APPLIED PHYSICS-1

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UNIT1

UNITS AND DIMENSIONS

DEFINITIONOFPHYSICSANDPHYSICALQUANTITIES

Physics: *Physics is the branch of science, which deals with the study of nature and properties of matter and energy*. The subject matter of physics includes heat, light, sound, electricity, magnetism and the structure of atoms.

Physical Quantities: *All quantities which can be measured are called physical quantities.*

For example: Distance, Speed, Mass, Force etc.

UNITS: FUNDAMENTALANDDERIVEDUNITS

Measurement: In our daily life, we need to express and compare the magnitude of different quantities; this can be done only by measuring them.

Measurement is the comparison of an unknown physical quantity with a known fixed/standard physical quantity.

Unit: The known fixed physical quantity is called unit.

OR

The quantity used as standard for measurement is called unit.

For example, when we say that length of the class room is 8 metre, we compare the length of class room with standard quantity of length called meter.

Length of classroom=8metre

$$Q=nu$$

Physical Quantity= Numerical value ×unit
Q=Physical Quantity n
= Numerical value
u=Standard unit
Mass of stool = 15 kg
Mass=Physical quantity
15 = Numerical value
Kg = Standard unit
Means mass of stool is15times of known quantity i.e. Kg.

ClassificationofUnits: Units can be classified into two categories.

- **Fundamental**
- **Derived**

Fundamental Quantity: *The quantity which is independent of other physical quantities*. In mechanics, mass, length and time are called fundamental quantities. Units of these fundamental physical quantities are called **Fundamental units.**

e.g. Fundamental Physical Quantity	Fundamental unit
Mass	Kg, Gram, Pound
Length	Metre, Centimetre, Foot
Time	Second

Derived Quantity: *The quantity which is derived from the fundamental quantities is a derived quantity*. For example area, speed etc.

$$\text{Area} = \text{Length} \times \text{Breadth}$$
$$= \text{Length} \times \text{Length}$$
$$= (\text{Length})^2$$
$$\text{Speed} = \text{Distance}/\text{Time}$$
$$= \text{Length}/\text{Time}$$

The units for derived quantity are called **Derived Units.**

SYSTEMSOFUNITS: CGS, FPS, MKS, SI

For measurement of physical quantities, the following systems are commonly used:-

(i) **C.G.S system**: In this system, the unit of length is centimetre, the unit of mass is gram and the unit of time is second.

(ii) **F.P.S system**: In this system, the unit of length is foot, the unit of mass is pound and the unit of time is second.

(iii) **M.K.S** :In this system ,the unit of length is metre, unit of mass is kg and the unit of time is second.

(iv) **S.I System**: This system is an improved and extended version of M.K.S system of units. It is called international system of unit.

Table of Fundamental Units

Sr.No.	**Name of Physical Quantity**	**Unit**	**Symbol**
1	Length	Metre	m
2	Mass	Kilogram	Kg
3	Time	Second	s
4	Temperature	Kelvin	K

5	ElectricCurrent	Ampere	A
6	LuminousIntensity	Candela	Cd
7	Quantity of Matter	Mole	mol

Table of Supplementary unit

Sr.No	**Name of Physical Quantity**	**Unit**	**Symbol**
1	Plane angle	Radian	rad
2	Solid angle	Steradian	sr

DEFINITIONOFDIMENSIONS

Dimensions: The powers, to which the fundamental units of mass, length and time written as M, L and T are raised, which include their nature and not

their magnitude are called dimensions of a physical quantity.

For example Area=LengthxBreadth

$=[L^1]\times[L^1]=[L^2]=[M^0L^2T^0]$

Power (0, 2, 0) of fundamental units are called dimensions of area in mass, length and time respectively.

e.g. Density=mass/volume

$=[M]/[L^3]$

$=[M^1L^{-3}T^0]$

DIMENSIONALFORMULAEANDSIUNITSOFPHYSICALQUANTITIES

Dimensional Formula: An expression along with power of mass, length & time which indicates how physical quantity depends upon fundamental physical quantity.

e.g. Speed= Distance/Time

$=[L^1]/[T^1]=[M^0L^1T^{-1}]$

It tells us that speed depends upon L&T. It does not depend uponM.

Dimensional Equation: An equation obtained by equating the physical quantity with its dimensional formula is called dimensional equation.

The dimensional equation of area, density &velocity are given as under-

Area = $[M^0L^2T^0]$

Density = $[M^1L^{-3}T^0]$

Velocity=$[M^0L^1T^{-1}]$

Dimensional formula &SI unit of Physical Quantities

Sr. No.	PhysicalQuantity	Formula	Dimensions	NameofS.Iunit
1	Force	Mass× acceleration	$[M^1L^1T^{-2}]$	Newton(N)
2	Work	Force×distance	$[M^1L^2T^{-2}]$	Joule(J)
3	Power	Work/time	$[M^1L^2T^{-3}]$	Watt (W)
4	Energy(allform)	Stored work	$[M^1L^2T^{-2}]$	Joule(J)
5	Pressure, Stress	Force/area	$[M^1L^{-1}T^{-2}]$	Nm^{-2}
6	Momentum	Mass× velocity	$[M^1L^1T^{-1}]$	$Kgms^{-1}$
7	Momentofforce	Force×distance	$[M^1L^2T^{-2}]$	Nm
8	Impulse	Force×time	$[M^1L^1T^{-1}]$	Ns
9	Strain	Changein dimension /Originaldimension	$[M^0L^0T^0]$	Nounit
10	Modulus of elasticity	Stress/Strain	$[M^1L^{-1}T^{-2}]$	Nm^{-2}
11	Surface energy	Energy/Area	$[M^1L^0T^{-2}]$	$Joule/m^2$
12	Surface Tension	Force/Length	$[M^1L^0T^{-2}]$	N/m
13	Co-efficient of viscosity	Force×Distance/ Area× Velocity	$[M^1L^{-1}T^{-1}]$	N/m^2
14	Moment of inertia	Mass×(radiusof gyration)^2	$[M^1L^2T^0]$	$Kg\text{-}m^2$
15	Angular Velocity	Angle/time	$[M^0L^0T^{-1}]$	radpersec
16	Frequency	1/Timeperiod	$[M^0L^0T^{-1}]$	Hertz
17	Area	Length×Breadth	$[M^0L^2T^0]$	$Metre^2$
18	Volume	Length×breadth× height	$[M^0L^3T^0]$	$Metre^3$
19	Density	Mass/volume	$[M^1L^{-3}T^0]$	Kg/m^3
20	Speed/ velocity	Distance/time	$[M^0L^1T^{-1}]$	m/s
21	Acceleration	Velocity/time	$[M^0L^1T^{-2}]$	m/s^2

22	Pressure	Force/area	$[M^1L^{-1}T^{-2}]$	N/m^2

PRINCIPLEOFHOMOGENEITYOFDIMENSIONS

It states that *the dimensions of all the terms on both sides of an equation must be the same*. According to the principle of homogeneity, the comparison, addition & subtraction of all physical quantities is possible only if they are of the same nature i.e., they have the same dimensions.

If the power of M, L and T on two sides of the given equation are same, then the physical equation is correct otherwise not. Therefore, this principle is very helpful to check the correctnessof a physical equation**.**

Example: A physical relation must be dimensionally homogeneous, i.e., allthe terms on both sides of the equation must have the same dimensions.

In the equation, $S = ut + ½at^2$

The length (S) has been equated to velocity (u) & time (t), which at first seems to be meaningless, But if this equation is dimensionally homogeneous, i.e., the dimensions of all the terms on both sides are the same, then it has physical meaning.

Now, dimensions of various quantities in the equation are:

Distance, $S = [L^1]$

Velocity, $u=[L^1T^{-1}]$

Time, $t=[T^1]$

Acceleration, $a=[L^1T^{-2}]$

½isaconstantandhasnodimensions.

Thus, the dimensions of the term on L.H.S. is $S=[L^1]$and

Dimensions of terms on R.H.S=

$$ut+ ½at^2=[L^1T^{-1}][T^1]+[L^1T^{-2}][T^2]=[L^1]+[L^1]$$

Here, the dimensions of all the terms on both sides ofthe equation are the same. Therefore, the equation is dimensionally homogeneous.

DIMENSIONALEQUATIONS, APPLICATIONSOFDIMENSIONALEQUATIONS

Dimensional Analysis: A careful examination of the dimensions of various quantities involved in a physical relation is called dimensional analysis. The analysis of the dimensions of a physical quantity is of great help to us in a number of ways as discussed under the uses of dimensional equations.

Uses of dimensional equation: The principle of homogeneity & dimensional analysishas put tothe following uses:

(i) Checking the correctness of physical equation.
(ii) To convert a physical quantity from one system of units into another.

1. **To check the correctness of Physical relations**: According to principle of Homogeneity of dimensions, a physical relation or equation is correct, if the dimensions of all the terms on both sides of the equation are the same. If the dimension of even one term differs from those ofothers, the equation is not correct.

Example1 Checkthecorrectnessofthefollowingformulaebydimensionalanalysis.

(i) $F = mv^2/r$ (ii)$= 2\pi\sqrt{l/g}$

Where all the letters have their usual meanings **Sol.** $\boldsymbol{F = mv^2/r}$

Dimensions of the term on L.H.S

Force, $F=[M^1L^1T^{-2}]$

Dimensions of the term on R.H.S

$\boldsymbol{mv^2/r}=[M^1][L^1T^{-1}]^2/[L]$

$=[M^1L^2T^{-2}]/[L]$

$=[M^1L^1T^{-2}]$

The dimensions of the term on the L.H.S are equal to the dimensions of the term on R.H.S. Therefore, the relation is correct.

(ii)$\boldsymbol{t=2\pi\sqrt{\frac{l}{g}}}$

Here,Dimension of term on L.H.S

$t=[T^1]=[M^0L^0T^1]$

Dimensions of terms on R.H.S

Dimensionoflength$=[L^1]$

Dimensionofg(acc.duetogravity)$=[L^1T^{-2}]$ 2π

being constant have no dimensions.

Hence,thedimensionsofterms$2\pi\sqrt{\frac{l}{g}}$on R.H.S

$=(L^1/ L^1T^{-2}])^{1/2}=[T^1]=[M^0L^0T^1]$

Thus, the dimensions of the terms on both sides of the relation are the same i.e., $[M^0L^0T^1]$.Therefore, the relation is correct.

2. **Toconvertaphysicalquantity fromonesystemofunitsintoanother.**

Physicalquantitycanbe expressedas

$Q=nu$

Let $n_1u_1$represent the numericalvalue and unit ofa physicalquantityinone systemand $n_2u_2$in the other system.

If for a physical quantity Q; $M_1L_1T_1$be the fundamental unit in one system and $M_2L_2T_2$ be fundamental unit of the other system and dimensions in mass, length and time in each system can be respectively a,b,c.

$u_1=[M_1^aL_1^bT_1^c]$

$u_2= [M_2^aL_2^bT_2^c]$

Aswe know

$n_1u_1=n_2u_2n_2$

$=n_1u_1/u_2$

$$n_2=n_1\frac{[M_1^aL_1^bT_1^c]}{[M_2^aL_2^bT_2^c]}$$

$$n_2=n_1\left[\left(\frac{M_1}{M_2}\right)^a\left(\frac{L_1}{L_2}\right)^b\left(\frac{T_1}{T_2}\right)^c\right]$$

While applying the above relations the systemofunit as first system in which numerical value of physical quantity is given and the other as second system

Thusknowing$[M_1L_1T_1]$,$[M_2L_2T_2]$a,b,candn_1,wecancalculaten_2.

Example1 Convertaforceof1Newtontodyne.

Sol.To converttheforce fromMKSsystemtoCGSsystem,weneedtheequation $Q=n_1u_1=n_2u_2$

Thus$n_2=\frac{n_1u_1}{u_2}$

Here$n_1=1$,$u_1=1N$,$u_2=dyne$

$$n_2=n_1\frac{[M_1L_1T_1^{-2}]}{[M_2L_2T_2^{-2}]}$$

$$n_2=n_1\left(\frac{M_1}{M_2}\right)\left(\frac{L_1}{L_2}\right)\left(\frac{T_1}{T_2}\right)^{-2}$$

$$n_2=n_1\left(\frac{kg}{gm}\right)\left(\frac{m}{cm}\right)\left(\frac{s}{s}\right)^{-2}$$

$$n_2=n_1\left(\frac{1000gm}{gm}\right)\left(\frac{100cm}{cm}\right)\left(\frac{s}{s}\right)^{-2}$$

$n_2=1(1000)(100)$

$n_2=10^5$

Thus**1N=**10^5**dynes**.

Example2 ConvertworkoF1ergintoJoule.

Sol: Hereweneedto convert workfromCGSsystemto MKSsystem Thus in the equation

$$n_2=\frac{n_1u_1}{u_2}$$

$n_1=1$

u_1=erg(CGSunitofwork)

u_2=joule(SI unitofwork)

$$n_2 = \frac{n_1 u_1}{u_2}$$

$$n_2 = n_1 \frac{M_1 L_1^2 T_1^{-2}}{M_2 L_2^2 T_2^{-2}}$$

$$n_2 = n_1 \left(\frac{M_1}{M_2}\right)\left(\frac{L_1}{L_2}\right)^2\left(\frac{T_1}{T_2}\right)^{-2}$$

$$n_2 = n_1 \left(\frac{gm}{kg}\right)\left(\frac{cm}{m}\right)^2\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = n_1 \left(\frac{gm}{1000gm}\right)\left(\frac{cm}{100cm}\right)^2\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = 1(10^{-3})(10^{-2})^2 \quad n_2 = 10^{-7}$$

Thus, **1erg=** 10^{-7} **Joule**.

UNIT 2

FORCEANDMOTION

SCALAR AND VECTOR QUANTITIES

Scalar Quantities:

Scalar quantities are those quantities which are having only magnitude but no direction.

Examples**:**Mass,length,density,volume,energy,temperature,electriccharge,current, electric potential etc.

Vector Quantities:

Vector quantities are those quantities which are having both magnitude as well as direction.

Examples**:** Displacement, velocity,acceleration,force,electricintensity,magneticintensity etc.

Representation of Vector: A vector is represented by a straight line with an arrow head. Here, the length of the line represents the magnitude and arrow head gives the direction of vector.

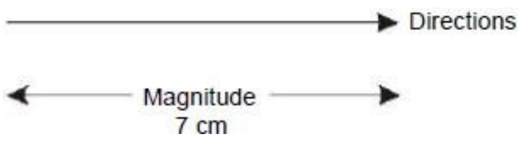


Figure:1

Typesof Vectors

Unit Vector: A vector divided by its magnitude is called a unit vector. It has a magnitude one unit and direction same as the direction of given vector. It is denoted by$\hat{A}$.

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

Collinear Vectors: Two or more vectors having equal or unequal magnitudes, but having same direction are called collinear vectors

Figure:2

Zero Vector: A vector having zero magnitude and arbitrary direction (be not fixed) is called zero vector. It is denoted by O.

ADDITIONOFVECTORS,TRIANGLE&PARALLELOGRAMLAW

AdditionofVectors

(i) Trianglelawofvectoraddition.

If two vectors can be represented in magnitude anddirectionbythetwosidesofatriangletakeninthe same order, then the resultant is represented in magnitude and direction, bythird side ofthe triangle taken in the opposite order (Fig. 2.5).

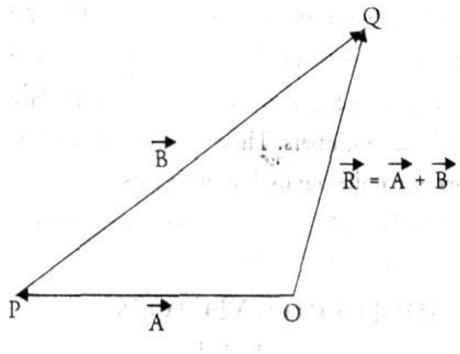


Figure:3

Magnitudeoftheresultant isgivenby

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

Anddirectionoftheresultantisgiven by

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

(ii) Parallelogram(||gm)lawofvectors:

It states that if two vectors, acting simultaneously at a point, can have represented both in magnitudeanddirectionbythetwoadjacent sidesofaparallelogram,theresultant isrepresented by thediagonalofthe parallelogrampassing throughthat point (Fig. 2.6).

Magnitudeoftheresultant isgivenby

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

Anddirectionoftheresultantisgiven by

$$\tan\Phi=\frac{Q\sin\theta}{P+Q\cos\theta}$$

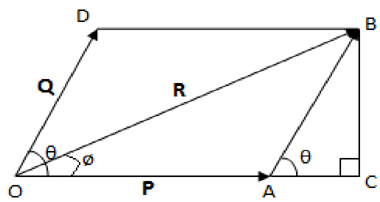


Figure:4

SCALARANDVECTORPRODUCT

MultiplicationofVectors

(i) Scalar(ordot)Product: Itisdefinedastheproductofmagnitudeoftwovectorsandthecosine ofthesmallerangle betweenthem.Theresultant isscalar.Thedotproductofvectors$\vec{A}$and$\vec{B}$ is defined as

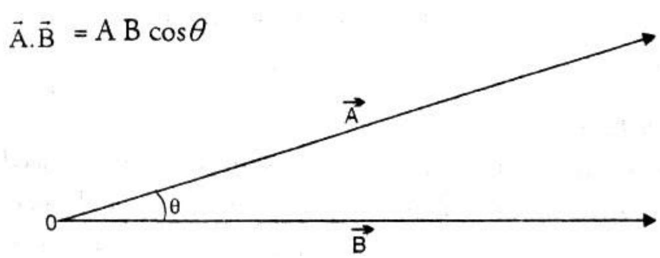


Figure:5

(ii) Vector(orCross) Product: Itisdefinedasavectorhavingamagnitudeequaltotheproductof the magnitudes ofthe two vectors and the sine of the angle between them and is in the direction perpendiculartotheplanecontainingthetwovectors.

Thus,thevectorproductoftwovectorsAandBisequalto

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

FORCEANDITSUNITS,CONCEPTOFRESOLUTIONOF FORCE

Force: Forceisanagentthatproducesaccelerationinthebodyonwhichitacts. Or *Itisapushorapullwhichchangeortendstochangethe positionofthebodyatrestorinuniform motion.* Forceisavectorquantityasithasbothdirectionandmagnitude.Forexample,

(i) Tomoveafootball,wehavetoexert apushi.e.,kickonthefootball

(ii) To stop footballor a bodymoving withsame velocity, we have to applypush ina direction oppositetothedirectionofthebody.

SI unit is Newton.

Dimensionformula:$[MLT^{-2}]$

ResolutionofaForce

Thephenomenonofbreakingagivenforceintotwoormoreforcesindifferentdirections is known as 'resolution of force'. The forces obtained on splitting the given force are called componentsofthegivenforce.

If these are at right angles to each other, then these components are called rectangular components.

Let a force F be represented by a line OP.LetOB (or F_x) is component of F along x-axis and OC(or F_y) is component along y-axis (Fig. 2.8).

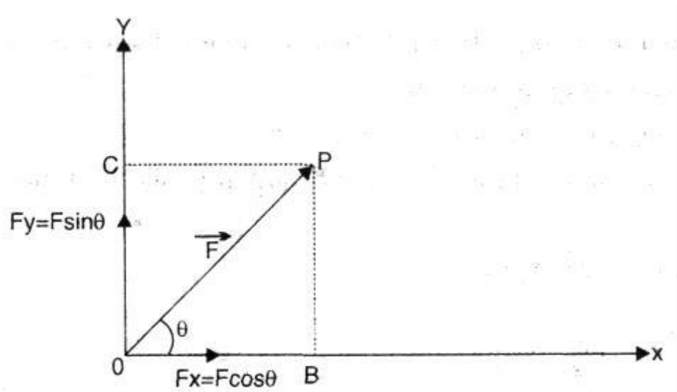


Figure:6

LetforceFmakesanangleθwithx-axis.

InΔOPB

$$\sin\theta = \frac{PB}{OP}$$

PB = OP $\sin\theta$ F_y = F $\sin\theta$

$$\cos\theta = \frac{OB}{OP}$$

OB=OP $\cos\theta$ F_x = F $\cos\theta$

Vector $\vec{F} = \vec{F}_x + \vec{F}_y$

Resultant: $F = \sqrt{F_x^2 + F_y^2}$

NEWTON'SLAWSOFMOTION

SirIsaacNewtongavethreefundamentallaws. Theselawsarecalled Newton'slawsofmotion.

Newton's First Law: *It states that everybody continues in its state of rest or of uniform motion in a straight line untilsomeexternalforceisappliedonit.*

For example, the book lying on a table will not move at its own. It does not change its position from the state of rest until no external force is applied on it.

Newton's Second law: *The rate of change of momentumof abodyis directly proportional to the appliedforceandthechangetakesplaceinthedirectionof forceapplied.*

Or

Accelerationproducedinabodyisdirectlyproportionaltoforceapplied.

Letabodyofmassmmovingwithavelocity*u*.Letaforce*F*beappliedsothat its velocity changes from *u* to *v* in *t* second.

Initial momentum = *mu*

Final momentum after time t second = *mv*

Total change in momentum = *mv-mu*.

Thus, the rate of change of momentum will be

$$\frac{mv-mu}{t}$$

FromNewton'ssecondlaw

$$F \propto \frac{mv-mu}{t} \text{ or } F \propto \frac{(v-u)}{t}$$

$$\text{but} \frac{v-u}{t} = \frac{Change\ in\ velocity}{Time} = \text{Acceleration(a)}$$

Hence,wehave

F∝ma

or F=kma

Where k is constant of proportionality, for convenience let k = 1.

Then F = ma

Newton's Third law: To every action there is an equal and opposite reaction or *action and reaction are equal and opposite*.

When a body exerts a force on another body, the other body also exerts an equal force on the first body, in opposite direction.

From Newton's third law these forces always occur in pairs.

F_{AB} (forceonAbyB)=-F_{BA}(forceonBbyA)

LINEAR MOMENTUM,CONSERVATIONOFMOMENTUM,IMPULSE

Linear Momentum(p):*The quantityofmotioncontainedinthebodyislinear momentum*.Itis given by product of mass and the velocity of the body. It is a vector and its direction is the same as the direction of the velocity.

Let m be the mass and$v$ is the velocity of a body at some instant,then momentum is given by $p=mv$

Example,afast-movingcricketballhasmoremomentuminitthanaslowmovingone.Butaslow- moving heavy roller has more momentum than a fast cricket ball.

Units of momentum:

The S Iunitiskgm/si.e.kg.ms^{-1}. Dimension formula=$[M^1L^1T^{-1}]$.

Conservation of Momentum

If external force acting on a system of bodies is zero then the total linear momentum of a system always remains constant.

i.e.IfF=0

Thus,= $\frac{dp}{dt}=0$

Hence,p(momentum) isconstant.

Recoil of the Gun: When a bullet is fired with a gun the bullet moves in forward direction and gun is recoiled/pushed backwards. Let

m=mass of bullet
u =velocity of bullet
M= mass of gun
v =velocity of gun

Thegunandbulletformanisolatedsystem,sothetotalmomentumofgunandbullet before firing = 0

Totalmomentumofgunand bullet afterfiring=$m.u+M.v$

Using law of conservation of momentum

$$0 = m.u+M.v$$

$$M.v = -m.u$$

$$v= \frac{-mu}{M}$$

This istheexpressionforrecoilvelocityofgun.

Here negative sign shows that motion of the gun is in opposite direction to that of the bullet. Also, velocityofgun is inverselyproportionalto its mass. Lesser the mass, larger will be the recoil velocity of the gun.

Impulse

Impulseisdefinedasthe total change inmomentum producedbythe impulsiveforce.

OR

Impulsemay be defined as the product of force and time andis equal to the total changein momentum of the body.

$$F.t = p_2 - p_1 = \text{totalchangeinmomentum}$$

ExampleAkickgiventoafootballor blowmadewithhammer.

CIRCULARMOTION

Themotion of a bodyin acircleof fixedradiusiscalled circularmotion.
Forexample,themotionofastonetiedtoastringwhenwhirledintheairisacircular motion.

AngularDisplacement:T*heangledescribedbyabodymovinginacircle*iscalledangular displacement.
Considerabodymovesinacircle,startingfromAtoBso that âˆBOAiscalledangulardisplacement

SIunitofangulardisplacementisradian(rad.)

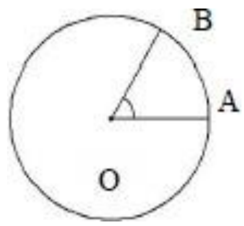


Figure:7

Angular Velocity: Angular velocity of a body moving in a circle is the *rate of change of angular displacement with time*. It is denoted by ω (omega)

Ifθistheangulardisplacementintimetthen

$$\omega = \frac{\theta}{t}$$

SIunitofangularvelocityisrad/s

Time Period: Timetakenbya bodymoving inacircleto completeonecycle iscalledtimeperiod. It is denoted by T

Frequency(*n*):Thenumberofcyclescompletedbyabodyinonesecondiscalledfrequency.

It isreciprocaloftime period

$$n = \frac{1}{T}$$

AngularAcceleration: The time rateofchangeofangularvelocityofabody.

It isdenoted byα. Let angular velocityofabodymoving inacirclechange from$\omega_1$to $\omega_2$in time *t*, then

$$\alpha = \frac{\omega_1 - \omega_2}{t}$$

SI unit of'α'israd/s^2

Relationshipbetweenlinearandangularvelocity

Consider abodymoving inacircleofradius *r*Letit start fromAandreachestoBaftertimet, so that âˆ BOA = θ (Fig. 2.9).

Now

$$angle = \frac{arc}{radius}$$

$$\theta = \frac{AB}{OA} = \frac{S}{r}$$

$$S = r\theta$$

Dividebothsidesbytime(t)

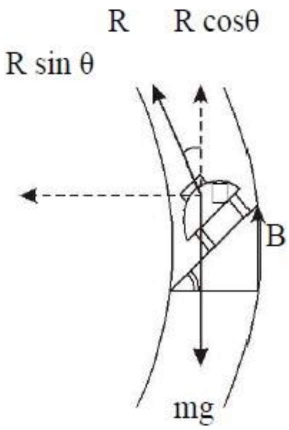
$$\frac{S}{t} = r\frac{\theta}{t}$$

Here $\frac{S}{t} = v$ islinearvelocity

And $\frac{\theta}{t} = \omega$ isangularvelocity

Hence $v = r\omega$

CENTRIPETALANDCENTRIFUGALFORCES



CentripetalForce

The force acting along the radiustowardsthe centreofcircle to keepa bodymovingwithuniformspeed inacircularpathiscalledcentripetal force. It is denoted by F_C.

$$F_c = \frac{mv^2}{r}$$

For example, a stone tied at one end of a string whose other endis held in hand, when round in the air, the centripetal force is supplied by the tension in the string.

Centrifugal Force: A body moving in circle with uniform speed experience a force in a direction away from the centre of the circle. This force is called centrifugal force.

For example, cream is separated from milk by using centrifugal force. When milk is rotatedin cream separator, cream particles in the milk being lighter, experience less centrifugalforce.

APPLICATIONOFCENTRIPETALFORCEINBANKINGBANKING OF ROADS

Banking of Roads: While travelling on a road, you must have noticed that *the outer edge of circular road is slightlyraised above ascompared totheinner edgeof road. Thisiscalled banking of roads (Fig. 2.10).*

Angle of Banking: The angle through which the outer edge of circular road is raised above the inner edge of circular roads is called angle of banking.

Application ofcentripetalforceinbanking ofroads

Let

m=massofvehicle

r=radiusofcircular road

v=uniformspeed (velocity)ofvehicle

θ=angleofbanking

Atthe bodytwo forces act.

Figure:8

(i) Weight(mg)ofvehicleverticallydownwards.

(ii) Normalreaction(R).

Rmakesanangleθanddividestheforces intotwocomponents

(i) Rsinθ towardsthecentre

(ii) Rcosθverticallyupwardsandbalancebyweightof(mg) vehicle

$R\sin\theta$providesthenecessarycentripetalforce$(\frac{mv^2}{r})$

$$R\ Sin\theta = \frac{mv^2}{r} \quad \text{-------- (1)}$$

and $$R\ Cos\theta = mg \quad \text{----------------------------(2)}$$

Divideequation1by2

$$\frac{RSin\theta}{RCos\theta} = \frac{\frac{mv^2}{r}}{mg}$$

$$tan\theta = \frac{v^2}{rg}$$

$$\theta = tan^{-1}(\frac{v^2}{rg})$$

ROTATIONALMOTIONWITHEXAMPLES

The*rotation of a bodyaboutfixedaxis*iscalled Rotationalmotion.Forexample,

(i) Motionofa wheelaboutitsaxis

(ii) Rotationofearthaboutits axis.

DEFINITIONOFTORQUEANDANGULARMOMENTUM

Torque (τ)

Itismeasuredbytheproductofmagnitudeofforceandperpendiculardistanceofthelineof action of force from the axis of rotation.

Itisdenotedbyτ,

$$\tau = \vec{F} x \vec{r}$$

Where *F*isforce and *r*is perpendicular distance.

Unit:Newton(N)

DimensionFormula:$[M^1L^2T^{-2}]$

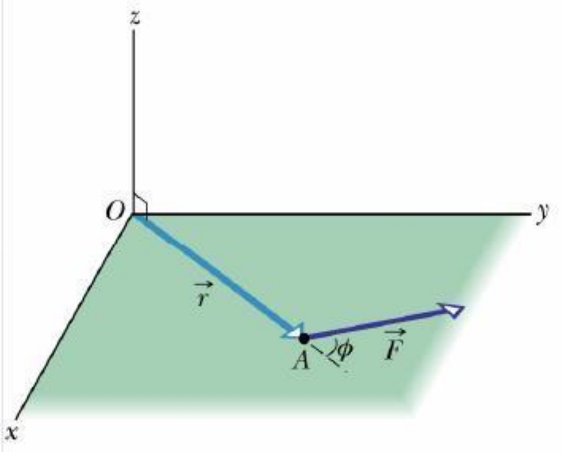


figure:9

AngularMomentum(L)

Angularmomentum of arotatingbody aboutitsaxisof rotationisthealgebraicsum of the linear momentum of its particles about the axis. It is denoted by L.

L =Momentum×perpendiculardistance

$$L = p \times r$$

or $$L = mvr$$

Unit:Kgm^2/sec

DimensionalFormula=$[ML^2T^{-1}]$

MOMENTOFINERTIAANDITSPHYSICAL SIGNIFICANCE

MomentofInertia

Moment ofInertia ofa rotating bodyabout anaxis is defined as *the sum of the product of the mass of various particles constituting the body and square of respective perpendicular distance of different particles of the body from the axis of rotation*.

Expression fortheMomentofInertia:
LetusconsiderarigidbodyofmassMhaving*n*numberof particles revolving about any axis. Let m_1, m_2, m_3..., $m_n$be the masses of particles at distance r_1, r_2, r_3... $r_n$from the axis of rotationrespectively(Fig.4.2).

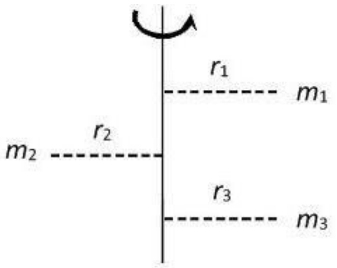


Figure: 10

Moment ofInertiaofwholebody

$$I = m_1r_1^2 + m_2r_2^2 + ... m_nr_n^2$$

or $$I = \sum_{i=1}^{n} m_ir_i^2$$

PhysicalSignificanceofMomentof Inertia

It is totally analogous to the concept of inertial mass. Moment of inertia plays the same role in rotational motion as that of mass in translational motion. In rotational motion, a body, which is free to rotate about a given axis, opposes any change in state of rotation. Moment of Inertia of a body depends on the distribution of mass in a body with respect to the axis of rotation

UNIT3

WORK,POWER AND ENERGY

WORK(DEFINITION,SYMBOL,FORMULAANDSIUNITS)

Work

Work is said to be done when the force applied on a body displaces it through certain distance in the direction of applied force.

$$Work = Force \times Displacement$$

Invectorform,itiswrittenas $\vec{F} \times \vec{S} = FS\ Cos\theta$

It is measured as the productofthe magnitude of force and the distance covered bythe bodyin the direction of the force. It is a scalar quantity.

Unit:SI unitofworkis joule(J).InCGSsystem, unitofworkiserg.

$1J = 10^7$ ergsDimension

ofwork $= [M^1L^2T^{-2}]$

Example1. What work is done in dragging a block 10 mhorizontallywhena 50 N force is applied by a rope making an angle of 30° with the ground?

Sol. Here, $F=50N, S=10m, \theta= 30$

$$W=FSCos\theta$$

$$W=50\times10\times Cos30°$$

$$W=50x10x\sqrt{3}/2$$

$$=612.4J$$

Example2.A man weighing 50 kg supports a body of 25 kg on head. What is the work done when he moves a distance of 20 m?

Sol. Totalmass=50+ 25= 75kg

$\theta=90°$

Distance=20 m

$W= FS\times 0$ $(Cos\ 90^o=0)$

$W=0$

Thus,workdoneis zero

FRICTION:FRICTIONISDEFINEDASTHERESISTANCEOFFEREDBYTHESURFACESTHAT AREINCONTACT WHENTHEYMOVEPAST EACHOTHER.

APPLICATIONS IN DAILY LIFE: 1. **Walking** –We can walk only if we apply frictional force.Friction is what holds your shoe to the ground. The friction present on the ice is very little, this is the reason why it is hard to walk on the slipperysurface ofthe ice.

3. **Writing –**A frictional force is created when the tip of the pen comes in contact with the surface of the paper. Rolling friction is what comes into play while writing with a ballpoint pen while sliding friction arises when one writes with a pencil.

4. **Skating –**Thin film of water under the blade is necessary to make the skate slide. The heat generated by the skate blade rubbing against the surface of ice causes some of the ice to melt right below the blade where the skater glides over the ice. This water acts as a lubricant reducing friction.

5. **Lighting a matchstick**– When the head of the matchstick is rubbed against a rough surface, heat is generated and this heat converts red phosphorous to white phosphorous. White phosphorous is highly inflammable and the match stick ignites. Sometimes, matchsticks fail to ignite due to the presence of water. Water lowers friction.

6. **Driving of the vehicle on a surface**- While driving a vehicle, the engine generates a force on the driving wheels. This force initiates the vehicle to move forwards. Friction is the force that opposes the tyre rubber from sliding on the road surface. This friction avoids skidding of vehicles.

7. **Applications of breaks in the vehicle to stop it-** Friction braking is the most widely used braking method in vehicles. This process involves the conversion of kinetic energy to thermal energy by applying friction to the moving parts of a vehicle. The friction force resists the motion and in turn, generates heat. This conversion of energy eventually bringing the velocity to zero.

ENERGY (DEFINITION AND ITS SI UNITS), EXAMPLES OF TRANSFORMATION OF ENERGY

Energy

Energy of a body is defined as *the capacity of the body to do the work*. Like work,energy is also a scalar quantity.

Unit: SI system-Joule, CGSsystem-erg Dimensional

Formula: $[ML^2 T^{-2}]$.

ExamplesofTransformation ofEnergy

Theenergychangefromoneformto anotheriscalled transformationofenergy.Forexample-

- Inaheatengine, heatenergychanges intomechanicalenergy
- Inanelectricbulb,theelectricenergychanges intolightenergy.
- Inanelectricheater,theelectric energychangesinto heatenergy.
- Inafan,theelectricenergychangesintomechanicalenergywhichrotatesthefan.
- Inthesun,masschangesintoradiantenergy.
- Inanelectricmotor,theelectricenergyisconvertedintomechanicalenergy.
- In burning of coal, oil etc., chemical energy changes into heat and light energy.
- Ina dam, potentialenergyofwaterchanges into kinetic energy, then K.E rotates the turbine which produces the electric energy.
- In an electric bell, electricenergychanges intosoundenergy.

- Inagenerator,mechanicalenergyisconvertedintotheelectricenergy.

KINETIC ENERGY(FORMULA,EXAMPLESANDITSDERIVATION)

KineticEnergy(K.E.):*Energypossessedbythebodybyvirtueofitsmotions*iscalledkinetic energy.Forexample(*i*)running water(*ii*)Windenergy;workontheK.E.ofair(*iii*)Moving bullet.

ExpressionforKinetic Energy

Consider F is the force acting on the body at rest (*i.e.*, $u = 0$), then itmoves in the direction of force to distance (s).

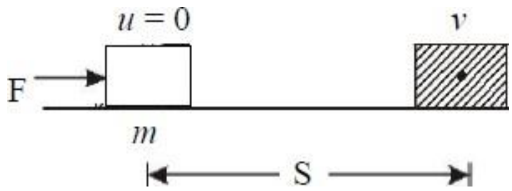


Figure: 11

Letvbethefinalvelocity.

Usingrelation $v^2 - u^2 = 2aS$

$$\frac{v^2 - u^2}{2S} = a$$

$$\frac{v^2 - 0}{2S} = a$$

$$\frac{v^2}{2S} = a \qquad \text{------------- (1)}$$

Now,workdone,$W = F.S$

or $W = maS$ (usingF=ma) -------------(2)

Byequation (1) and (2)

$$W = m.\frac{v^2}{2S}.S$$

or $W = \frac{1}{2}mv^2$

This work done is stored in the body as kinetic energy. So kinetic energy possessed by the body is (K.E.) = $\frac{1}{2}mv^2$

POTENTIALENERGY(FORMULA,EXAMPLESANDITSDERIVATION)

Potential Energy (P.E.): *Energy possessed by the body by virtue of its position is called potential energy*. Example

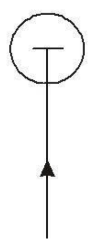
(i) Waterstoredinadam

(ii) Mangohanging onthebranchofatree

ExpressionforPotentialEnergy(P.E)

Itisdefinedasthe energypossessed bythebodybyvirtue ofitspositionabove thesurface ofearth.

$W = F \text{x} S$



Workdone =Force×height

$= mg \times h = mgh$

h

This workdone isstoredintheformofgravitationalpotentialenergy.
Hence Potential energy $= mgh$.

Figure: 12

Law of Conservation of Energy

Energy can neither rbe created nor be destroyed but can be converted from one form to another.

CONSERVATIONOFMECHANICALENERGYOFAFREEFALLINGBODY

LetusconsiderK.E.,P.E.andtotalenergyofabodyofmassmfallingfreelyundergravity from a height h from the surface of ground.

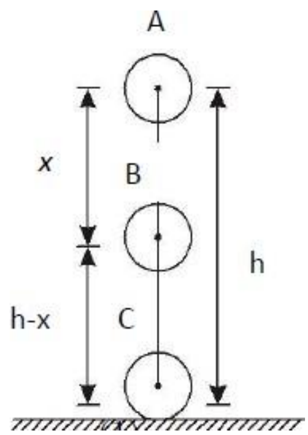


Figure: 13

AccordingtoFig.3.3 At position A:

Initialvelocity(u)= 0

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

P.E.=mgh

TotalEnergy=K.E+P.E

$= 0 + mgh$

$= mgh$ -- (1)

AtpositionB

Potentialenergy=$mg(h-x)$

Velocity at point B= u

FromequationofmotionK.E.= $\frac{1}{2}mu^2$

As $V^2 - U^2 = 2aS$

Hence $u^2 - 0^2 = 2gx$

or $u^2 = 2gx$

Puttingthisvalueweget,KE=$\frac{1}{2}m(2gx)$

or K.E. $= mgx$

TotalEnergy=K.E+P.E

$= mgx + mg(h-x)$

$= mgh$ -- (2)

AtpositionC

Potentialenergy=0(as$h$=0)

Velocity at Point B= v

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

As $V^2 - U^2 = 2aS$

Hence $v^2 - 0^2 = 2gh$

or $v^2 = 2gh$

Puttingthisvaluewegetk KE=$\frac{1}{2}m(2gh)$

or K.E. $= mgh$

TotalEnergy=K.E+P.E

$= mgh + 0$

$= mgh$ -- (3)

From equations (1), (2) and (3), it is clear that total mechanical energy of freely falling body at all the positions is same and hence remains conserved.

POWER

Power is defined as the *rate atwhichwork is done* by aforce. T*hework done per unit time*is also called power.

IfabodydoworkWintimet, thenpoweris

$$P = \frac{W}{t}$$

UnitsofPower:SIunitofpoweriswatt(W)

Powerissaid tobe1 W,if1 Jwork isdonein1 s.

$$1W = \frac{1J}{1s}$$

Biggerunitsofpowerare:

Kilowatt(KW) $= 10^3$W

Megawatt(MW) $= 10^6$W

Horse power (hp) =746W

Dimension of power = $[M^1 L^2 T^{-3}]$

Example5A man weighing 65 kglifts a mass of 45 kg to the top of a building 10 meters high in 12second. Find;

(i) Totalworkdonebyhim.

(ii) Thepower developedbyhim.

Solution Mass of the man, m_1=65kg

Mass lifted m_2= 45 kg

Heightthroughwhichraised$h$ = 10m

Timetaken$t$= 12seconds.

(i) Totalworkdone bytheman,$W = mgh$

$= 110 \times 9.81 \times 10 = 10791.0$J

(ii) Powerdeveloped $P = \frac{W}{t} = \frac{10791J}{12s} = 899.25W$

CHAPTER - 4

PROPERTIESOFMATTER

Topicstobecovered:

1. Definition of Elasticity,Deformingforce,Restoringforce,example of Elastic and plastic body,
2. DefinitionofStressandstrain,Hooke'slaw,ModulusofElasticity
3. Pressure(definition, atmosphericpressure,gaugepressure,absolutepressure,Pascal'sLaw
4. Surface tension: definition, SI unit, applications of surface tension, effect oftemperature on Surface tension
5. Viscosity:definition, unit,examples,effect oftemperatureonviscosity.

DeformingForces: Theforceswhichbringthechangeinconfigurationofthebodyarecalled deforming forces.

RestoringForce: Itisaforceexertedonabodyorasystemthattendstomoveittowardsan equilibrium state.

Elasticity: Itistheproperty of solidmaterialsbyvirtue of which abody returnsto theiroriginal shape and size after the deforming forces have been removed from the body.

Elastic Body: It isthebodythat returnsto itsoriginalshapeaftera deformation. Examplesare Golf ball, Soccer ball, Rubber band etc.
Plastic Body: It is the bodythat does not returnto its originalshape after a deformation. Examples are Polyethylene (PE), Polypropylene (PP), Polystyrene (PS) and Polyvinyl Chloride (PVC) etc.

Stress: Itisdefinedastherestoringforceperunitareaofamaterial. i.e.

Stress=RestoringForce/areataken.

Strain: Itisdefinedastheratioof changeinconfiguration to theoriginal configuration,when a deforming force is applied to a body.

Thestrain isofthree types:

1. Longitudinalstrain=Changeinlength(Δl) /originallength (l)

2. Volumetricstrain=Changeinvolume(Δv)/originalvolume (v).

3. Shearingstrain=LateralDisplacement/Distancebetweensurfaces

$=\Delta\theta/\boldsymbol{l}=\tan\Phi$

Hook's Law/Modulusof Elasticity:

Hook's law: According to this law, "Within elastic limits, the stress applied on a body is directlyproportional to the strain." i.e.
StressαStrain

Stress= E×Strain;
WhereE=proportionalityconstantwhichisknownasmodulusofelasticity.
ModulusofElasticity:Theratioofstressandstrainiscalledmodulusofelasticity.i.e

$$E=\frac{stress}{strain}$$

TypesofModulusofElasticity: There arethreetypesofModulusofElasticitygivenasbelow:

1. Young's Modulus(Y): Theratio ofnormalstresstothe longitudinalstrainis definedasYoung's modulus and is denoted by the symbol ' Y '.

Sincestrainisadimensionlessquantity,theunitofYoung'smodulusisthesameasthatofstress i.e.Nm^{-2}.

2. Bulk Modulus (B): The ratio ofnormal (hydraulic) stress to the volumetric strain is called bulk modulus. It is denoted by symbol ' B '.

$$B = \Delta P/(\Delta V/V)$$

Where:

B:Bulk modulus

ΔP: changeof the pressure orforce appliedperunit areaonthe material ΔV:

change of the volume of the material due to the compression

V:Initialvolumeofthematerial.

SI unit ofbulkmodulusisthesameasthat ofpressurei.e.Nm-^{2}orPa.

Shear Modulus or Modulus of rigidity (♈): The ratio of shearing stress to the corresponding shearing strain is called the shear modulus of the material andis represented by'♈'. It is also called the modulus of rigidity.

♈= Tangentialstress/Shear strain

UnitofshearmodulusisN/ $m^{-2} or$Pressure.

Itisdefined astheforceperunitareaoverthesurfaceofabody.Itisdenoted by'P '.

P=F/A

SI unit=Nm^{2}orPa(Pascal)

Atmospheric Pressure: Atmospheric pressure at that spot is the force acting on a unit area around a location as a result ofthe full height ofthe air column ofthe atmosphere above it.

Absolute Pressure: Absolute pressure is the pressure measured in proportion to absolute zero pressure in a vacuum.

Gauge Pressure: Gauge pressure is the difference between absolute pressure and atmospheric pressure at apoint. Ifthe gauge pressure isabove the atmospheric pressure, it ispositive, otherwise negative.

Pascal Law:"A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid and to the walls of its container."
F=pAwhere

F=force(N)

p=pressure(Pa,N/m^2) A

= area (m^2)

SurfaceTension: Thepropertyofaliquidduetowhichitsfreesurfacebehaveslikestretched membrane and acquires minimum surface area. It is given by force per unit length. i.e.

S=F/L

Surface tension allows insects (e.g. water striders), usuallydenser than water, to float and stride ona water surface.

SIunit=N/m.

Applicationsofsurfacetension: Itplaysanimportantrole inmanyapplicationsinourdailylife as given

here:

1. Washingclothes
2. Cleaning
3. Cosmetics
4. Lubricantsinmachinesetc.
5. Spreadingofink,colours
6. Wetting ofa surface
7. Paints,insecticides
8. Creatingfuel-sprayinautomobileengines
9. Passingofliquidinporousmediaetc.

EffectofTemperatureonSurfaceTension:

Surface tension decreases when temperature increases and vice versa. This is because cohesive forces decrease with an increase of molecular thermal activity. The influence of the surrounding environment is due to the adhesive action liquid molecules have at the interface.

Viscosity: The property of liquid due to which it oppose the relative motion between the layers of fluid. It is also known as liquid friction.

SIunitofviscosityisPascal-second(Pas)andCGSunitisPoise.

EffectofTemperatureon Viscosity:

1. In liquids the source for Viscosity is considered to be atomic bonding. As we understand that, with the increase of temperature the bonds break and make the molecule free to move. So, we can conclude that the viscosity decreases as the temperature increases and vice versa.

2. In gases, due to the lack of cohesion, the source of viscosity is the collision of molecules. Here, As the temperature increases the viscosity increases and vice versa. This is because the gas molecules utilize the given thermal energy in increasing its kinetic energythat makes themrandom and therefore resulting in more the number of collisions.

CHAPTER-5

HEATANDTEMPERATURE

Topics to be covered:

1. Definition of heat and temperature(on the basis of kinetic theory)
2. Difference between heat and temperature
3. Principle and working of mercury thermometer
4. Modes of transfer of heat(Conduction, convection and radiation with examples)
5. Properties of heat radiation
6. Different scales of temperature and their relationship.

Heat: Heat is the form of energy that is transferred between two substances at different temperatures. The direction of energy flow is from the substance of higher temperature to the substance of lower temperature.

Heat on the basis of kinetic theory: According tothekinetictheory, heat ofabodyistotalkinetic energy of all its molecules. If a body have 'n' number of molecules having mass m and velocities v1, v2, v3, --------,vn. Then

Totalheatenergyinthebody(H)=Sumofkineticenergyofallmolecules

$$= \frac{1}{2} m(v_1^2 + v_2^2 + v_3^2 + \ldots\ldots\ldots\ldots + v_n^2)$$

Temperature: Temperature is a measure ofthe average kinetic energy ofthe particles in a system. Temperature is measured in the Kelvin or Celsius scales, with Fahrenheit. For the above given n molecules, the Temperature is written as:

$$\text{Temperature (T)} = \frac{\text{Sumofkineticenergyof all molecules}}{\text{number ofmolecules}}$$

$$= \frac{1}{n}\{\sqrt{[\frac{1}{2} m(v_1^2 + v_2^2 + v_3^2 + \ldots\ldots\ldots\ldots + v_n^2)]}\}$$

DifferencebetweenHeat andTemperature:

SR. NO.	Heat	Temperature

1	Heat is a form of energy that can transfer from hot body to cold body.	Temperatureisthedegreeofhotnessandcoldness of a body.
2	Heat is the total kinetic energy and potentialenergyobtained bymolecules in an object.	Temperature is the average K.E of molecules in a substance.
3	Heatflowsfromhotbodytocold body.	It rises when heated andfallsdown when an object is cooled down.
4	Ithasaworkingability.	Itdoesnothavetheworkingability.
5	ItsSIunitis“Joule”.	ItsSIunitis“Kelvin”.
6	Itismeasuredbythe calorimeter.	Itismeasuredbythe thermometer.
7	Itisrepresented by“Q”.	Itisrepresented by“T”.

PrincipleandworkingofMercury Thermometer:

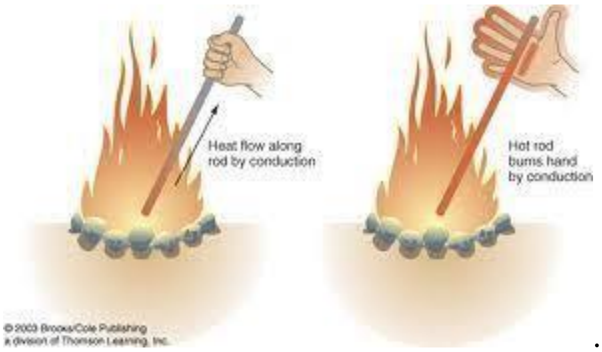
Principle: Mercury thermometers are based on the principle that liquids expand when heated and contract when cooled. So when the temperature increases, the mercury expands and rises up the tube and when the temperature decreases, it contracts and does the opposite.

Working: Ina mercurythermometer, aglass tubeis filledwithmercuryandastandardtemperature scale is marked on the tube. With changes in temperature, the mercury expands and contracts, and the temperature can be read from the scale, Mercury thermometers can be used to determine body, liquid and vapor temperature. Mercury thermometers are used in households, laboratory and industrial applications.

ModesofTransferof Heat:

1. Conduction: It is defined as that mode oftransfer of heat inwhichthe heat travels fromparticle to particle in contact, along the direction offalloftemperature without anynet displacement ofthe particles.

For example, if one end of a long metal rod (iron or brass) is heated, after some time other end of rodalso becomes hot duetothetransfer ofheat energyfrom hot atoms tothe nearbyatoms because of conduction.



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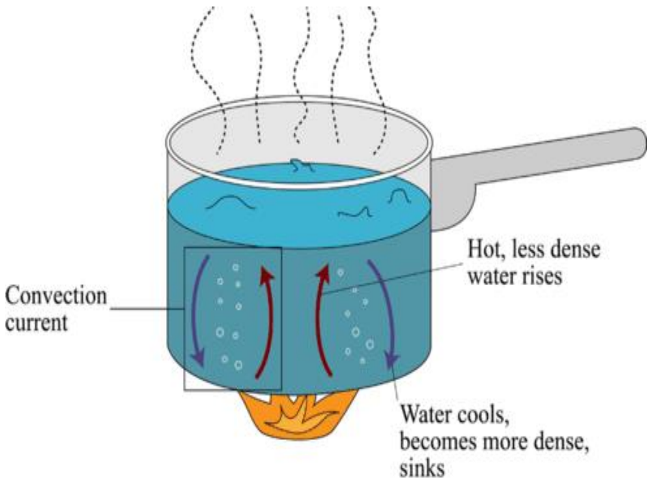
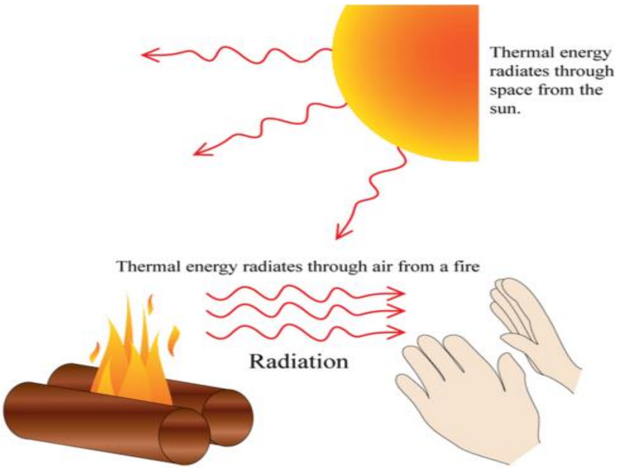
2. Convection: The process of transmission of heat in which heat is transferred from one point to another by the physical movement of the heated particles is called convection.



For example, if a liquid in a vessel is heated byplacing a burner below the vessel, after some time the top surface of liquid also becomes warm. Other examples are heating of water, cooling of transformers, heating of rooms by heater etc.

3. Radiation: The process of heat transfer in which heat is transmitted from one place to another without heating the intervening medium is called radiation. Thermal radiations are the energy emitted by a body in the form of radiations on account of its temperature and travel with the velocity of light. For example, We receive heat from sun by radiation process.



PropertiesofHeatRadiations:

1. Theydonotrequireamediumfortheirpropagation.
2. Heat radiationstravelinstraightline.
3. Heatradiationsdonotheattheinterveningmedium.
4. Heatradiationsareelectromagneticwaves.
5. Theytravelwithavelocity3 $\times 10^8$m/sinvacuum.
6. Theyundergoreflection,refraction,interference,diffractionandpolarization.
7. Theyobeyinversesquarelaw.

DifferentscalesofTemperature:

ThemainscalesofTemperaturearegivenasbelow:

1. **CelsiusScale**
2. **Kelvin Scale**
3. **Fahrenheit Scale**

Relationamong the Scales of Temperature: Temperature of a body can be converted from one scale to the other. Let

L=lowerreferencepoint(freezingpoint) H

= upper reference point (boiling point) T

= temperature read on the given scale.

Now ,

Let ustakeabodywhosetemperatureisdeterminedbythreedifferentthermometers

givingreadings in ℃ ,°F and K respectively.

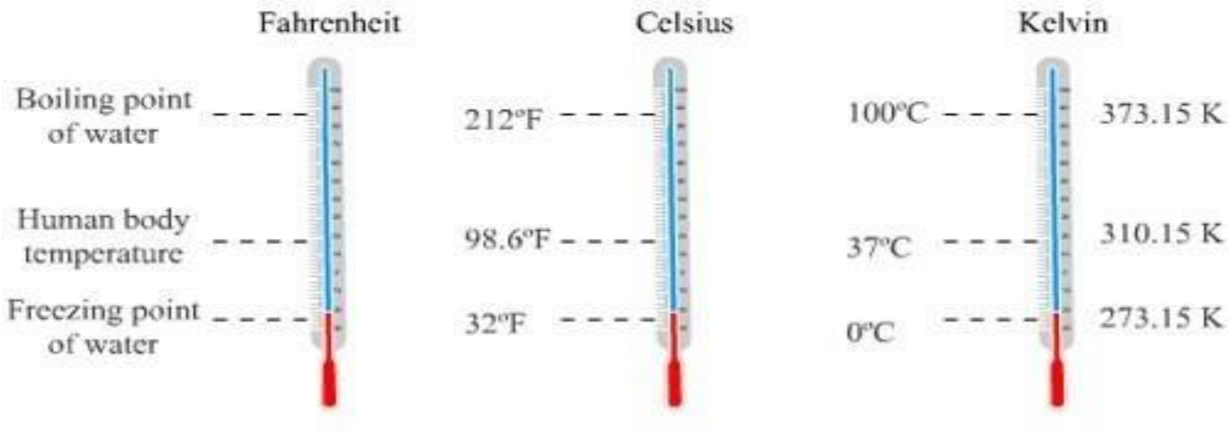


fig.DifferentscalesofTemperature Let

T1 = C = Temperature in °C, L1 = 0°C, H1 =100°C

T2 = F=Temperature in°F,L2=32°F,H2= 212°F

T3=K=TemperatureKelvin, L3=273K,H3=373K Then

$$\frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{K-273}{373-273}$$

$$\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100}$$

$$\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5} \quad \ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(A)}$$

Thisistherelationamongdifferentscalesoftemperature.