array}{l} i.i = j.j = k.k = 1 \\ i.j = j.k = k.i = 0 \end{array}\right]$$

Vector product of two vectors

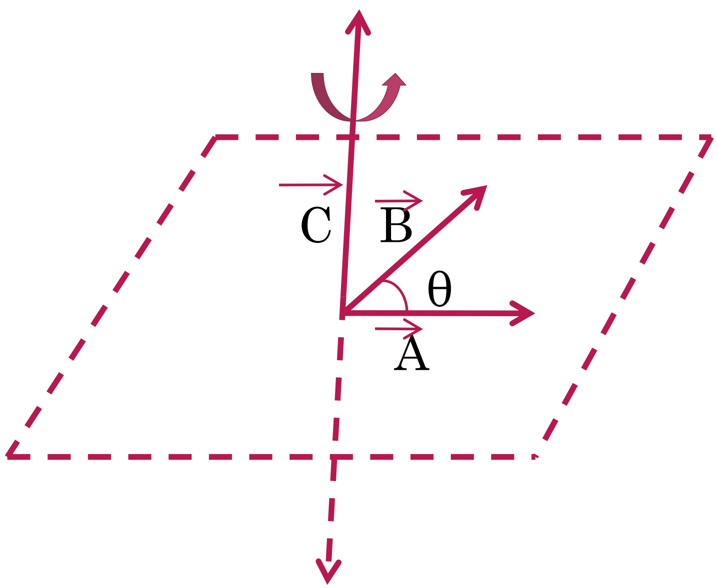
Vector product of two vectors is a vector whose -

I. Magnitude is equal to the product of magnitude of two vector s and sine of smaller angle between them .

II. And direction is perpandicular to plane of two vectors .

It is also known as cross product .it is vector quantity .

Let A and B are two vectors and θ is the smaller angle between them .



Then magnitude of their vectors product C is given as

$C = |\vec{C}| = |\vec{A} \times \vec{B}| = AB \sin\theta$

Magnitude and direction of vector product $\vec{C}$ is given as –

$\vec{C} = \vec{A} \times \vec{B} = AB \sin\theta \, \vec{u}$

Where $\vec{u}$ is a unit vector in the direction of $\vec{C}$

The direction of vector product C id found by right hand srew rule or Right hand thumb rule .

Characteristics of Vector Product

1) It does not obey commutative law.

Let $\vec{A}$ and $\vec{B}$ are two vectors, then

$\vec{A} \times \vec{B} \neq \vec{B} \times \vec{A}$.

2) It obeys distrubutive law .

let A , B , and C are three vectors then

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

3) Vector product of a two parellel or antiparallel vectors is zero .

$$\vec{A} \times \vec{B} = AB \sin\theta$$

$$\vec{A} \times \vec{B} = 0 \qquad (\sin 0 = \sin 180 = 0)$$

4) Vector product of a vector with itself (self cross product is equal to zero .

$$\vec{A} \times \vec{A} = A A \sin \theta$$

$$\vec{A} \times \vec{A} = A A \sin 0$$

$$\vec{A} \times \vec{A} = 0 \qquad \ldots\ldots\ldots\ldots(\sin 0 = 0)$$

5) Vector product of rectangular unit vectors -

$$\vec{i} \times \vec{i} = \vec{j} \times \vec{j} = \vec{k} \times \vec{k} = 0$$

$$\vec{i} \times \vec{j} = \vec{k} , \vec{j} \times \vec{k} = \vec{i} , \vec{i} \times \vec{k} = \vec{j}$$

$$\vec{j} \times \vec{i} = -\vec{k} , \vec{k} \times \vec{j} = -\vec{i} , \vec{i} \times \vec{k} = -\vec{j}$$

5) vector product of two vectors in terms of magnitude of their rectangular components -

$A = i\,A_x + j\,A_y + k\,A_z$

$B = i\,B_x + j\,B_y + k\,B_z$

Therefore ,

$A \times B = (i\,A_x + j\,A_y + k\,A_z) \times (i\,B_x + j\,B_y + k\,B_z)$

$= (i \times i)\,A_x B_x + (i \times j)\,A_x B_y + (i \times k)\,A_x B_z + (j \times i)\,A_y B_x + (j \times j)\,A_y B_y + (j \times k)\,A_y B_z + (k \times i)\,A_z B_x + (k \times j)\,A_z B_y + (k \times k)\,A_z B_z$

$= k\,A_x B_y - j\,A_x B_z - k\,A_y B_x + i\,A_y B_z + j\,A_z B_x - i\,A_z B_y$

$i\,(A_y B_z - A_z B_y) - j\,(A_x B_z - A_z B_x) + k\,(A_x B_y - A_y B_x)$

$$A \times B = \begin{vmatrix} i & j & k \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

THANK YOU

Thermal expansion subtopics:-

1)specific heat capacity
2) Calorimetry
3)Change of state
4)Latent heat
5)Heat transfer
i)Conduction ii)convection iii)Radiation

Specific Heat Capacity

- Specific heat of a substance is defined as the quantity of heat required to raise the temperature of unit mass of a substance through 1◦C(1 K).
- The amount of heat required to change the temperature of a substance is directly proportional to the mass of the substance and change in the temperature θ.

FORMULA OF SPECIFIC HEAT CAPACITY

$$Q = mc\theta$$

m = mass	(kg)
c = specific heat capacity	($J\ kg^{-1}\ {}^{o}C^{-1}$)
θ = temperature change	(°C)

Specific heat of a gas

- At constant volume

The quantity of heat required to raise the temperature of unit mass of a gas through 1K when its volume is kept constant.

- At constant pressure

The quantity of heat required to raise the temperature of unit mass of a gas through 1K when its pressure is kept constant.

Molar specific heat of gas

- At constant volume
- The quantity of heat required to raise the temperature of one mole of the gas through 1K(1°C).when its volume is kept constant.

- At constant pressure
- The quantity of heat required to raise the temperature of one mole of the gas though 1K(1°C) .when its pressure is kept constant.

The number of molecules in one mole of a gas is given by Avogadro's number

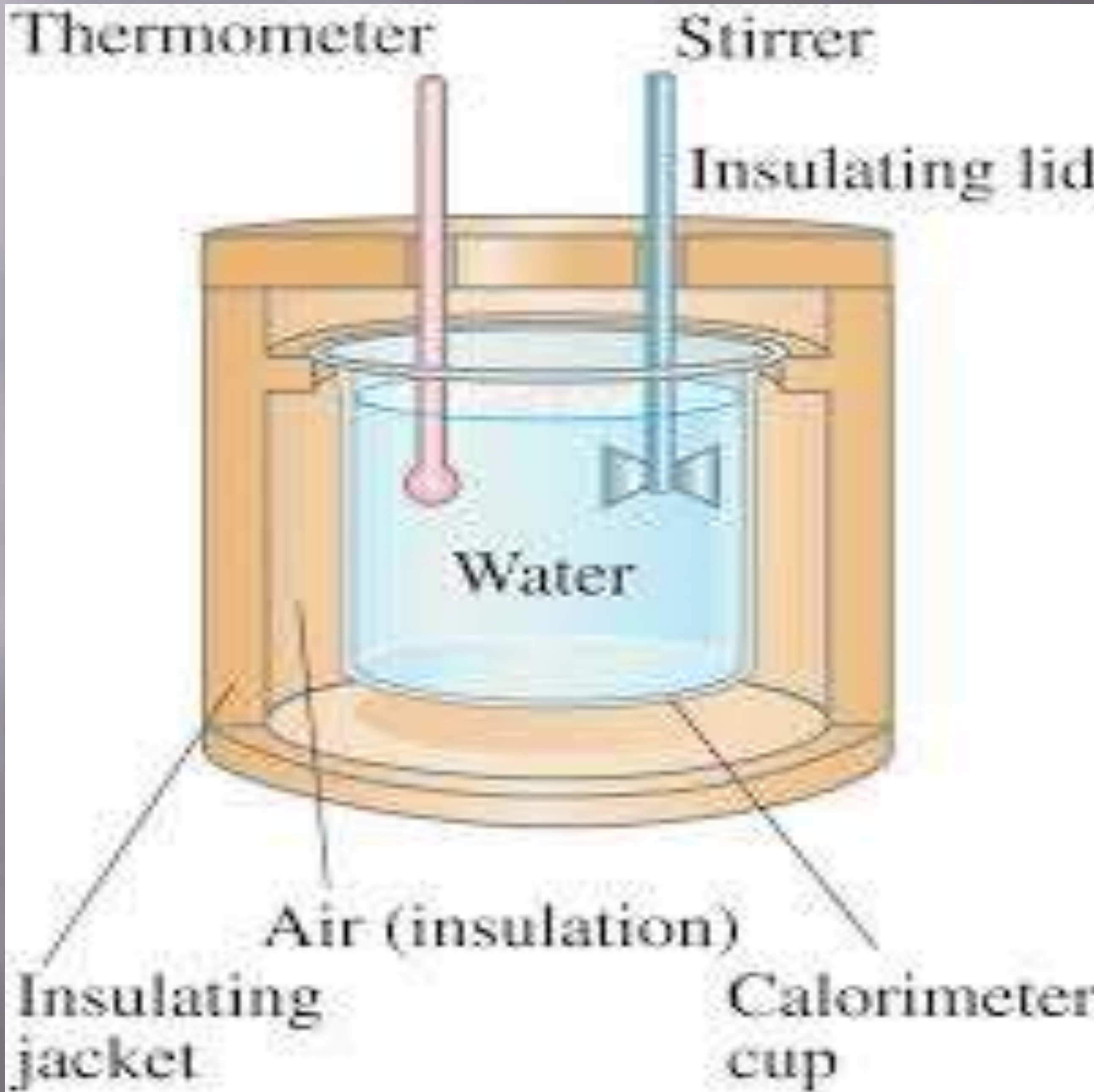
23

N=6.023×10^ molecules per mole=6.023×10^26 molecules per kilomole .

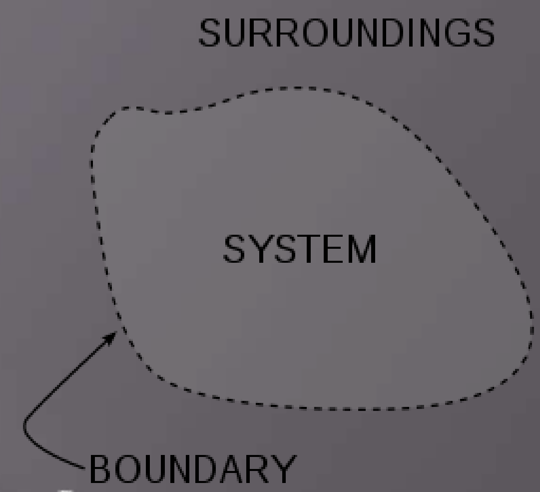
The SI unit of molar specific heat is J/K and mole K.
The molar specific heat = molecular weight ×principal specific heat.
$C_p = M \times c_p$ and $C_v = M \times c_v$

Calorimetry

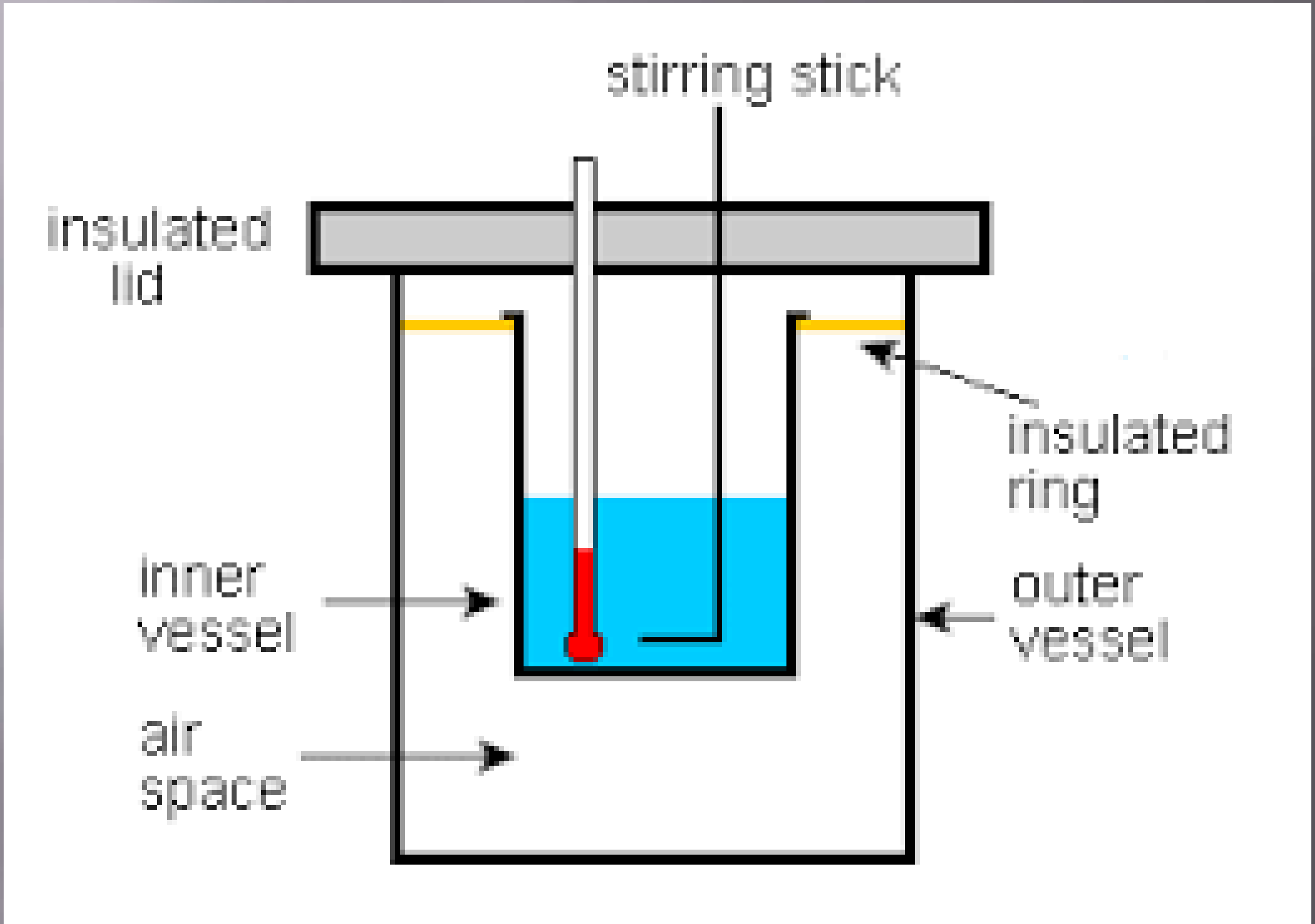
- Calorimetry means measurement of heat.
- A device in which heat measurement can be made is called calorimeter.


Thermometer
Stirrer
Insulating lid
Water
Air (insulation)
Insulating jacket
Calorimeter cup

Isolated system-



Isolated system means if no exchange or transfer of heat occurs between the system and its surroundings.


stirring stick
insulated lid
insulated ring
inner vessel
outer vessel
air space

Structure of Calorimetry

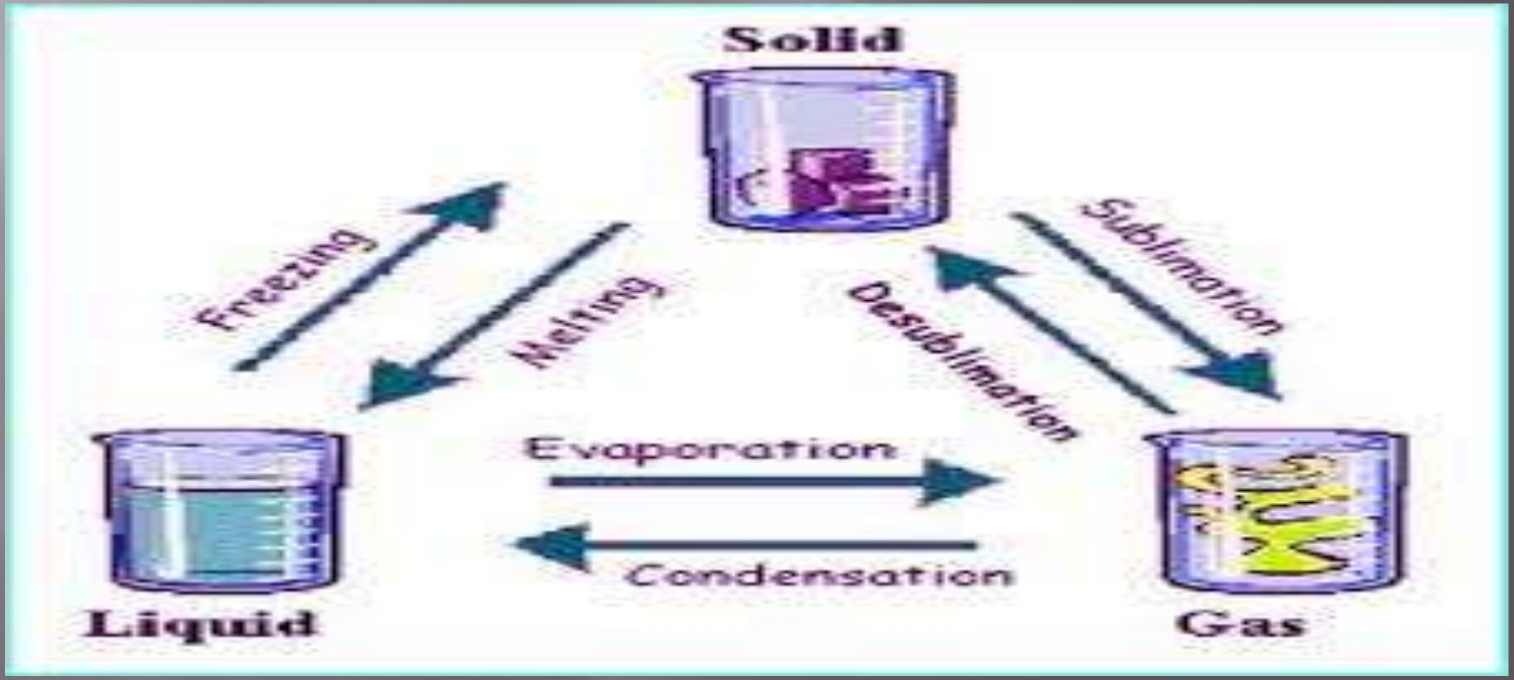
- It consist of metallic vessel and stirrer Of the same material like copper or aluminium .
- The vessel is kept inside a wooden jacket which contains heat insulating materials like glass ,wool etc.
- The outer jacket acts as a heat reduce the heat loss from the inner vessel
- There is opening in the outer jacket through which a mercury thermometer can be inserted into the calorimeter.
- It is used to determine specific heat of a substance.

Change Of State

Example : water (Solid ,liquid ,Gas)

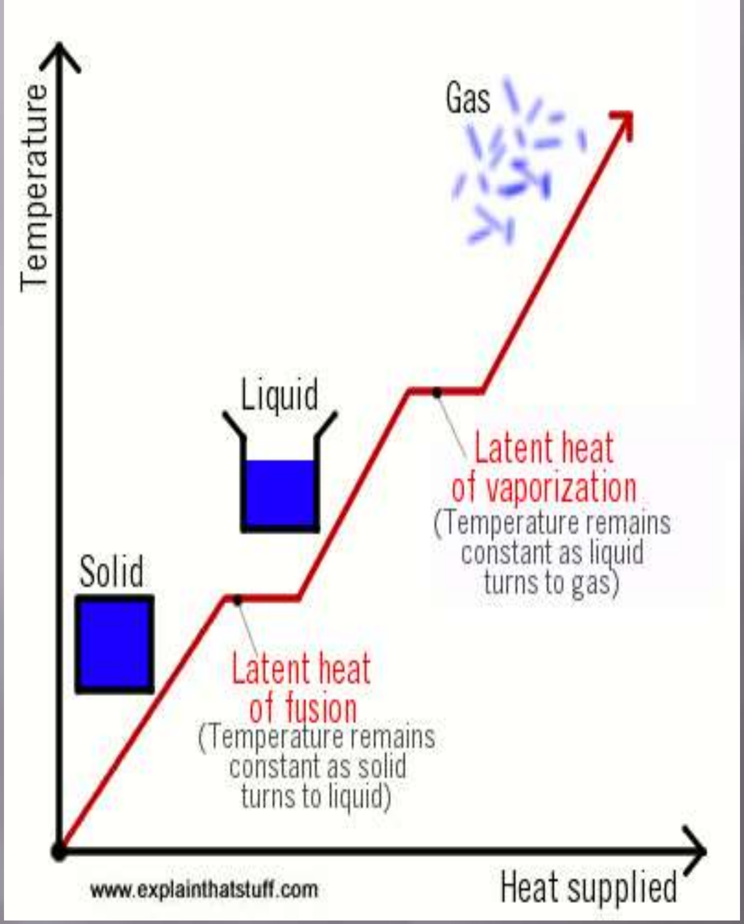
Three states

1. **Solid (Ice)**
2. **Liquid (Water)**
3. **Gas (Steam)**



- At standard pressure the temperature at which a substance changes its state from solid to liquid is called melting point. Melting point of water is $0^{o}C$.
- At standard pressure the temperature at which a substance changes its state from liquid to gas is called boiling point. boiling point of water is $100^{o}C$.

Latent heat



Latent heat of a substance is the quantity of heat required to change the state of unit mass of the substance without changing its temperature.

Two types

- **Heat of fusion**

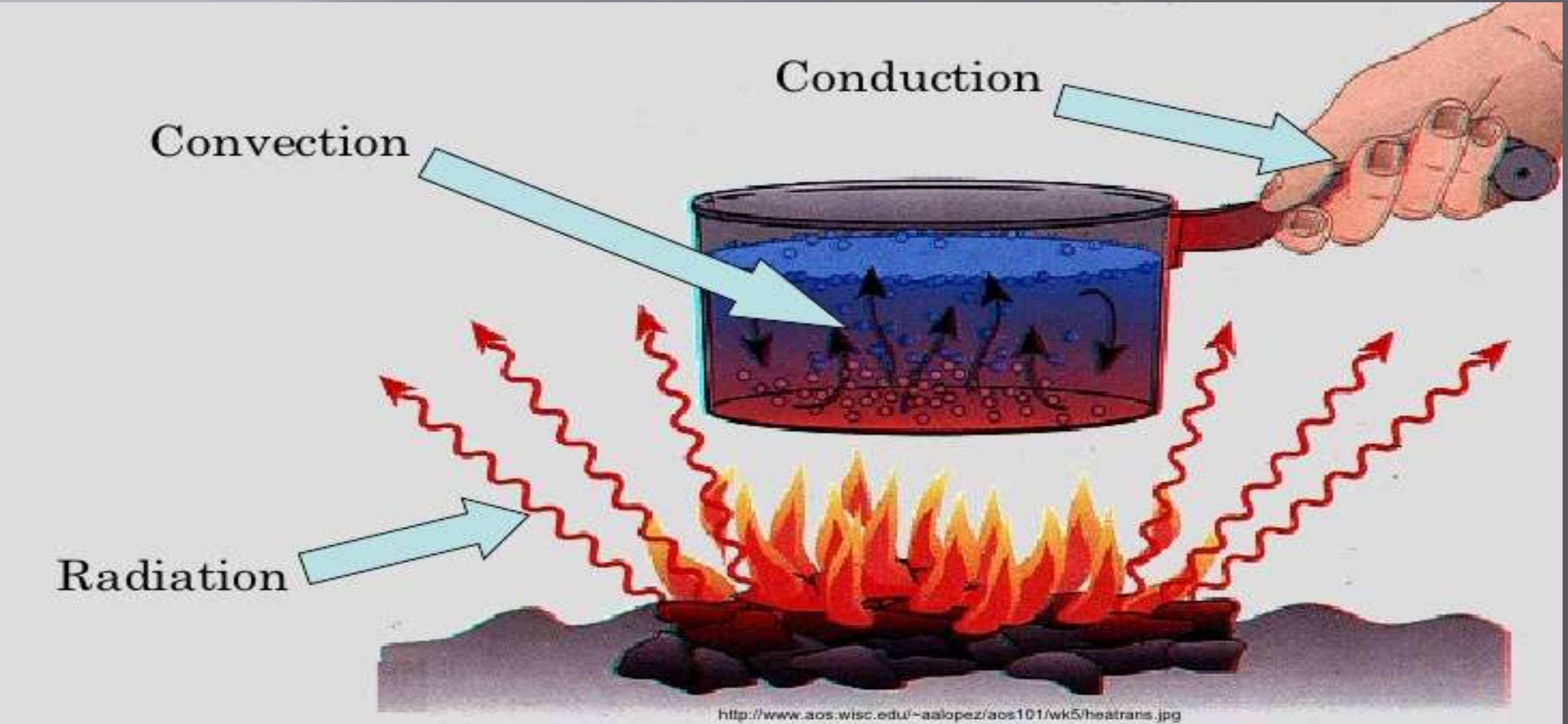
The quantity of heat required to convert unit mass of a substance from its solid state to the liquid state , at its melting point , without any change in its temperature .

- **Heat of vaporisation**

The quantity of heat required to convert unit mass of a substance from its liquid state to vapor state , at its boiling point ,without any change in its temperature .

Three types of heat transfer

3 types of heat transfer



This picture illustrates all three type of heat transfer.
Can you identify them all?

Conduction

In this case the molecules of the rod do not move from their positions, but the heat travels from the hotter to the colder part . This transmission of heat is called conduction.

For conduction of heat to take place from one point to another following condition must be satisfied-

1) The two points should be at different temperatures.

2)There should be a medium between the two points .

The substances , which conduct heat easily ,are called good conductors. All metals are good conductor of heat.

E.g. steel, silver , aluminium etc.

The substances , which do not conduct heat easily ,are called bad conductors of heat or insulators.

e.g. glass ,wood , air , paper, cloth etc.

Conduction through metal rod

- Consider a long uniform metal bar AB
- Having number of drilled at equal distances.
- To read temperature , a sensitive thermometer is placed in each of the holes.
- The thermometer T1 which close to the hot end first shows rise in the temperature. Then thermometers T2,T3,T4 respectively show rise in the temperature.
- Consider small portion D, which receives heat from C. It absorbs the part of the heat received, hence there is a rise in the temperature and transfer heat to its neighbouring cooler portion E. During the process , some part of the heat is lost by radiation from its exposed surface .

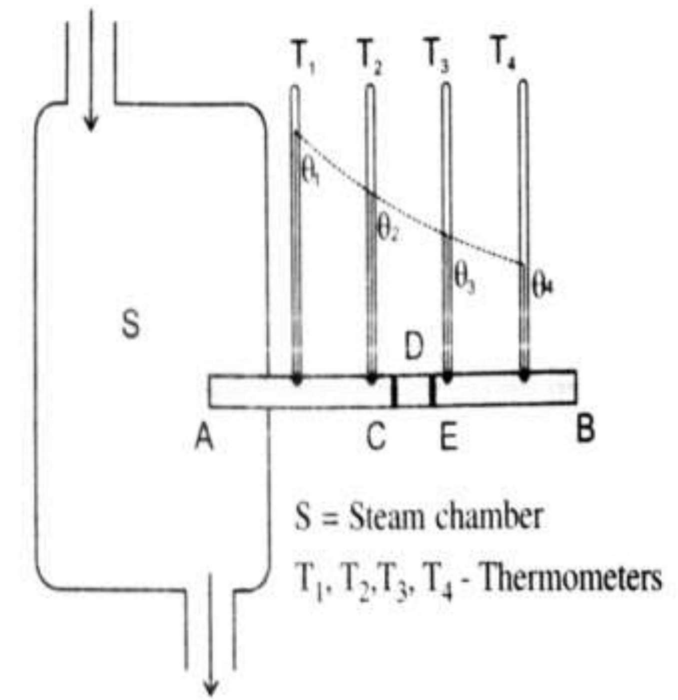


Fig. 7.5 Conduction through metal rod.

- After sufficiently long time ,all the thermometer cease to show any further rise in temperature , this state is called steady state.
- Hence in steady state condition heat received by the segment in one second and heat lost by conduction and radiation in one second becomes equal.

Uses of good and bad conductors.

1)When hot water is poured in a breaker of thick glass ,the beaker cracks: When hot water is poured in the glass beaker ,the inner surface of the glass is a bad conductor of heat , the heat inside does not reach the outer surface quickly so outer surface doesn't expand and glass cracks.

2)Cooking utensils are made of metals with handles of bad conductor. Here heat can be easily conducted through metals, as metals are good conductors of heat. Bad conductors will not conduct the heat from the utensils to our hand.

3)Mica is bad conductor of electricity but good conductor of heat , so it is used as an electrical insulator . It is coated over a coil of an iron.

Convection of heat

This water is in turn heated ,it expands, its density decreases and it moves upward .This cycle goes on repeating so long as the water is being heated. This process of transfer of heat is called convection of heat.

Radiation of heat

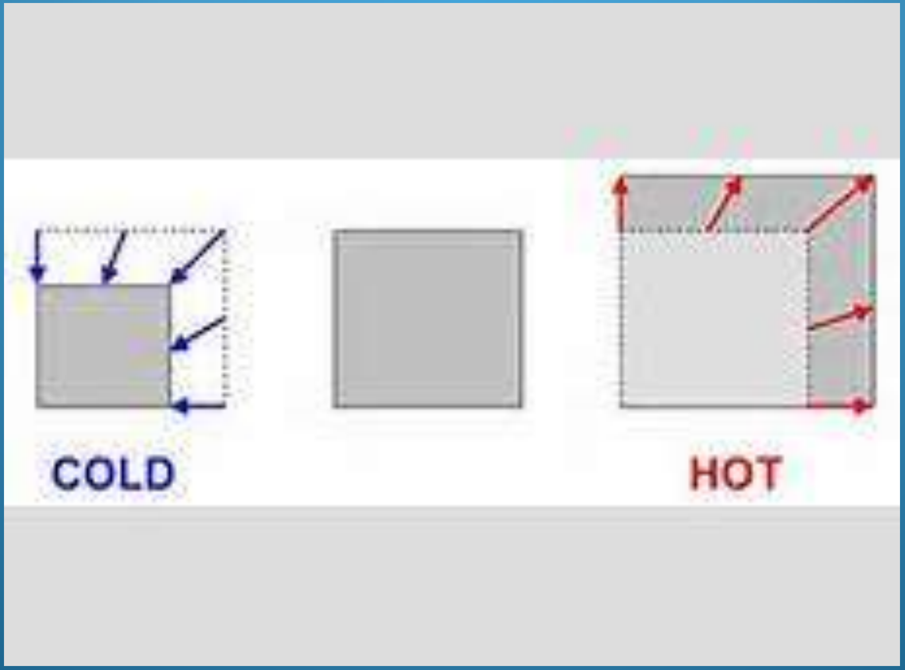
The transfer of heat from the sun to the earth takes place by another process known as radiation of heat.

Radiation of heat is defined as the process of transfer of heat in the form of electromagnetic waves ,for which material medium is not necessary.

Thank you

TOPIC

THERMAL EXPANSION



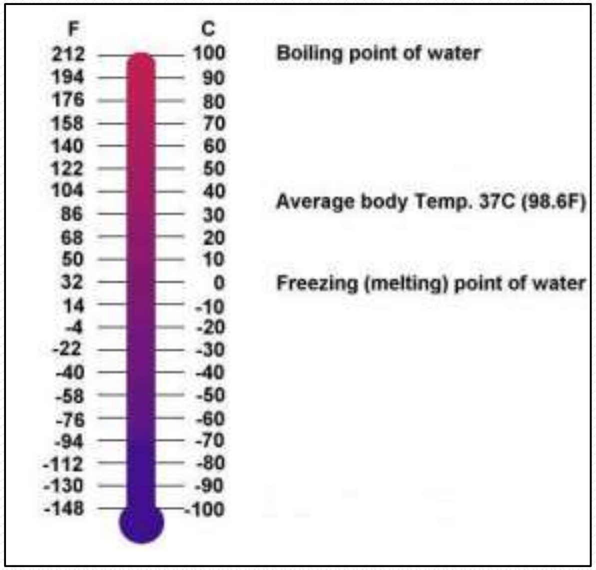
THERMAL EXPANSION

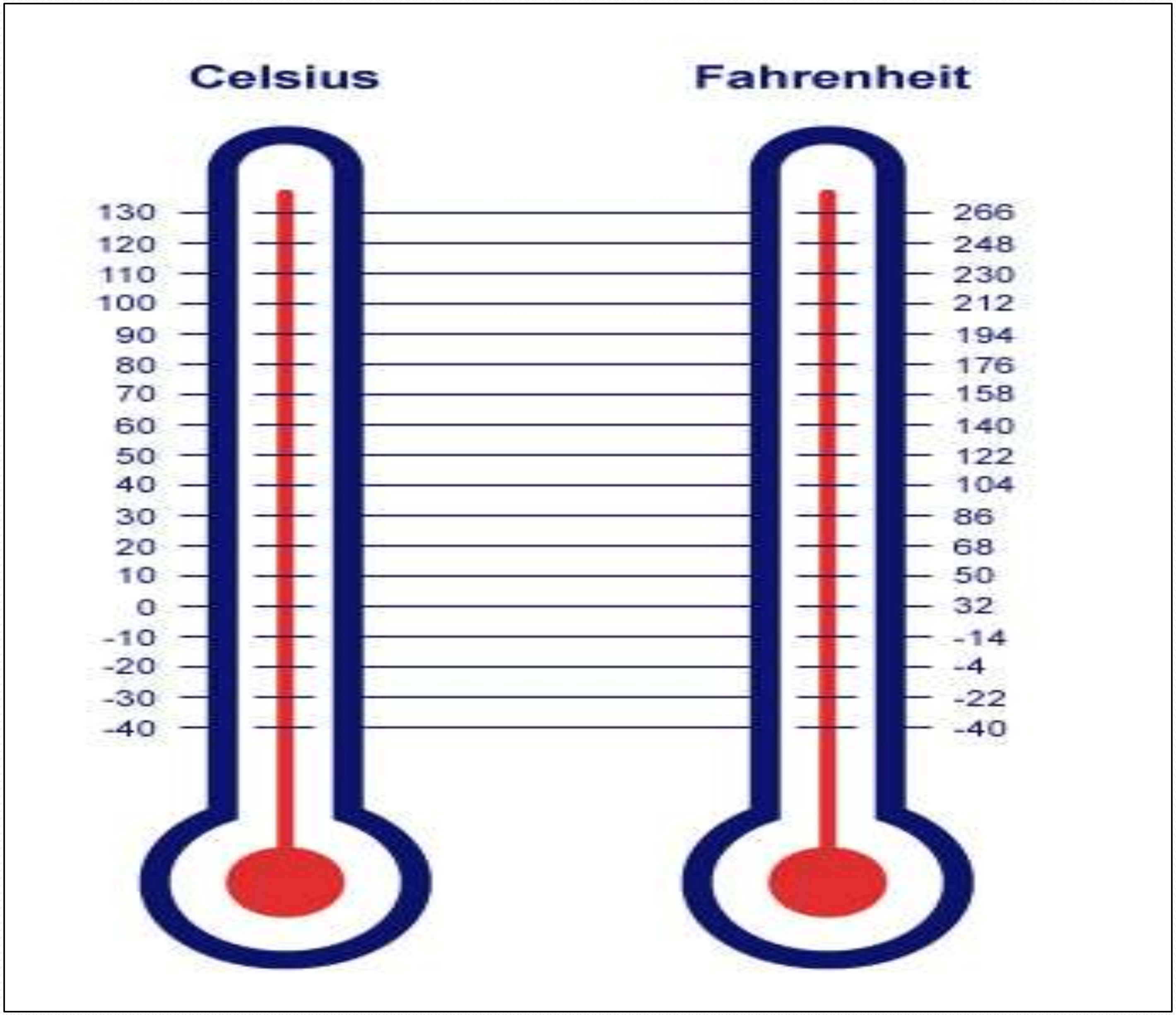
- TEMPERATURE AND HEAT

- Heat is form of energy which produces the sensation of hotness or coldness. Heat energy flows from a hot body to a cold body.
- The degree of hotness or coldness of the body is called temperature
- SI unit of heat is Joule(J)and CGS unit is erg.
- Practical unit of heat is calorie (cal).

Measurement of temperature

- A device used to measure the temperature of a body is called thermometer.
- A branch of science which deals with the measurement of temperature of a substance is called thermometry.
- Various temperature scales used to calibrate a thermometer are :
  1) Celsius scale
  2) Fahrenheit scale
  3) Kelvin Scale





Celsius
Fahrenheit
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
266
248
230
212
194
176
158
140
122
104
86
68
50
32
-14
-4
-22
-40

- **Celsius scale**
- On this scale the ice point (melting point of pure ice)is marked as 0 ^{0}c and the steam point (boiling point of water)is marked as 100 ^{0}c ,both taken at normal atmospheric pressure. The interval between this points is divided into 100 equal part. Each of these divisions is called as 1^{0}C
- **FARENHEIT SCALE (^{0}F)**
- In the Fahrenheit scale, the melting point of pure ice at standard atmospheric pressure is 32^{0}F and marked as the lower fixed point on the thermometer. The boiling point of pure water (steam point) at standard atmospheric pressure is 212 ^{0} F and marked as the upper fixed point on the thermometer.
- The interval between the lower fixed point and the upper fixed point is divided into 180 equal parts or divisions. Each part or a division is called one degree Fahrenheit (1^{0}F)

KELVIN SCALE

- The temperature scale that has its zero at – 273.15 ^{o}c and temperature interval are same as that on the Celsius scale is called as Kelvin scale or absolute scale.
- The interval between the lower fixed point and the upper fixed point is divided into 100 equal parts or divisions. Each part or division is called one Kelvin (K)
- The lowest possible temperature on this scale is K (-273.15) and it is called as **absolute zero of temperature**.
- The temperature scale which begins at absolute zero is called Kelvin scale or absolute temperature scale
- Temperature intervals of the Kelvin scale are same as Celsius scale.
- If T is the absolute temperature and t is Celsius temperature the T = t + 273.15
- The formula for conversion of one temperature scale into another is given below. C/100 = (F-32)/180=(K-273)/100

  Where C,F and K denote the temperature of a body in Celsius, Fahrenheit and
- Kelvin scales of temperature C= 5/9 * (F-32)

Ideal gas Equation

- The gas whose molecules are extremely small point masses among which no intermolecular forces act is called an ideal or perfect gas.
- Only the force they exert is when they physically collide. Thus, in an ideal gas, the molecules have only kinetic energy and no potential energy.
- The equation of an ideal gas for n mole is $PV=nRT$
- And for 1 mole is $PV = RT$
- Where R is the universal (molar) gas constant.
- The Si unit of R is J/mol K and CGS unit is erg/mol K

- # Boyle’s Law
- At constant temperature the volume of given mass of gas is inversely proportional to its pressure. $V \alpha$ **1**/P , at constant temperature
- # Charle’s Law
- At constant pressure the volume of given mass of gas is directly proportional to its absolute temperature
- $V \alpha T$ at constant pressure

Relation between three variables of gas i.e pressure ,volume and temperature

- $V \alpha 1/P$ at constant temperature (By Boyle's law)........1

- $V \alpha T$ at constant pressure (By Charle's law) 2

- Combining 1 and 2 ,
  - PV/T = constant 3

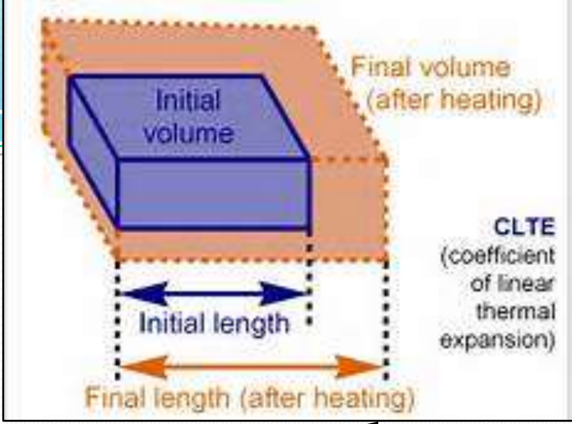
  For one mole of gas, constant of proportionality is R

  Therefore, $PV/T = R$...4

  Or, $PV=RT$

  This relation is called as ideal gas equation.

Thermal Expansion



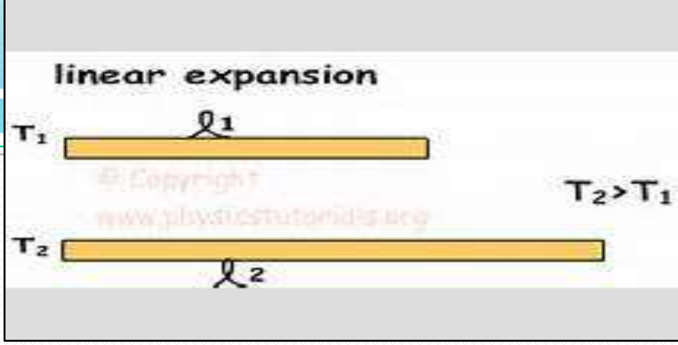
- It is our common experience that most substance expand on heating and contract on cooling.
- A change in the temperature of body causes the change in dimension.
- The increase in the dimension of body with increase in temperature is called as thermal expansion.
- The increase in length of solid on heating is called linear expansion.
- Increase in surface area is called areal or superficial expansion.
- Increase in volume is called volume cubical expansion

Expansion of Solids

- Solids are made up of atoms and molecules.
- When solid is heated its temperature increase
- Due to this the amplitude of vibration of molecules increases and consequently the intermolecular distance between the molecules increases.
- Due to this increase in intermolecular distance, solid expands.
- Solids can be divided into 2 categories, a) Isotropic solids, b) Anisotropic solids

Definition

- Isotropic Solids = Solids which have the same properties in all direction and expand equally in all directions are called Isotropic solid. Metals, glass , rock salt are isotropic solids.
- Anisotropic Solids = Solids which have different properties in different direction and expand in one direction and contract in perpendicular dimension are called anisotropic solid.



Linear Expansion

- Consider a long uniform metal rod of original length L_o at o degree Celsius . When the rod is heated its length increases.
- Let L_t be the length of rod at T degree Celsius.
- Then $L_t - L_o$ is increase in length of rod. This increase in length of rod called linear expansion.
- Experimentally it is observed that, increase in length of the rod is directly proportional to the
- A) Its original length L_o
- B) The rise in temperature $t^0C - o^0C = t^0C$
  - i.e $L_t - L_o$ directly proportional to $L_o t$

  Therefore, $L_t - L_o = \alpha L_o t$
- $Lt = L_o (1 + \alpha t)$ where α is called coefficient of linear expansion of the material of the rod. Its value depends upon the nature of material of the rod and temperature
- i.e. $\alpha = L_t - L_o / L_o t$
- Coefficient of linear expansion = increase in length/original length * rise in temperature

Coefficient of linear expansion (α)

- Coefficient of linear expansion of a material of solid is defined as the increase in length per unit original length per degree rise in temperature.
- The unit of α is per ^0C ($^0C^{-1}$) or per K(K^{-1}).
- If L_1 and L_2 are the length of the rod at temperature t_1 ^0C and t_2 ^0C resp. then coefficient of linear expansion of the rod is given by,

$$L_1 = L_0 (1+ \alpha t1) \text{ and } L_2 = L_0 (1 + \alpha t2)$$

Dividing we get,

$$L_2/L_1 = L_0 (1 + \alpha t2) \ / \ L_0 (1+ \alpha t1)$$

$$L_2/L_1 = (1 + \alpha t2)*(1+ \alpha t1)^{-1}$$

Coefficient of linear expansion (α)

By Binomial expansion,

$(1+ \alpha\ t1)^{-1} = (1- \alpha\ t1) + 2\ \alpha^2 t_1^{\,2} + \ldots\ldots\ldots\ldots\ldots\ldots$

Expanding binomially and neglecting higher order terms of α As they are very small. We get,

$L_2/L_1 = L_0\ (1 - \alpha t1) + \alpha\ t2 - \alpha^2\ t1\ t2$

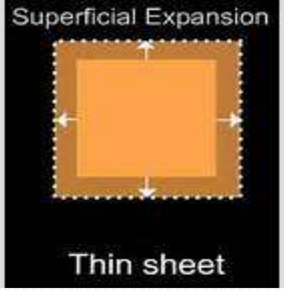
$L_2/L_1 = 1 + \alpha\ (t_{2-}\ t_{1)}$ ……………………(neglecting $\alpha 2\ t1\ t2)$

$L_{2\,=}\ L_{1\,[}\ 1 + \alpha\ (t_{2-}\ t_{1)\,]}$

$L_{2\,-}\ L_{1\,=}\ L_1\ \alpha\ (t_{2-}\ t_{1\,)}$

$\alpha = L_{2-}\ L_{1/}\ L_{1\,(}t_{2-}\ t_{1)}$

Areal Expansion



- Consider a metal plate of surface area A_o at ^{0}C. When the metal plate is heated, its surface area increases.
- Let A_t its surface area at t ^{0}C. Then A_t-A_o is the increase in surface area is called areal expansion or superficial expansion.
- Experimentally it is observed that, increase in surface area of the metal plate is directly proportional to
- A) its original surface area A_o and
- B) The rise in temperature $t^0C - 0^0C = t^0C$

$$\text{i.e } A_t = A_o (1 + \beta t)$$

Where β is constant called coefficient of areal or superficial expansion of the material of the plate and temperature.

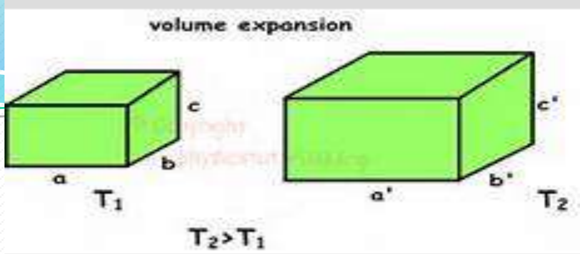
$$\beta = A_t - A_o / A_o t$$

Coefficient of areal expansion = Increase in area / original area * rise in temperature

Coefficient of areal expansion (β)

- Coefficient of areal expansion of a material of a solid is defined as a increase in area per unit original area per degree rise in temperature.
- Let A_1 & A_2 are the surface area of the plate at temperature t_1 and t_2 degree celcius resp. Then, coefficient of areal expansion of the metal plate is given by,

- $\beta = A_2 - A_1 / A_1(t_2 - t_1)$



Volume expansion

- Consider a metal block volume V_o at 0^oC. When the metal block is heated , its volume increases.
- At V_t be its volume at t^oC . Then $V_t - V_o$ is the increase in volume of metal block. This increase in volume is called volume expansion or cubical expansion.
- Experimentally it is observed that, the increase in volume of the metal block is directly proportional to
  - A)its original volume V_o and
  - B) the rise in temperature $t^oC - 0^oC = t^oC$
- $V_t = V_o(1+ \Upsilon t)$
  - Where ϒ is a constant called coefficient of volume or cubical expansion of the material of the metal block and temperature.
  - $\Upsilon = V_t - V_o / V_o t$

Coefficient of volume expansion(Υ)

- Coefficient of volume expansion of material of solid is defined as the increase in volume per unit original volume per degree rise in temperature.
- The unit of Υ is per ^oC ($^oC^{-1}$) or per K (K^{-1})
- If V_1 and V_2 are the volumes of the block at temperature $t_1{}^oC$ and $t_2{}^oC$ resp. the coefficient of volume expansion of the block is,
- $\Upsilon = V_2 - V_1 / V_1 (t_2 - t_1)$

Relation

- Relation between α and β
  - The coefficient of areal expansion of the material of a solid is approximately equal; to two times the coefficient of linear expansion
  - i.e $\beta = 2\alpha$
  - Relation between α and ϒ
  - The coefficient of cubical expansion of a material of a solid is approximately equal to three times the coefficient of linear expansion
  - $\Upsilon = 3\alpha$
  - Relation between α , β , ϒ
  - $\alpha = \beta/2 = \Upsilon/3$
  - i.e $2\alpha = 3\beta = 6\Upsilon$


Thank You!