GOVT. TOOL ROOM AND TRAINING CENTRE

KARNATAKA

REFERENCE NOTES

APPLIED SCIENCE

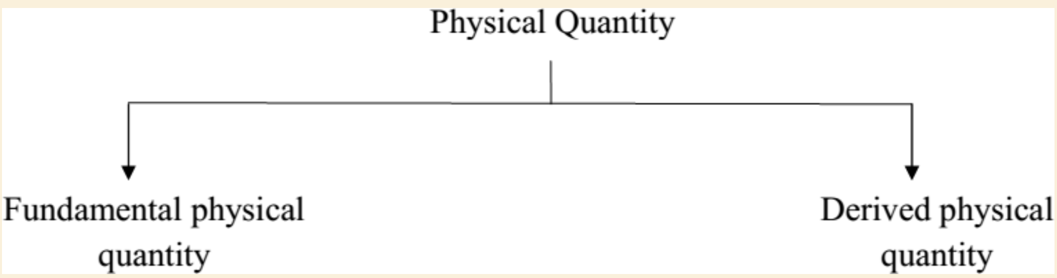
FOR
: DIPLOMA IN TOOL AND DIE MAKING
: DIPLOMA IN PRECISION MANUFACTURING

UNIT 1: UNITS, DIMENSIONS AND MEASUREMENTS

Physical Quantity

Any measurable quant ities are called physical quantities. The physical Quantities are length, mass, time, area, density, volume, temperature & force etc.

Types of Physical Quantity



Fundamental physical quantity

The quantities like length, mass and time are mutually independent and are called as fundamental physical quantity.

These are represented by length, mass & time.

Derived physical quantity

The quantities which are derived from fundamental physical quantities (length, mass & time) are called as derived physical quantity.

Ex: Area = Length (L) x Breadth (B) = L x B =L x L = L^2

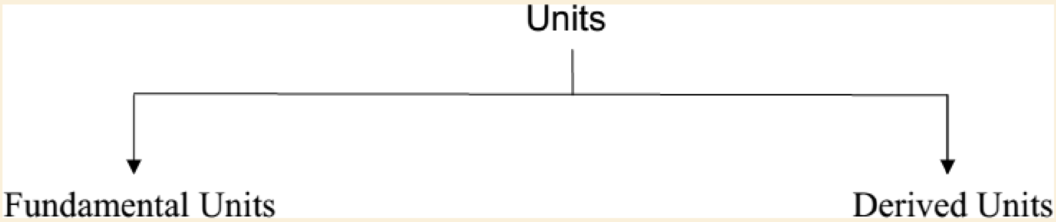
Units

It is the standard reference for measurement & it compares with the given physical quantity.

Ex: Length of the rod is 10 cm.

This centimeter (1cm) is the standard reference and 10 is the number. This means the length of the rod is 10 times more than 1 cm (standard Reference).

Types of Units



Fundamental Units

The units for fundamental quantities (length, mass & time) are called Fundamental Unit.

Ex: cm, meter, feet, gram, kilogram, pound, seconds.

Derived Units

The unit which are derived from the fundamentals units are called Derived units.

Ex: Unit of Area= Lx B=L x L=L^2 = m^2, cm^2 etc.

System of Units

System	Units		
	Length	Mass	Time
CGS	Cm	Gram	Second
FPS	Feet	Pound	Second
MFS	Metre	Kilogram	Second

SI System

Now a days SI system is a commonly used measurement of physical quantity. SI system means 'System International ale d' Unit' (System of International) System International de-units. In 1960, General conference held on weight and measurement and all scientists are accepted basic units [S.I] for "7" basic Physical quantities and two supplementary quantities.

Table for Basic physical quantities

Sl.No	Quantity	SI unit	Symbol
1	Length	Metre	m
2	Mass	Kilogram	kg
3	Time	Second	S
4	Temperature	Kelvin	K
5	Electric current	Ampere	A
6	Luminous Intensity	Candela	Cd
7	Amount of Substance	Mole	mol

Supplementary Quantities

Sl. No	Quantity	SI. Unit	Symbol
1	Plane angle	Radian	rad
2	Solid angle	Steradian	Sr

Multiples & Sub-multiples

The larger numbers like 1000000000 & smaller numbers like 0.000000002 are expressed in the form of 10^{+x} or 10^{-x}. Here 10^{+x} is called multiples and 10^{-x} are called sub-multiples.

Ex:

- $1000000000=1X10^{9}$ {Multiple value}
- $0.00000001=1X10^{-9}$ {Sub multiple value}

Multiples	Prefix	Symbol
10^{1}	Deca	da/D
10^{2}	Hecta	h/Ha
10^{3}	Kilo	K
10^{6}	Mega	M
10^{9}	Giga	G
10^{12}	Tera	T
10^{15}	Pera	P
10^{18}	Exa	E

Submultiples	Prefix	Symbol
10^{-1}	Deci	d
10^{-2}	Centi	c
10^{-3}	Milli	m
10^{-6}	Micro	µ
10^{-9}	Nano	n
10^{-12}	Pico	p
10^{-15}	Femto	f
10^{-18}	Atto	a

Rules of writing S.I. Units

- If a unit is named after person, the symbol is capital letter.
  Ex: N or J
- Other than that should be write in small letters.
  Ex: cm, m etc.
- Symbols are not expressed in plural forms.
- Full stop, commas or other punctuation marks are not to be written after symbols of units.
- There is no space between prefix and symbols. {Ex: Kilogram}

Advantages of S.I. units

- Decimal relationship between units of same quantity makes it possible to express any small or large quantity as a power of 10.
- It is a rationalized system of units. It means there is one unit for one physical quantity.
- i.e., Mechanical energy, electrical energy, heat energy etc are all expressed in Joules.
- It is a coherent system.
- Symbols assigned by SI system remains same irrespective of the languages used.

Dimensions

The power to which fundamental physical quantities are raised to obtain (to express) the units of given physical quantity is called Dimensions.

These are represented by $[M^a L^b T^c]$

Where a, b, c are called numbers (Constants) and are depends on given physical quantity. Ex:

Area = L x b=L x L=L^2

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

Dimensional Equations

It is the relation between values (powers) of fundamental physical quantities of given

physical quantities.
Ex: Volume = L x b x h=L x L x
$L=L^3$ Volume = $[M^0 L^3 T^0]$
Density = Mass/Volume= $M^1 / L^3 = M^1 L^{-3}$ Density = $[M^1 L^{-3} T^0]$

Table for Dimensions of Physical Quantities

Physical quantity	Formula	SI Unit	Dimensions
Length	L	m	$[M^0 L^1 T^0]$
Mass	M	Kg	$[M^1 L^0 T^0]$
Time	T	s	$[M^0 L^0 T^1]$
Area	$A=L \times b=L \times L=L^2$	Sq. m (m^2)	$[M^0 L^2 T^0]$
Volume	$L \times b \times h=L \times L \times L= L^3$	m^3 (Cubic meter)	$[M^0 L^3 T^0]$
Density	Mass/Volume $= M^1 / L^3$	Kg/m^3	$[M^1 L^{-3} T^0]$
Velocity	Distance/time= L/T	m/s or ms^{-1}	$[M^0 L^1 T^{-1}]$
Acceleration	Velocity/Time $=L/T/T = L/T^2$	m/s^2 or ms^{-2}	$[M^0 L^1 T^{-2}]$
Force	Mass x acceleration $=M \times L/T^2$	Kg-m/s^2 or Newton	$[M^1 L^1 T^{-2}]$
Momentum	Mass x velocity $= M \times L/T$	Kg-m/s	$[M^1 L^1 T^{-1}]$
Impulse	Force x time $=M \times L/T^2 \times T$	Kg-ms^{-1}	$[M^1 L^1 T^{-1}]$
Work	Force x distance $= M \times L/T^2 \times L$	Kg-m^2s^{-2}	$[M^1 L^2 T^{-2}]$
Energy	$E=mc^2$ $= M \times L/T^2 \times L$	Kgm^2s^{-2} – Joule	$[M^1 L^2 T^{-2}]$
Pressure	P=F/A $=M \times L/T^2 /L^2$	$Kgms^{-2}/m^2$	$[M^1 L^{-1} T^{-2}]$
Power	P = Work/Time	Kgm^2/s^{-3}	$[M^1 L^2 T^{-3}]$

Application of dimensional analysis

1. It is used to check the correction of the given equation.
2. It is used to convert system of one unit into system of another unit.
3. It is used to derive simple equations.

Limitations of dimensional analysis

1. We cannot derive constants [like 2π] and numbers.
2. We can derive only simple equations which contain L M T.
3. We cannot derive equations which contains more than three fundamentals physical quantities and complicated equations.

Measurement

Measurement is an act or the result of quantitative comparison between a predefined standard and unknown magnitude.

Instruments used to measure accurately are,

- Vernier /Slide Caliper
- Screw gauge/micrometer
- Height gauge (Vernier)
- Internal screw gauge/micrometer
- Thread micrometer
- V-Anvil micrometer
- Bench micrometer
- Taper screw operated internal micrometer
- Bore gauges
- Depth Gauge

Least count of measuring instruments

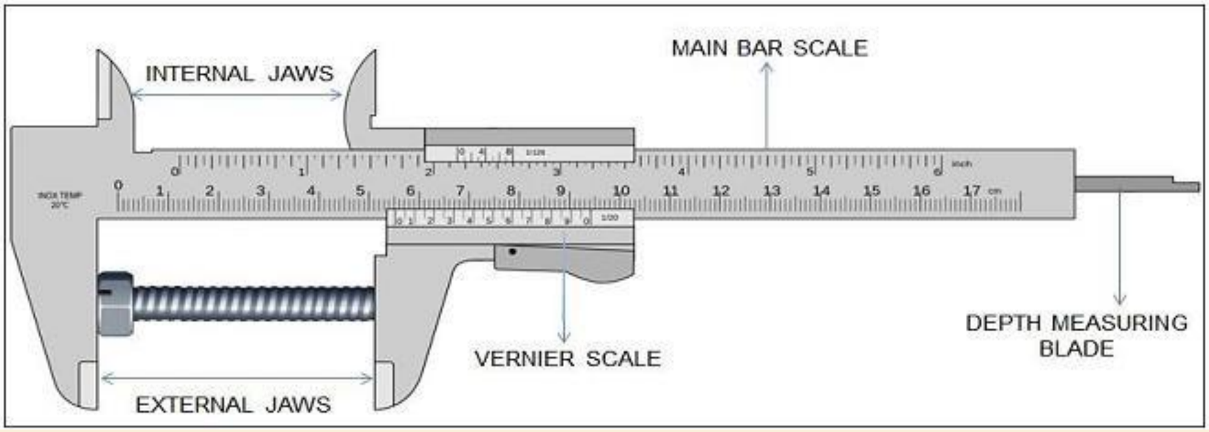
A smallest distance that can be measured from any instrument is called least count of a instrument.

Principle of Vernier

It is a secondary scale used on main scale for measuring dimensions of given object accurately distance between the divisions on main scale.

OR

It is a secondary scale which slides along the main scale. It is used to measure the length, depth, diameter accurately to any desired fractions of the smallest divisions on the main scale



A French scientist (1550-1637) **PIERCE VERNIER** designed a secondary scale on main scale for measurement of smallest distance between two divisions on main scale and it is called as Vernier scale.

The length of the Vernier

is, 10VSD=9MSD
1VSD=9MSD/10 or 0.9 MSD

Least count of Vernier

The smallest distance that can be measured by the Vernier scale is called least count of the Vernier. Least count is measured by the difference of value of 1MSD and1VSD.

i.e, L.C =1MSD – 1VSD---------------- (1)

L.C =1MSD –

(9MSD/10) L.C = [1-

9/10] MSD

L.C =1/10 MSD or 0.1MSD

In general, if "n" Vernier scale divisions are equal to (n-1) divisions on the main scale
"n" VSD= (n-1) MSD

VSD= (n-1/n) MSD-----------------------------from equation (1)

L.C = 1 MSD – (n-1/n) MSD

L.C = 1/n MSD Thus L.C is given as

L.C= Value of one MSD/No. of divisions on Vernier.

Measurement of MSR and VSR(CVD)

The end "A" of work piece is placed on a main scale zero and other end "B" touches Vernier zero, the length of object is little more than "7" MSD as in the main scale. The extra length is nothing but CB and it is equal to CD-BD (refer fig)

Length= 7MSD + CB Length = 7MSD + [CD-BD]

Length=7MSD + [6MSD-6VSD] Length =7MSD +6 [1MSD-1VSD]

Length =7MSD +6[1 /10 MSD] FIGURE

Length = 7.6 MSD

Thus reading corresponding to 'C' is called main scale reading (MSR) and at 'D' the Vernier and main scale divisions coincide and number of division coinciding on Vernier is called coinciding Vernier scale division (CVD).

Then combined reading = MSR + (CVD x LC)

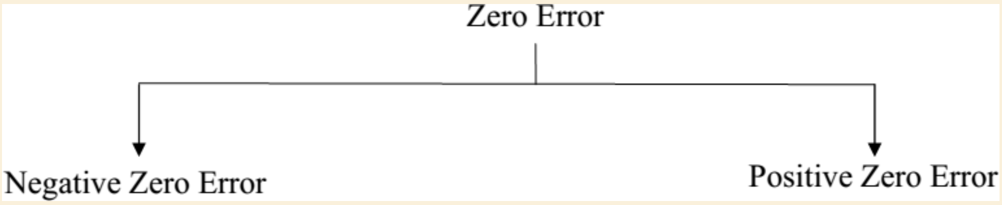
Uses of Vernier caliper

- To measure the length & thickness of objects.
- To measure external and internal diameter of a round object.
- To measure step length both inside and outside.
- To measure accurate value by taking smallest distance between and division on main scale.

Zero Error

In a given instrument if Vernier scale zero exactly coinciding with main scale zero. Then instrument is said to be No error. If not, it is said to be Zero error.

Types Zero Error



Negative Zero Error

If the Vernier scale zero is on left hand side of the main scale zero, then error is said to be Negative Zero Error.

From fig
CVSD= Coinciding Vernier Scale division =5

ZE=-5

ZC=+5

Corrected reading, CR=CVSD x LC
= +5 x 0.1mm
=+ 0.5 mm

Positive Zero error:

If the Vernier scale zero is on right hand side of the main scale zero, then error is said to be positive error.

From fig
CVSD= Coinciding Vernier Scale division =4 ZE=+4
ZC=-4

Corrected reading, CR= - [CVSD x LC]

= - [4 x 0.1]

= -0.4mm

Total reading

Total reading of the given instrument can be measured by using the below relation.

T. R= MSR + [CVSD x LC]

If there is a zero error

TR= {MSR + [CVSD x LC]} + CR

Where,

CR= CVSD x LC or CR= ZC x LC.

Note:

If the value of L.C decreases, then accuracy of the instrument increases.

i.e. accuracy inversely proportional to L.C.

Screw Gauge or Micrometer

The instruments screw gauge works on the principles of screw and nut. Screw can be moved forward or backward by giving rotation on screw head. The threads of the screw should be uniform.

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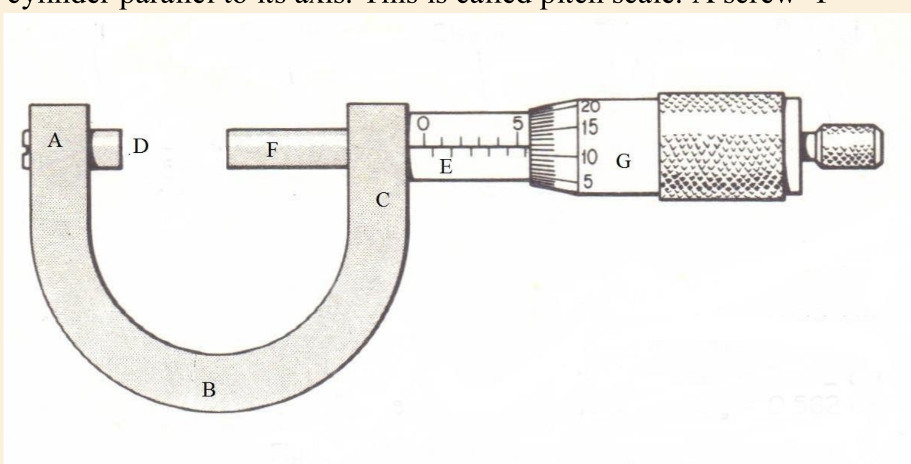
Construction

It consists of ‘U’ shaped frame ABC, one arm of which carries a hallow cylinder E.

A scale in mm is graduated on the cylinder parallel to its axis. This is called pitch scale. A screw ‘F’ works through the cylinder ‘E’ and its ends in the plane face. A Co-axial sleeve “G’ with a bevelled edge attached to the screw head moves over the cylinder E. The bevelled edge of the screw is divided into number of equal parts. This is called Head scale. The other arm of ‘U’ shaped frame carries plane surface “D” opposite to “F”.



Pitch of a screw

It is the distance between two consecutive threads of a screw is called pitch of a screw

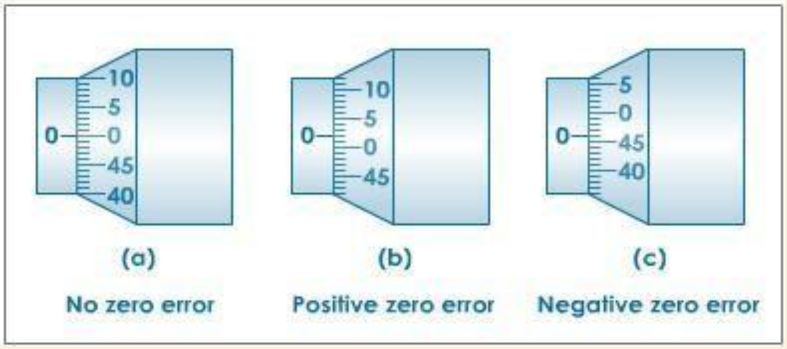
Practically Pitch of a screw is obtained by the relation.

Pitch=Distance moved on pitch scale/Number of rotations given to screw head.

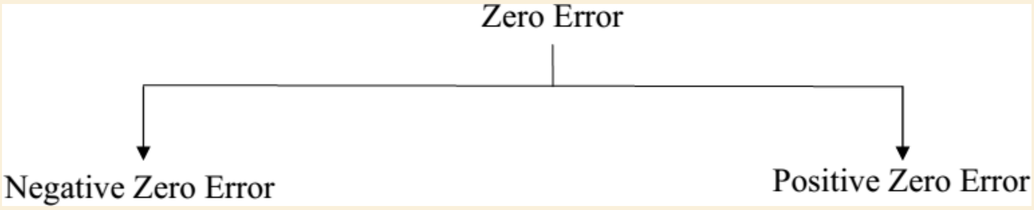
Zero Error

When metallic plugs of a screw gauge contact with each other if head scale zero coinciding with pitch line then instrument is said to be no error. If not it is said to be zero error.

ZE=0, Zc=0 ------------fig (a)



Types of Zero error



Negative Zero error

If the head scale zero is above the pith line, then error is said to be negative zero error and zero correction is positive as shown in fig(c)

ZE= -4(-ve) ZC=+4(+ve)

Positive Zero error

If the head scale zero is below the pith line, then error is said to be positive and zero correction is negative as shown in fig(b).

ZE= (+2) +ve ZC = (-2) -ve

Least Count (L.C)

The smallest distance that can be measured by the screw gauge is called least count of screw gauge.

Least count of screw gauge is measured by the relation,

L.C= Pitch/ No. Of Head scale divisions.

Where,

Pitch=Distance moved on pitch scale/Number of rotation given to the head scale.

Total Reading (T.R)

The dimensions [Diameter, Thick] of a given object can be calculated by using the following relation.

T. R=PSR+{[HSD+ZC] x LC}

Uses of Screw gauge

It is used to measure thick and diameter of small objects like thin metal sheet, thin wire etc.

It is used to measure dimension accurately of given objects compared to scale calipers, because Least Count of screw gauge is small compared to slide calipers.

PROBLEMS

1) The main scale is divided into 1/2 mm. The length of the Vernier is attached to it is 12 mm long & is divided into 25 equal parts. Calculate the value of 1 VSD & Least count of Vernier.

Given data: 1MSD = 1/2mm =0.5 mm, Total VSD = 25 Divisions i.e.,

25 VSD = 12 mm

1VSD = 12/25 mm I VSD = 0.48 mm

Least Count = 1MSD-1VSD

= 0.5- 0.48

L.C=0.02 mm

2) A Vernier has 10 divisions & they are equal to 9 divisions on main scale in length. Main scale being graduated in mm. While measuring the diameter of a cylinder the following observations are made.

MSR = 2.3 cm, VSD =5, Zero Error= -4, Total Reading =? Least count =? Actual Reading =?

Given Data: MSR = 2.3cm, VSD =CVSD=5, Zero Error= -4, Zero Correction =+4, Total Reading =? Least count =? Actual Reading =?

To find Least count

L.C= 1msd- 1vsd

L.C =1msd-(9/10) MSD

L.C =(1-9/10) MSD
T.R =2.35 cm
L.C=0.1mm or 0.01cm

Total Reading

T.R=MSR+ {CVSD x LC}
T.R = 2.3+ {5 x 0.01}
T.R =2.3+0.05

Correction Reading,
C. R= ZC x LC

C.R =+4 x 0.01

C.R = 0.04 cm

Actual Reading, A. R= TR±CR
=2.35+0.04

A.R = 2.39 cm

3) A screw gauge has a pitch of ½ mm & 50 division on its sleeve. At the zero setting the reading was found to be +5 divisions on the head scale while gripping a wire pitch scale reading was 1.5 mm & 17 divisions on the head scale. What is the diameter of the wire?

Given data:
Pitch= ½ mm = 0.5 mm,
Number of HSD =50 Div,
ZE= +5, ZC= -5, PSR= 1.5 mm, HSD = 17 div

Least count, L.C= Pitch / Number of HSD
L.C = 0.5/50
L.C =0.01 mm
Dia if wire, T.R= PSR+[HSD +ZC] x LC

T.R =1.5+{[17+(-5)] x 0.01}
T.R =1.5+{[12] x 0.01}
T.R =1.5+0.12 T.R=1.62 mm

4) In measuring the diameter of a wire using a vernier caliper, the zero of vernier is found to be between 3.65 cm & 3.7 cm and the 5th vernier division coincides with the main scale division. If the least count of vernier is 0.05mm,what is diameter of wire?

Given data:

PSR = 3.65cm = 36.5 mm, LC = 0.05cm = 0.005mm, CVSD = 5^{th} Div. ZE=0, ZC = 0

Diameter of wire,

Total reading, TR= PSR+[HSD +ZC] x LC

TR =36.5+[5+0]x0.005 TR =36.5+[5 x 0.005]

TR =36.5+0.025 TR =36.675mm

EXERCISES

I. Fill in The Blanks

a) Smallest distance measured by any instrument is called.................

b) Least count of Vernier Caliper.....................

c) Least count of Screw Gauge...........

d) If Zero error is +5 then Zero correction is.............

e) Distance between two consecutive threads is................

II. Multiple Choice Questions

a) SI unit of Area is

a) mm^3 b) mm c) mm^2 d) mm^{-2}

b) SI unit of Density is

a) kg/m^3 b) mm c) kg/mm^2 d) kg/m^{-3}

c) If the Vernier scale zero is on left hand side of the main scale zero, then error is

a) Error b) Positive zero error c) Negative zero error d) None of these

III. Answer the following Questions

a) Define fundamental unit? With examples.

b) Define derived unit? With examples.

c) Explain SI system

d) Write the Seven basic physical Quantities.

UNIT 2: BASICS OF DYNAMICS

a) Write the dimension equation for volume, work, force & speed

b) Explain Vernier calipers with neat sketch.

c) Explain screw gauge with neat sketch

d) Explain types of zero error in Vernier caliper.

e) Explain types of zero error in screw Gauge.

Introduction:

It is a branch of physics which deals with the study of properties of body in "motion" and "rest" under number of forces acting.

Definition of important terms

Motion/Dynamics:

If a body changes its position with respect to time is called motion. Motion of a body called dynamics. There are three kinds of motion namely, Linear motion, Rotatory motion, Vibratory motion.

Linear: A body moving with straight Line. Ex: Car moving on a straight Road, stone	**Rotatory**: A body rotating about an axis (centre). Ex: Wheel of a cycle, Electric Fan	**Vibratory**: A body performing to & fro motion about a fixed point on its path. Ex: vibrating prongs of a tuning fork, Oscillating Simple Pendulum.

Rest/Static:
If a body does not change its position with respect to time is called rest. Static is the study of a body at rest.

Scalars: Any physical quantities which are represented by magnitude only are called Scalars.
Ex: Length, Mass, Density, Speed, Distance.

Vectors: Any physical quantities which are represented by both magnitude & direction are called Vectors.
Ex: Velocity, Acceleration, Displacement, Force etc.

Distance: A body changes its position without giving its direction is called Distance.

It is scalar Quantity.

SI unit: Metre [m]

Displacement [D]: If a body changes its position in a definite direction is called displacement.
It is vector Quantity.

SI unit: Metre [m]

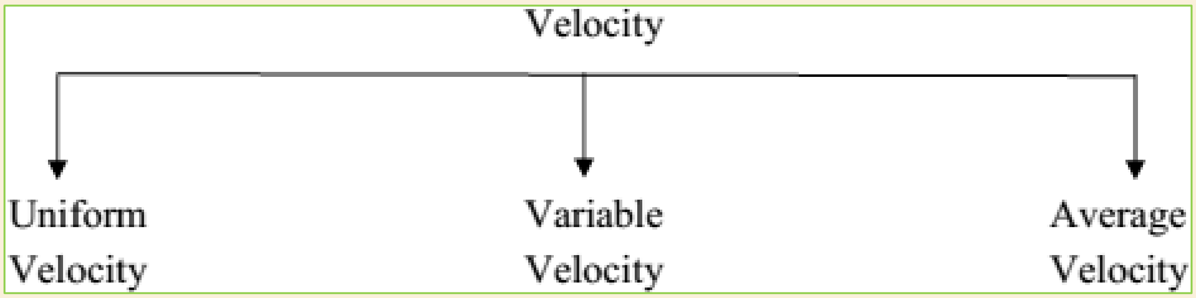
Speed [S]: The rate of change of distance of a body is called speed. i.e. Speed = Distance/Time

SI Unit: m/s or ms^{-1}

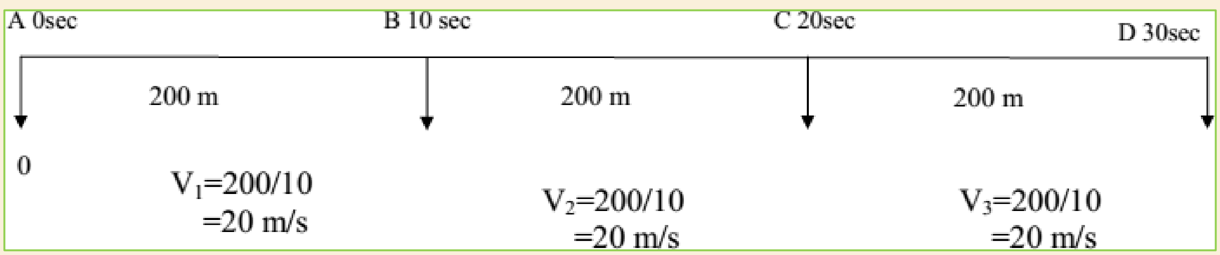
Velocity [V]: The rate of change of displacement of a body is called velocity. i.e. Velocity = Displacement/Time

SI Unit: m/s or ms^{-1}

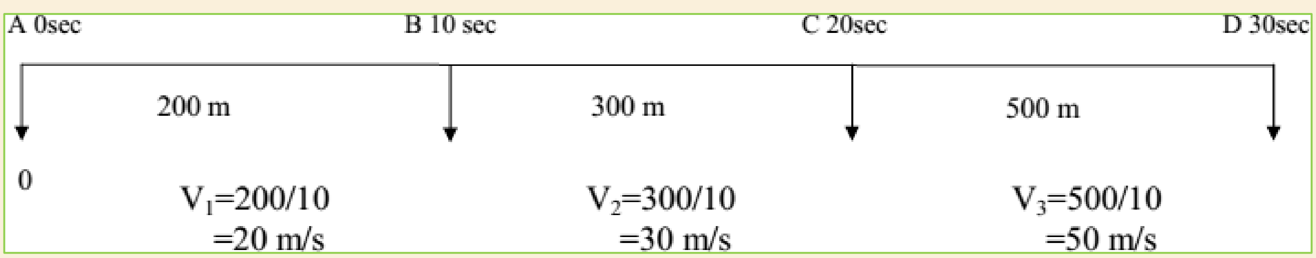
Types of velocity:



Uniform Velocity: If a body covers equal distance in equal interval of time is called uniform velocity.



Variable Velocity: If a body covers unequal distance in equal interval of time is called variable velocity.



Average Velocity: If a body travel with variable velocity then the average velocity is defined as the ratio of total distance to the total time taken.

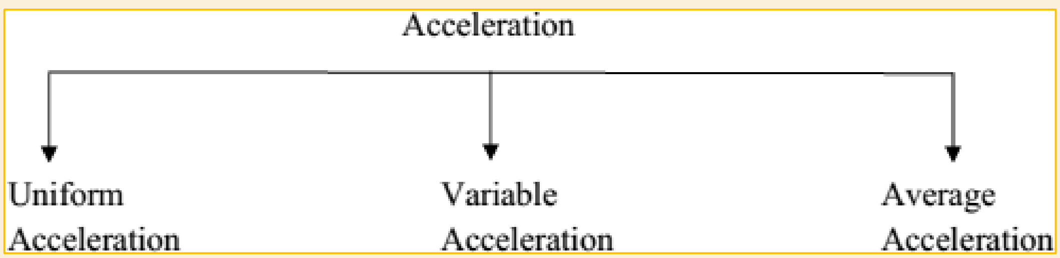
$$V_{av} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

Acceleration [a]: The rate of change of increase in velocity is known as acceleration. i.e.

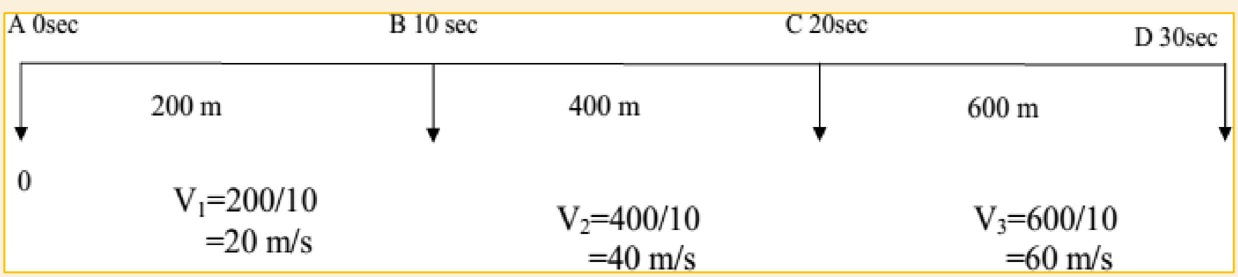
Acceleration [a] = Change in Velocity [v] / Time [T]

SI Unit: m/s^2 or ms^{-2}

Types of Acceleration:



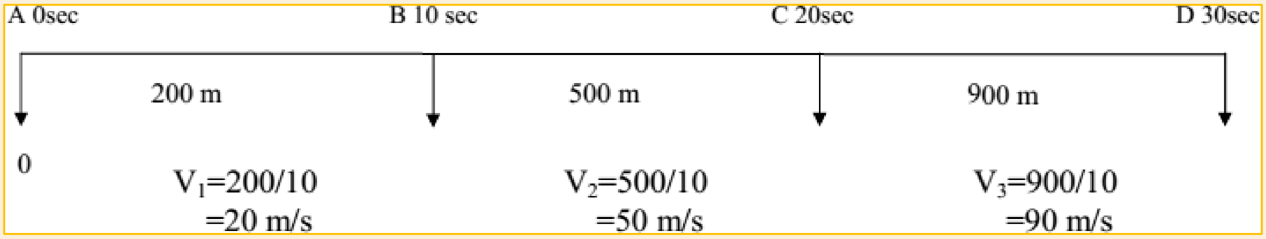
Uniform Acceleration: A body travelled with uniform increase velocity in equal interval of time is called Uniform Acceleration.



$$a_1=(v_2-v_1) / t = (40-20)/10=20/10 = 2 \text{ m/s}^2$$

$$a_2 = (v_3 - v_2) / t = (60-40)/10 = 20/10 = 2\ m/s^2$$

Variable Acceleration: A body travelled with Variable velocity in equal interval of time is called Variable Acceleration.



$$a_1 = (v_2 - v_1)/t = (50-20)/10 = 30/10 = 3\ m/s^2$$

$$a_2 = (v_3 - v_2)/t = (90-50)/10 = 40/10 = 4\ m/s^2$$

Average Acceleration: It is the ratio of average variable velocity to the total time taken. i.e.

Average Acceleration = Average Variable Velocity / Total Time taken

Retardation [-a]: The rate of change of decrease in velocity is called Retardation. It is also called Negative acceleration (Deceleration).

SI Unit: m/s^2 or ms^{-2}

Acceleration due to Velocity: The velocity with which an objected towards the earth surface due to gravitational force is called Acceleration due to Velocity.

It is denoted by 'g'

Value of g $=9.81\ m/s^2$

Equation of Motion:

If a body is moving along straight line, then the following relations are used.

I. For Increase in Velocity
1. $v = u+at$
2. $v^2=u^2+2as$

II. For Decrease in Velocity
1. $v = u-at$
2. $v^2=u^2-2as$

3. $S=ut+1/2at^2$
4. $S_n=u+a/2\{2n-1\}$

3. $S=ut-1/2at^2$
4. $S_n=u-a/2\{2n-1\}$

Where,
s= Displacement, v= Final velocity, u= Initial velocity, a= Acceleration, t=Time.

Problems:

1) The velocity of an automobile reduces from 35m/s to 15m/s in travelling a distance of 500m. Find its retardation.

Given data:
u = 35m/s
v = 15m/s
-a = ?
s = 500m

We know that

$v^2 = u^2+2as$

$(15)^2 = (35)^2+2a\,(500)$

225 = 1225 + 1000a

225-1225 = 1000a

-1000 = 1000a

a = -1000/1000

a = -1 m/s or –a = 1 m/s

2) A body moving with velocity 20m/s when breaks are applied to bring it to rest in 2 minutes. Calculate the retardation & distance travelled before come into rest.

Given data:
v=0
u=20m/s
t=2m
-a=?
S=?

To find acceleration

V = u+at

0 = 20 + (a) x120

to find displacement

$V^2 = u^2+2as$

$2as = v^2-u^2$

$0 = 20+120a$

$-20 = 120a$

$a = -20/120$

$a = -0.1667 m/s^2$

$-a = 0.1667 m/s^2$

$S = (v^2-u^{2)})/2a$

$S = (0^2-20^{2)}/ (2 \times -0.1667)$

$S = (0-400)/ (-0.3334)$

$S = 1199.76m$

3) An arrow shot vertically upward with velocity 49m/s. Find arrow maximum height reached & total time for which arrow was in air? [$g=9.81m/s^2$]

Given data:

$u=49m/s$

$V=0$

Height=h=s=?

$g=9.81m/s^2$

Total time=?

$t_1 =?$

$t_2=?$

$V^2= u^2-2gS$

$S = u^2-v^2/2g$

$= [(49)^2-0^2] / [2\times9.81]$

$= 2.401/19.62$

$S = 122.37m$

$V = u-gt$

$gt_1 = u-v$

$t_1 = u-v/g$

$t_1 = [49-0]/9.81$

$t_1 = 4.99$

$t_1 =5$ sec

Total time = Time for ascending + time for descending

$t = t_1 + t_2$ (Where $t_1 =t_2$)

$t = t_1 + t_1$

$t = 2t_1$

$t = 2 \times 5$

$t =10$ sec.

4) A car travel 108km/hr. is uniformly retarded & brought to rest in 7.5 seconds. Find its de-acceleration & distance travelled before coming to rest.

Given data

to find de-acceleration

$u = 108 km/hr. = 30 m/s$

$t = 7.5$ sec

$V = 0$,

$-a = ?$

$S = ?$

$v = u + at$

$v - u = a + t$

$a = v - u/t$

$a = (0-30)/7.5$

$a = -4$

$-a = 4 m/s^2$

To find distance

$V^2 = u^2 + 2as$

$2as = V^2 - u^2$

$S = V^2 - u^2/2a$

$S = [(30)^2 - (0)^2] / (2x4)$

$S = 900/8$

$S = 112.5m$

5) A stone is dropped from a building height & at the same the ground. Which a velocity 50m/s. Find the when & where two stones will meet. [$g=9.81m/s^2$]

For 1st body falling

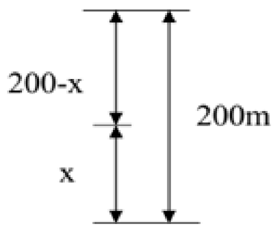
Given Data

$u=0$

$V=?$

$g=9.81 m/s^2$

$s_1=200-x$



$$V^2 = u^2+2gs_1$$
$$V^2 = (0)^2+2 \times 9.81(200-x)$$
$$V^2=19.6(200-x) \quad \rightarrow 1 \text{ equation}$$

W.k.t

$$S_1= ut+1/2gt^2$$
$$(200-x) = (0)2t+1/2\ 9.81$$
$$(200-x) = 0+4.9t^2$$
$$(200-x) = 4.9t^2 \quad \rightarrow \text{(A) Equation}$$

$$V = u+gt$$
$$V= 0+9.81t$$
$$V= 9.81t \quad \rightarrow \text{(B) Equation}$$

For 2nd body raising

Given Data

u=50m/s

V=?

S_2=x

g=9.81m/s²

$$V^2 = u^2 - 2gs_2$$

$$V^2 = (50)^2 - 2(9.81)\, x$$

$$V^2 = 2500 - 19.6x \rightarrow 2 \text{ Equation}$$

W.k.t

$$S_2 = ut - 1/2\, gt^2$$

$$x = (50)\, t - 1/2(9.81)t$$

$$x = 50t - 4.9t^2 \rightarrow \text{(C) Equation}$$

Equating equation (B) in equation (C):

$$x = 50t - 4.9t^2$$

$$x = 50t - (200 - x)$$

$$x = 50t - 200 + x$$

$$0 = 50t - 200$$

$$50t = 200$$

$$t = 200/50$$

$$t = 4 \text{ sec}$$

Substitute 't' value in equation (C)

$$x = 50t - 4.9t^2$$

$$x = 50(4) - [4.9\, (4)^2]$$

$$x = 200 - 78.4$$

$$x = 121.6\text{m}$$

Basic Fundamental Forces in Nature

The fundamental forces are,

→ **Gravitational Force**: Any two particles attract each other by virtue of their masses, this force is called Gravitational Force.

→ **Electromagnetic Force**: In addition to gravitational force, two charged particles exert electromagnetic force on each other.

→ **Nuclear Force**: It is defined as the force exerted between number of neutrons.

Force

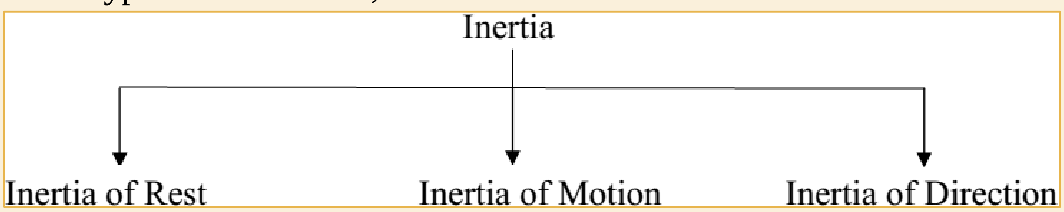
It is an external agent; it can change the position of the body or try to change the position of the body.

S.I unit = Newton [N]
Dimension = $[M^1 L^1 T^{-2}]$

Inertia

It is an internal property & the body& it opposes the change in position of the body.

Three types of inertia are,



1. Inertia of rest: It is inability of the body to change by itself.

Ex: A passenger sitting in bus at rest has a tendency to fall back, when the bus suddenly starts. The lower part of the body moves whereas upper part at rest due to inertia.

2. Inertia of motion: It is inability of the body to change by itself its state of uniform motion along straight line.

Ex: A person sitting in moving bus gets a forward jerk as it suddenly stops. The person has the velocity of the bus when suddenly stops, lower part of the body comes to rest & upper part moves forward.

3. Inertia of direction: It is the inability of the body to change its direction of motion by itself.

Ex: Mud sticking to vehicle tyre flies of tangentially.

Newton's 1st law of motion [law of inertia]

Statement: Everybody continues its state of rest or uniform motion along a straight line unless & until its compelled by an external force acting.

Momentum (P)

Statement: The mass associated with the moving body is called momentum. It is measured by the product of mass & velocity.

$P = m.v$

S.I Unit = kg-m/s or $kgms^{-1}$

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

Newton's 2nd law of motion [law of force]

Statement: The rate of change of momentum of a body is directly proportional to the external force acting on it along the direction of motion.

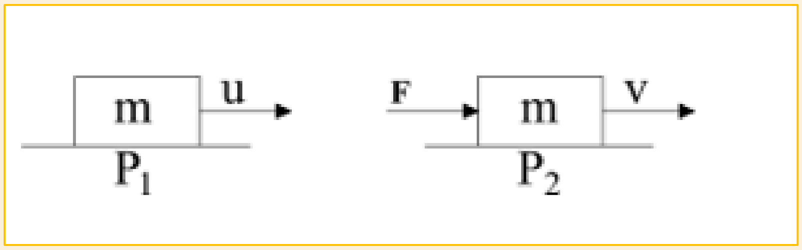
$$(dp/dt) \propto F$$

Derive (prove) F=ma by using [Newton's second law]

Considered a body of mass 'm' moving with initial velocity (u) subjected to an external force (f) when the velocity 'u'changes to final velocity (v) with mass (m) along the direction of motion.

Initial momentum of a body, P_1 =mu

Final momentum of a body, P_2 =mv



Change in momentum
$dp= P_2-P_1$
$dp= mv-mu$
$dp= m (v-u)$

Rate of change of momentum = dp/dt
$dp /dt = (P_2-P_1)/t$

$dp/dt = (mv-mu)/t$

$dp / dt =m(v-u)/t$

According to Newton's 2nd law of motion
$F \alpha\ dp/dt$ (or) $dp/dt\ \alpha\ F$

$F=k\ dp/dt$

$F=k\{m(v-u)/t\}$

By the definition of acceleration,
$a=(v-u) / t$
$F=k.ma$

Where 'k' is constant & its value depends on choice of unit.
Theoretical value of
$k=1$
$F=kma$
$F= 1.m.a$
$F=ma.$

Define one (1) Newton

We have,
$F=ma$
$F=1kg \times 1m/s2$
F=1 Newton

The force on the body is to be one Newton if 1kg mass of a body moving with uniform acceleration of $1m/s^2$.

Newton's 3rd law of motion

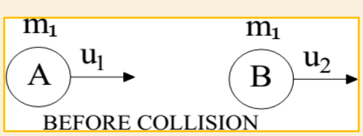
Statement: For every action there is an equal & opposite reaction.

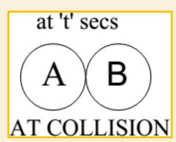
Ex:

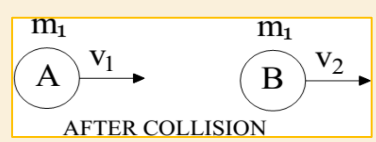
- A rubber ball normally hitting on the wall it bounces back. Hence hitting is action & rebounce is the reaction.
- A swimmer pushed water back & he moves forward that is pushes back is the action & moves forward is the reaction.
- Recoil of gun: A bullet moves forward is the action & gun moves backward is the reaction.
- Launching of rockets.

Law of conservation of momentum

Statement: When two or more bodies collide with each other then sum of the momentum before collision is equal to sum of the momentum after collision provided no external force acting on them.







Consider two bodies A & B of their masses 'm_1 ' & 'm_2 ' moving velocities 'u_1 '& 'u_2 ' respectively along a straight line. Let them collide with each other then the velocity is of A & B are changes from 'u_1 ' to 'v_1 ' & 'u_2 ' to 'v_2 ' without changing their masses of shown.

During collision force on the body 'A' transferred to 'B'

i.e. F_{AB} = mass of B x acceleration of B

$$F_{AB} = m_2 \times [v_2 - u_2/t] \quad \rightarrow (1)$$

At the same time the force on the 'B' transferred to 'A' i.e. F_{BA}= mass of 'A' x acceleration of 'A'

$F_{BA} = [m_1 \ x\ (v_1 - u_1)/t] \rightarrow (2)$

According to Newton's 3rd law of motion F_{AB} is the action & F_{BA} is the reaction.

i.e. $F_{AB} = - F_{BA}$ from equation (1) & (2)

$m_2 \ x\ [v_2 - u_2 /t] = -m_1$

$[v_1 - u_1 /t]\ m_2 \ v_2 - m_2$

$u_2 = -m_1 \ v_1 + m_1$

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

$m_1 \ u_1 + m_2 \ u_2$

That is total momentum before collision = Total momentum after collision. This verifies law of conservation of momentum

NOTE:

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

1) If $u_1 = 0$,

   $m_1 \ (0) + m_2 \ u_2 = m_1$

   $v_1 + m_2 \ v_2$ i.e. $m_2 \ u_2$

   $= m_1 \ v_1 + m_2 \ v_2$

2) If $u_1 = u_2 = 0$

   $m_1 \ (0) + m_2 \ (0) = m_1 \ v_1 + m_2 \ v_2$

   i.e. $m_1 \ v_1 + m_2 \ v_2 = 0$

3) $v_1 - v_2 = v_1$

   $m_1 \ u_1 + m_2 \ u_2 =$

   $m_1 \ (v) + m_2 \ (v)\ m_1 \ u_1 +$

   $m_2 \ u_2 = (m_1 + m_2)\ v$

Impulse [I]:

A very large force acting on a body in short interval of time is called impulse. i.e. $I = F.t$

S.I Unit = N-S

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

Ex:

→ A cricket ball hit by a bat
→ Kicking of foot ball
→ A nail hit by a hammer.

Difference between Momentum & Impulse.

Momentum	Impulse
✓ The mass associated with the moving body is called momentum	✓ A very large force acting on a body in short interval of time
✓ It is a vector quantity	✓ It is a vector quantity
✓ $P = mv$	✓ $I = F.\ t$
✓ S.I Unit = kg . m/s & $[M^1.L^1.T^{-1}]$	✓ S.I Unit = N.S & $[M^1.L^1.T^{-1}]$

PROBLEMS

1) A Force of 20N acts on a body of mass 50 kg at rest for 4 seconds. Find the velocity required.

Given data

F = 20.N

m = 50 kg

t = 4 Sec

u = 0

v = ?

Force formula

$F = m.a$

$20 = 50 \times v/4$

$20 \times 4 = 50v$

$80 = 50v$

$V = 80/50$

$V = 1.6 m/s$

$a = (v-u) / t$

$a = (v-0) / 4$

$a = v/4\ m/s^2$

2) A bullet of mass 30 grams enters a block of wood with a velocity of 600 m/s and it penetrates to a depth of 20 cm. What is the average resistance of the wood to penetration of bullet?

Given data	W.k.t
m= 30 grams = 0.03 kg	$v^2 = u^2 + 2as$
u = 600m/s	$a = v-u^2/2s$
S = 20 = 0.2 meter	$a = [(0)^2 – (600)^2] / [2(0.2)[$
Resistance of force, F =?	a = -360/0.4
a = ?	$a = -900000\ m/s^2$
v = 0	$-a = 900000 m/s^2$
	Then
	F = ma = 0.03 x 900000 = **27 x 10^3** N

3) A resultant force 130 N acting on a mass of 40 kg for 5 seconds which is initially at rest.

Find the velocity increased due to that force?

Given data	F = ma	
F = 130 N	130 = 40 x a	Where,
m = 40 kg	130 = 40 x v/5	a = (v-u)/t
t = 5 seconds	130 x 5 = 40 v	a = (v-0)/5
u = 0	650 = 40 v	a = v/5
v = ?	v = 650/40	
	v = 16.25m/s	

4) A 10 grams' bullet is shot from a 5 kg. Gun with velocity of 400 m/s. What is the recoil velocity of the gun?

As before firing the bullet both the gun and the bullet were at rest, so the total momentum before firing is zero

after firing the velocity of bullet (v)= 400 m/s, say the velocity of gun is **V**

mass of bullet (m)= 10/1000 kg , mass of gun (**M**)= 5 kg

From momentum conservation,

0= mv + **MV**

V = - (m/**M**)*v

V = - (10\5000)*400 m/s

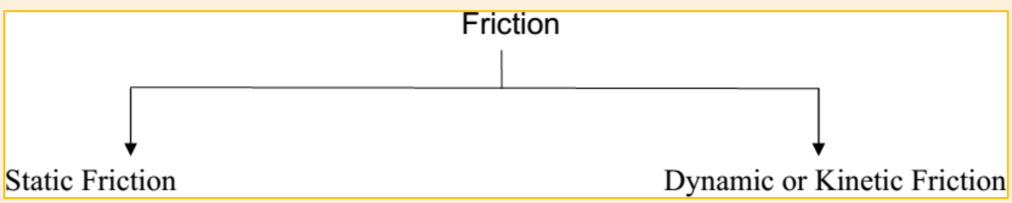
V = - 0.8 m/s (Negative sign indicates that velocity of gun and bullet is in opposite direction)

so the recoil velocity of the gun is 0.8 m/s

FRICTION:

A property of a body by virtue of which resisting force is created between two rough bodies when they are contacts each other.

Types of Friction



1. **Static friction**: It is the friction experienced by a body when it is at rest.

2. **Dynamic or kinetic friction**: It is the friction experienced by a body when it is in motion.

   It has following 3 types.

a. Sliding friction: It is the friction experienced by a body when it slides over another body.
b. Rolling friction: It is the friction experienced between the surfaces which has ball or rollers interposed between them
c. Pivot friction: It is the friction experienced by a body due to motion of rotation

Advantages of Friction

- To walk on road
- To drive the vehicle on road
- To power transmission between belt & pulley
- Sharpening the tool
- Engagement & disengagement of engine by clutches.

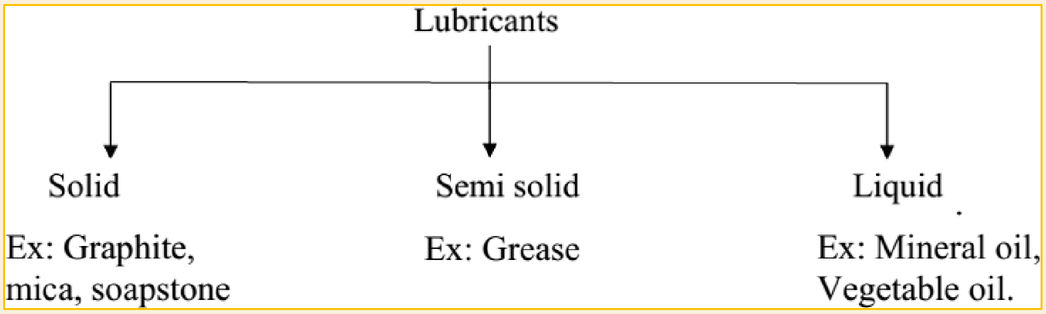
Disadvantages of Friction

- It produces heat
- Wear & tear between metal contact surfaces
- It reduces the speed of moving parts like piston , shafts etc....
- More power consumption.

Preventive or Reducing of Friction

- Smooth or polished surface: Friction between two smooth surfaces are minimum compared to rough surfaces
- Ball bearing: Ball bearings are used on rotating members
- Lubricants: Between two surfaces make a thin film [layer] & which fill the irregularities.

There are three types of lubricants

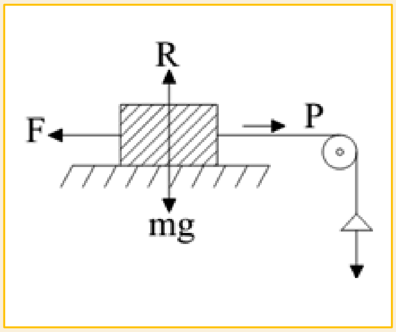


Stream Lining

Flying bird/fish shapes on the high speed bodies to reduce friction by air or water.

Limiting Friction

Consider a wooden block of mass 'm' is placed on a flat surface & block one end is tied with a string (wire) & another end of the wire is connected to the weight through roller or pulley which 'P' (pull force) is acting.



- When 'P' is smaller the block will not move
- When 'P' is slightly increased P = F (frictional force)
- When 'P' is increased again the Block moves at this stage F_{max} (Maximum frictional force) will acts and further frictional force will not increases.

Hence we can say that the limit beyond which the frictional force cannot be increased is called as limiting friction & it refers to maximum value of the frictional force.

Law of limiting friction four laws

The friction force always opposes the relative motion between surfaces & limiting friction depends on nature & smoothness of surfaces.

Friction force is always tangential to the surface in contact.

Limiting friction [F] varies directly with normal reaction [N]

$$F \propto N$$

$F = \mu N$ (Where μ = Co- efficient of friction)

i.e. $\mu = F/N$

When normal reaction is constant the magnitude of limiting friction is independent of area & shape of surfaces in contact.

Co- efficient of friction is defined as the ratio of frictional force to the normal force

Causes of Friction

- Roughness
- Deformation
- Adhesion
- Fluids
- Molecular attraction

Exercises

I. Fill In The Blanks

a) Any quantity represented by only in magnitude is known as.......................

b) The rate of change of distance of a body is called.....................

c) The rate of change of displacement of a body is called...........

d) SI unit of acceleration is.............

e) SI unit of Force is................

II. Multiple Choice Questions

a) Value of 'g' is

a) $9.81 m/s^2$ b) $981 m/s^2$ c) $98.1 m/s^2$ d) None of these

b) Bearings are used to reduce

a) Friction b) velocity c) retardation d) gravitation

c) Momentum is denoted by

a) M b) m c) P d) None of these

III. Answer the following Questions

a) Define velocity? Explain their types.

b) Define acceleration? Explain their types.

c) State Newton's 1st Law of motion.

d) State Newton's second law of motion and Derive F=ma

e) Derive law of conservation of momentum by third law of motion

f) Explain Limiting of Friction

g) Mention advantages & disadvantages of Friction.

h) A bullet of mass 20g is fired with a velocity of 960 m/s from a rifle of mass 3kg.

Find the velocity of recoil of the rifle

i) A car travel 75km/hr is uniformly retarded & brought to rest in 5 seconds. Find its de-acceleration & distance travelled before coming to rest.

UNIT 3: CIRCULAR AND PLANETARY MOTION

Introduction:

Circular motion

An object which revolving round the circumference of a circle about fixed point is called Circular motion.

Ex:

- A rotating fan
- A rotating wheel
- Moon & artificial satellites revolving round the earth.

Definitions of Important terms:

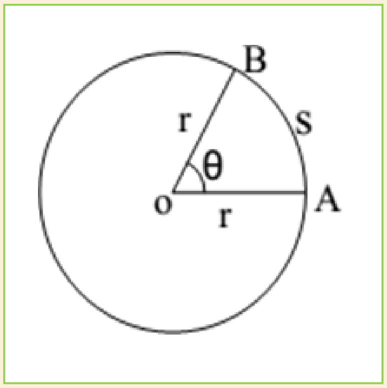
Angular Displacement (θ= theta)

The angle made by the particle during its circular motion.

S.I. Unit = radian

Dimension= No Dimension [M° L° T°]

In the figure let "r" be the radius r= OA= OB



∟BOA = θ = angular displacement and AB = S = Arc length the relation between r, θ & S is given by

S = r. θ

Angular velocity (ω=omega)

The rate of change of angular displacement of a body during Circular motion is called Angular Velocity.

Angular velocity $\omega=\theta/t$ rad/s

If a body completes 'N' rotation per minute then its angular velocity is given by

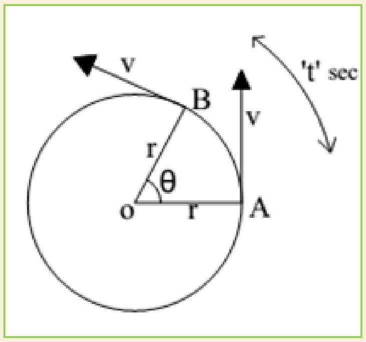
$\omega = 2nN/60$ rad/s

SI Unit = rad/s

Dimension: $[M^\circ L^\circ T^{-1}]$

Relation b/w angular speed/velocity & linear speed/velocity.

Ques: Derive $v= r.\omega$ using usual notations/Derive angular velocity & linear velocity



Consider a body revolving round the circumference of a circle of radius (r) with centre 'o'.

If the body changes its position from 'A' to 'B' in time 't' seconds then angular displacement 'θ' is produced by the definition of angular velocity.

$\omega =\theta/t$

But $s = r.\theta$ or $\theta = s/r$ Where, s=Arc length $\omega =(s/r) / t$

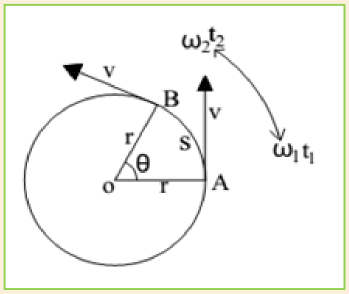
$\omega = (1/r). (s/t)$

$\omega = (1/r).v$ Where, v=Distance(s) / Time (t) $v=\omega.r$ or $v=r.\omega$

Angular acceleration (α= alpha)

Statement: The rate of change of angular velocity of a body during circular motion is called angular acceleration.

If a body changes its position A to B in time's' seconds. Then angular acceleration is given by,



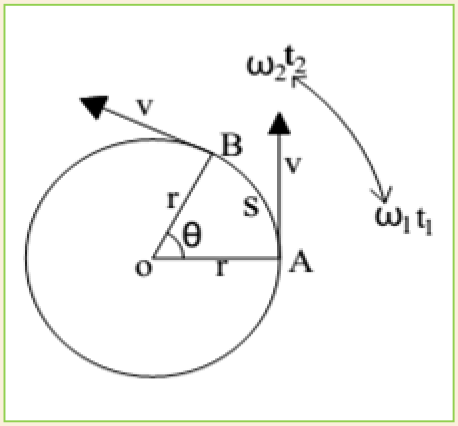
α =change in angular velocity/time

i.e. $\alpha = (\omega_2 - \omega_1)/(t_2 - t_1) = (\omega_2 - \omega_1)/t = \omega/t$ $\alpha = \omega/t$

S.I Unit: (rad/s)/s=rad /s^2 [ω = rad /s] Dimension: [$M° L° T^{-2}$]

Relation between angular acceleration & linear acceleration

Ques: Derive a=r.α with usual rotations.



Consider a body revolving round the circumference of a circle of radius (r) with center 'o'

Let 'ω_1' be the angular velocity in 't_1' seconds at position

'A' & 'ω_2' be the angular velocity in 't_2' seconds at position 'B' By the definition of angular acceleration,

α = change in angular velocity / Change in time $\alpha = (\omega_2 - \omega_1)/(t_2 - t_1)$

$\alpha = (\omega_2 - \omega_1)/t$ → 1 equation

By the relation of angular velocity & linear velocity v=r.ω or ω = v/r

i.e. $\omega_1 = v_1/r$ & $\omega_2 = v_2/r$

Put the values of ω_1 & ω_2 in equation 1

$\alpha = (v_2/r - v_1/r) / t$

$\alpha = (1/r).(v_2 - v_1) / t$

$\alpha = (1/r).a$

Where, $a = (v_2 - v_1) / t$

$a = r.\alpha$

Planetary Motion

Gravity: Newton has discovered gravitational force, gravitational force is an weakest force in nature. It acts between any two masses & is always attract with each other.

Ex: Motion of moon around the earth etc.

Acceleration due to gravity (velocity)

It is the force which increases the velocity of the object when it is moving towards the earth or ground surface.

OR

Acceleration of freely falling body is called acceleration due to gravity & it is denoted by 'g'

S.I Unit: m/s^2

Dimension: $[M^\circ L^\circ T^{-2}]$

Newton's Law of Gravitation

Statement: Everybody in the universe attracts with each other then the force of attraction between two bodies is directly proportional to the product of their masses & inversely proportional to the square of the distance between them.

Explanation:

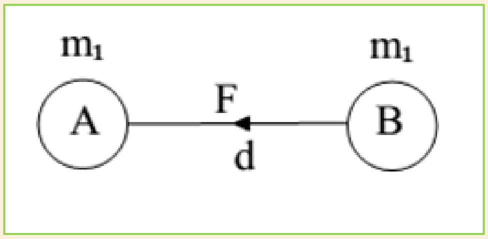
Consider two bodies 'A' & 'B' of mass 'm_1' & 'm_2' separated by distance 'd'. According to Newton's law of gravitation

$F \alpha m_1 m_2$

$F \alpha 1/d^2$

$F \alpha (m_1 m_2)/d^2$

$F = (G.m_1 m_2)/d^2$



Where **G**=Constant proportionality & is called gravitation constant

$G=(Fd^{2)}/(m_1m_2)$

S.I Unit = $N\text{-}m^2/kg^2$

Dimension: $[M^{-1}\ L^3\ T^{-2}]$

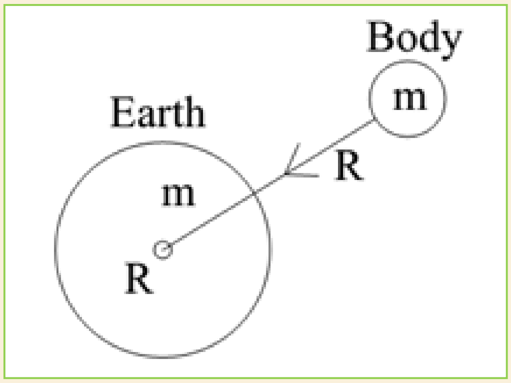
Relation between ‘g’ & ‘G’

(g= Acceleration due to gravity, G=Gravitational constant)

Consider a body of mass ‘m’ just above the earth surface of radius ‘R’ with mass ‘m’.

According to Newton’s second law of motion $F_1=mg$

(1)



According to Newton’s law of gravitation

$F_2=GMm/R^2$(2)

Equating the equation (1) & (2)

$F_1= F_2$

$mg = (Gmm)/R^2$ $g = (G.m)/R^2$

From above equation ‘g’ not depends mass of a body but it depends on radius & mass of earth.

Variation of ‘g’

- If height increases ‘g’ decreases & vice versa
- If depth increases ‘g’ decreases & vice versa

Note:

R = Radius of earth = $6.38\text{x}10^6$ m

G = Gravitational constant = $6.63\text{x}10^{-11}$ $N\text{-}m^2/kg^2$ M = Mass of earth = $5.94\text{x}10^{24}$ kg

PROBLEMS

1) The speed of rotation of a body changes from 100 rpm to 250 rpm in 20 seconds calculate the angular acceleration.

Given data to find angular velocity

Speed, N_1=100 rpm $\omega_1 = 2\pi N_1/60$ $\omega_2 = 2\pi N2/60$ Speed, N_2= 250 rpm $\omega_1 = 2 \times \pi \times 100/60$

$\omega_2 = (2 \times n \times 250)/60$ Time, t_1=20sec $\omega_1 = 20\pi/6$ $\omega_2 = 50n/6$

Angular acceleration, α =? $\omega_1 = 10.46$ rad/s ω_2=26.16rad/s

rpm=rotation per minute

To find angular acceleration

$\alpha = (\omega_2 - \omega_1)/t$

$\alpha = (26.16-10.46)/20$

$\alpha = 0.785 \text{rad/s}^2$

2) Grinding wheel has a diameter of 0.52m. Calculate the linear speed of a point on its periphery when wheel revolves at 2600rpm

Given data

Diameter d=0.52m $\omega = 2\pi N/60$

Radius=0.52/2=0.261m $\omega = 520n/6$

Speed N=2600rpm ω = 272.27 rad/s Linear speed=v=?

W.k.t.

Linear Speed

$v = r.\omega$

v=0.261 x 272.27

v = 70.89 m/s

3) A body is moving with circular path of radius 3m. If its speed increases from 140 rpm to 200 rpm in 5seconds. Calculate the angular acceleration & linear acceleration.

4) The pulley starting from rest accelerated uniformly reaches a speed of 900 rpm in 18 seconds.

Given data

Speed, N_1 =140rpm

Speed, N_2 =200rpm

Time, t =5 sec

Radius =3m

Angular acceleration, α =? rad/sLinear acceleration, a=?

To find angular velocity

$\omega_1 = (2nN_1)/60$

$\omega_1 = (2xnx140)/60$

$\omega_1 = (28n)/6$

$\omega_1 = 14.66$

$\omega_2 = 2nN_2/60$

$\omega_2 = (2 \times n \times 200)/60$

$\omega_2 = (40n)/6$

ω[illegible]=20.94rad/s

To find angular acceleration

$\alpha = (\omega_2 - \omega_1)/t$

$\alpha = (20.94 - 14.66)/5$

$\alpha = 1.255\ rad/s^2$

To find linear acceleration

= r.α

a = 3 X 1.255

$a = 3.77 m/s^2$

Calculate angular acceleration.

Given data

Speed, N_1 =0 rpm

Speed, N_2 =900rpm

Time, t =18 sec

Angular acceleration, α =?

Angular velocity, ω_1 & ω_2 =?

To find angular velocity

$\omega = 2\pi N/60$

$\omega_1 = (2\pi N_1)/60$

$\omega_1 = (2 \times \pi \times 0)/60$

$\omega_1 = 0$ rad/s

$\omega_2 = (2 \times \pi \times 900)/60$

$\omega_2 = (1800\pi)/6$

$\omega_2 = 94.2$ rad/s

To find angular acceleration

$\alpha = (\omega_2 - \omega_1)/t$

$\alpha = (94.2-0)/18$

$\alpha = 5.2$ rad/s^2

5) On a planet whose size is same & mass 4times as that of the earth. 'g' (acceleration due to gravity) on earth is 9.81m/s^2. Calculate the 'g' on the planet.

Given data

Planet

Radius, $R_1 = R_2$

Mass, $m_1 = 4m_2$

g^1=?

$g^1 = (Gm_1)/R_1^2$

Earth

Radius= R_2

Mass = m_2

g=9.81m/s^2

$g = (Gm_2)/R_2^2$

To find g^1

$g^1 \div g = (Gm_1/R_1^2)/(Gm_2/R_2^2)$

$g^1 \div g = (m_1/R_1^2) \times (R_2^2/m_2)$

Put $m_1 = 4m_2$ & $R_1 = R_2$

$g^1 \div g = (4m_2/R_1^2) \times (R_1^2/m_2)$

$g^1 \div g = 4m_2/m_2$

$g^1 \div g = 4$

$g^1 = 4g$

$g^1 = 4 \times 9.81$

$g^1 = 39.2$ m/s^2

6) The mass & radius of Earth is 4 times of that of the Planet & 'g' of Earth is 9.81m/s^2. Calculate the Planet 'g'.

Given data

Earth

Radius, $R_1 = 4R_2$

Mass, $m_1 = 4m_2$

$g = 9.81 m/s^2$

$g = (Gm_1)/R_1^2$

Planet

Radius $= R_2$

Mass $= m_2$

$g^1 = ?$

$g^1 = (Gm_2)/R_2^2$

To find g^1

$g^1 \div g = (Gm_2/R_2^2)/(Gm_1/R_1^2)$

$g^1 \div g = (m_2/R_2^2) \times (R_1^2/m_1)$

Put $m_1 = 4m_2$ & $R_1 = 4R_2$

$g^1 \div g = (m_2/R_2^2) \times \{(4R_2)^2/4m_2\}$

$g^1 \div g = (m_2/R_2^2) \times \{(16R_2^2/4m_2\}$

$g^1 \div g = 16/4$

$g^1 = 4g$

$g^1 = 4 \times 9.81$

$g^1 = 39.2 m/s^2$

Exercises

I. Fill in The Blanks

a) SI unit of angular velocity is.......................

b) The rate of change of angular displacement of a body is called...........

c) SI unit of angular acceleration is.............

d) The rate of change of angular velocity of a body is called................

e) If height increase ‘g’ value will be...................

II. Multiple Choice Questions

a) Relation between linear velocity and angular velocity is

a) $v=r.\omega$ b) $v = r/\omega$ c) $\omega = r/v$ d) None of these

a) Relation between linear acceleration and angular acceleration is

a) $v=r.\omega$ b) $a = r.\alpha$ c) $\alpha=r.a$ d) None of these

b) Relation between G & g is

a) $g=Gm/R$ b) $G=gm/R^2$ c) $g=Gm/R^2$ d) $R^2=gm/G$

III. Answer the following Questions

a) Define angular velocity?

b) Define angular acceleration?

c) Derive the relation between linear & angular Velocity.

d) Derive the relation between linear & angular acceleration

e) Derive law of conservation of momentum by third law of motion

f) Derive Newton's law of gravitation

g) The wheel starting from rest accelerated uniformly reaches speed of 800 rpm in 16 seconds. Calculate its angular acceleration.

UNIT 4: WORK, POWER AND ENERGY

Work

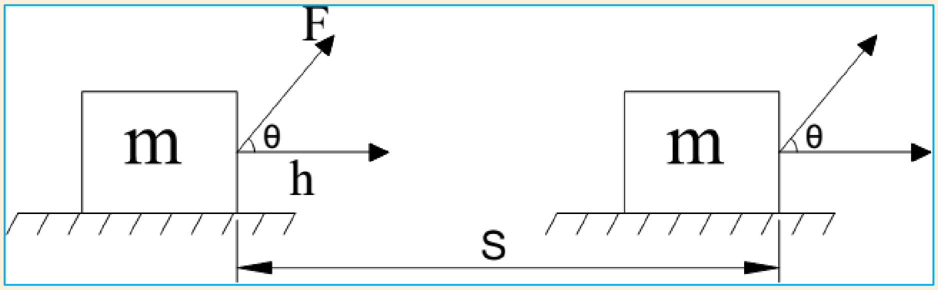
The point of application of force undergoes displacement is called work.
It is measured by the product of Force (F) and displacement (S)

- If the 'F' & 'S' are in the same direction.
- i.e. Work = Force x displacement

W = F x S

SI unit =N -m or Joule (J) Dimension= $[M^1 L^2 T^{-2}]$

- If when the body gets displaced with an angle 'θ' with force of direction.



Consider a body of mass 'm' undergoes displacement (S) by inclined force (F) making an angle (θ) with respect to horizontal.

Then the amount of work done on the body is given by,

Work done, W = Horizontal force (H) × displacement.

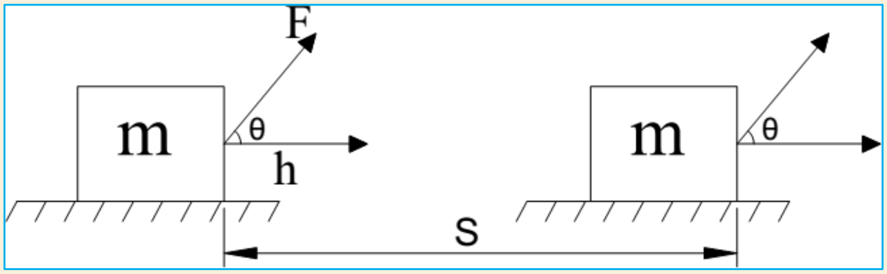
$W = H \times S$

$W = F.\cos\theta \times S$ $W = F.S.\cos\theta$

SI unit =N -m or Joule (J)

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

☞ If when the body gets displaced with an angle ‘θ’ with force of direction.



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Then the amount of work done on the body is given by, Work done,

W = Horizontal force (H) × displacement.

$W = H \times S$

$W = F.\cos\theta \times S$

$W = F.S.\cos\theta$

Special cases

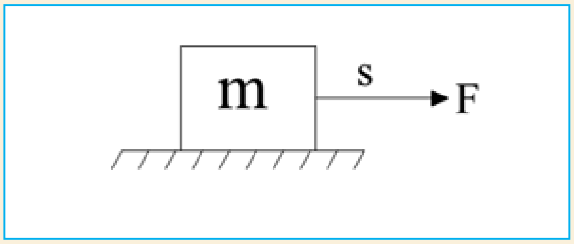
1. Positive work or maximum work

The work done on the body is said to be positive, when ‘F’and‘S’ are in same direction.

Then $\theta = 0$.

$\cos\theta = \cos(0) = 1$

$W = F \times S \cos\theta$ $W = F \times S\,(1)$ $W = F \times S$



2. Negative work

The work done on the body is said to be negative, when ‘F’ and ‘S’ are in opposite direction.

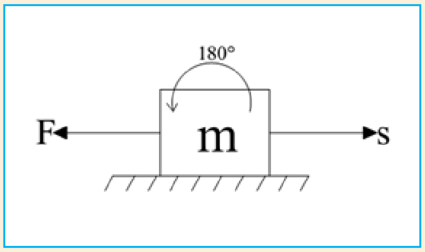
Then $\theta = 180^{\circ}$

$\cos\theta = \cos(180) = -1$

$W = F \times S \cos\theta$

$W = F \times S(-1)$

$W = -(F \times S)$



3. Zero work

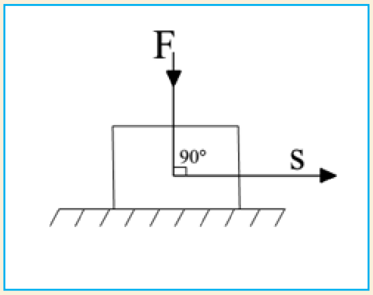
The work done on the body is said to be zero, when 'F' and 'S' are in perpendicular to each other

Then $\theta = 90^{\circ}$

$\cos\theta = \cos(90) = 0$

$W = F \times S \cos\theta$

$W = F \times S(0)\ W = -0$



Power

The rate of doing work is called Power

Power = work/time

$P = W/t$

SI Unit: Watt (w) or Joule/sec

Dimension: $[M^1 L^2 T^{-3}]$

Note: Watt is a smaller unit for measurement of power hence **kilowatt** (kW) is called as practical unit.

1 kW = 1000w

Horse power (HP)

HP Is the F.P.S System of units. It is defined as amount of power required of lift a body of mass **550** pound through a distance one feet against the gravity in one Second is called Horse Power (H.P)

1 Horse power = 746 watts

Energy

The capacity for doing work

SI unit: Joule (J)

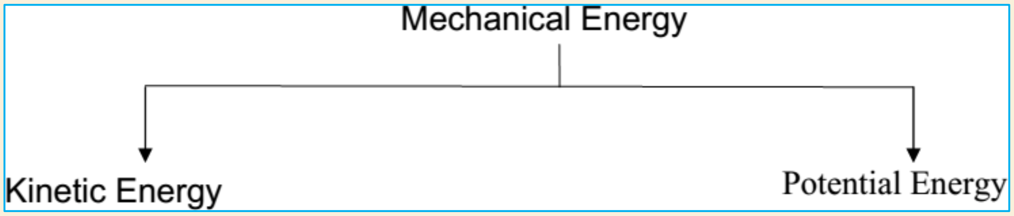
Dimension: $[M^1 L^2 T^{-2}]$

Different forms of energy:

Mechanical Energy, Heat Energy, Light Energy, Wind Energy, Atomic Energy, Sound Energy, Chemical Energy & Electrical Energy etc.

Types of Mechanical Energy

There are two types of mechanical energy



1) Kinetic Energy (K.E)

The energy possessed by the body due to its motion is called Kinetic Energy.

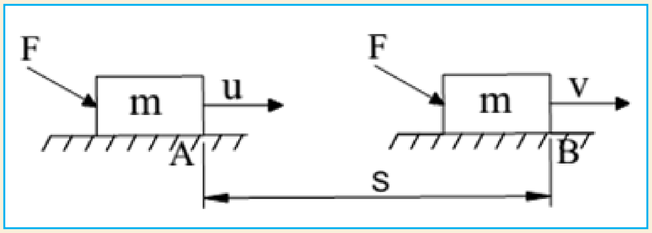
Ex:

- A bullet fired from a gun possess Kinetic Energy
- Flowing water has Kinetic Energy
- A Moving ball

Expression for Kinetic Energy

Ques: Derive an expression for K.E of a body of mass ‘m’ moving with velocity ‘V’

Consider a body of mass ‘m’ which is at rest apply an external force ‘F’ on the body which sets the body in motion with velocity ‘V’ let ‘S’ be the displacement or distance travelled by the body with velocity from A-B.



Then work done on the body is given by,

Wore done = Force x displacement i.e.

$$W = F \times S\text{------------ (1)}$$

According to Newton's 2nd Law of motion

F =ma

Put the 'F' value in Equation (1)

W= ma x S (2)

From equation for motion

V^2= u_2+3as

But Initial velocity, u=0.

$$V^2=2as \text{ or } as=v^2/2$$

Substituting 'as' value in Equation (2)

W=m x (v^2/2) or ½ (m v^2)

Work done on the body is completely in the form of Kinetic energy,

K. E=W

K. E = ½ mv²

Potential Energy

The energy possessed by the body due to virtue of its position is called Potential Energy

Ex:

- Water stored in a Tank
- Water stored in a Dam
- Wounded spring of a Clock
- Water fall

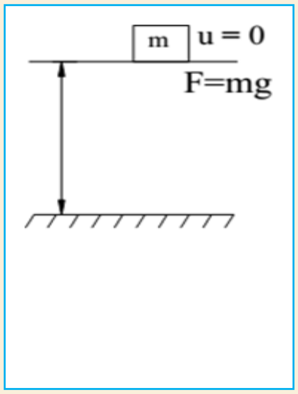
Expression for Potential Energy

Ques: Obtain a formula for P.E of a body of mass ‘m’ at a height ‘h’ from above the ground.
Consider a body of mass ‘m’ which is at a height ‘h’ from above the ground.
Work done on the body to take it from the ground is given by,
Work done,

W = Force x displacement

W = F x height

W = F x h ---------- (1)



According to Newton’s 2nd Law of motion
F = m.g (2)
Substitute ‘F’ in equation (1)
W = m.g.h
The work done on the body is completely on the form of Potential energy.
P.E=W
P.E=mgh

Note:

1. P.E= mgh
   a. h =0 P.E=0 (at ground h = 0)
   b. P.E is maximum at maximum height (If ‘h’ increases P.E also increases)

2. K.E = ½(mv^2)
   a. If v = maximum, K.E = maximum
   b. If v = 0, K.E= 0

Law of Conservation of body or Energy

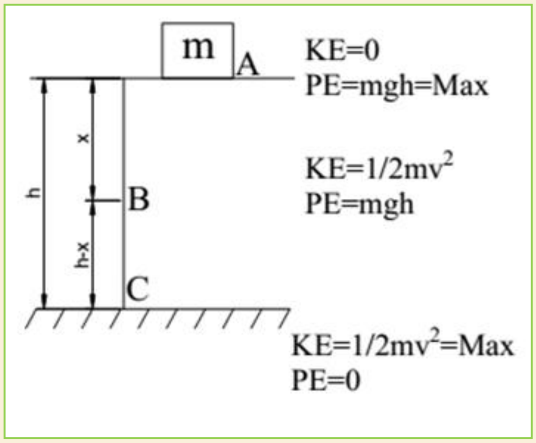
Statement: In a closed system energy neither be created nor be destroyed, but it can be converted from one form of energy in to another form. (In closed system Total Energy is constant)

i.e. Total Energy, T.E = K.E + P.E

Illustration of Law of Conservation of Energy

For Freely Falling Body

Consider a body of mass 'm' which at a height from above the ground.



@ Position A

Initial velocity, $u=0$

$K.E = ½ mv^2 = 0$

$P.E = mgh$

Total energy,

$T.E = K.E + P.E$

$TE = 0 + mgh$-------- (1)

At 'A' total energy completely in the form of P.E

@ Position B

For falling body equation of motion is given by

$v^2 = u^2 + 2gS$

But $u = 0$ & $S=x$

$v^2 = 0+2gx$

$v^2 = 2gx$

Multiply by m/2 on both sides

$mv^2/2 = 2gxm/2$

$½ mv^2 = mgx$

i.e. Increase in K.E = Decrease in P.E Hence Total energy remains same

$T.E = K.E+P.E$

$T.E=½ mv^2 + mgx$--------- (2)

@ Position C

$h = 0$, $P.E = 0$

$v = max$, $KE = ½$

mv^2 = max

T.E = K.E + P.E

T.E = ½ mv^2 + 0

T.E = ½ mv^2 (3)

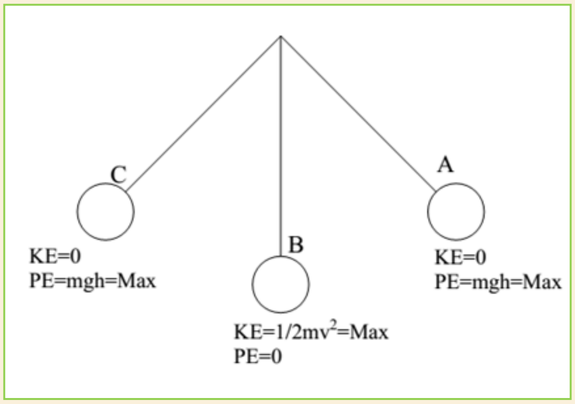
at 'C' total energy is completely in form of K.E

From equation A, B & C Total energy remains same & energy carried from P.E to K.E.

For Simple Pendulum

Considered a simple pendulum oscillating about its mean position.

@ Extreme position 'A' (Turning point)



K.E = 0 (v = 0) & P.E = mgh = max

@ **A,** T.E = K.E + P.E

T.E = 0+ P.E

T.E = mgh (1)

T.E is completely in the form of P.E

@ Position B (mean position)

P.E = 0(h = 0) & K.E = ½ mv^2 = max

@ **B,** T.E = K.E + P.E

T.E = ½ mv^2 + 0 (2)

T.E is completely in the form of K.E

@ position 'C'

K.E = 0 (v = 0) & P.E = mgh = max

@ **C,** T.E = K.E + P.E

T.E = 0+ P.E

T.E = mgh (3)

From equation A, B & C it is clear that energy can be converts from P.E into K.E & vice versa.

i.e. T.E remains same

PROBLEMS

1) What is the work done when a body is pulled through 10m by a force of 20N?
   a. With the horizontal
   b. Acting at an angle of 60^0 with the horizontal.

Given data a) W = F x S b) W = F x S x Cos θ

F = 20N W = 20x10 W = 20 x 10 x cos60□

S = 10m W = 200 N–m or J W = 100 J

$\theta = 60^0$

W =?

2) A body of mass 1 kg is moving with $3m/s^2$ and travelled 5m distance what is the work done?

Given data <u>To find force</u> <u>To find Work Done</u>

m = 1kg F = ma W = F x S

S = 5m F = 1 x 3 W = 3x5

a = 3m/s2 F = 3N W = 15 J

W =?

3) What is the work done when the body is passed through a 20m distance by force of 5N in the opposite direction?

Given data W = F x S x Cos θ

S = 20m W = 20 x 5 x cos (180)

F = 5N W = 100 x -1

W =? W =-100 J

Negative because force applied & displacement in opposite direction.

4) A block of mass is 2kg lifted up through a distance of 2m in 5seconds. What is the power?

Given data to find Power

m = 2kg P = W/t

S = 2m P = (F x s)/t

t = 5sec P = (m x g x s)/t (F = ma = mg)

P =? P = (2 x 9.81 x 2)/5

P = 7.84 W or 7.84×10^{-3} kW

5) A man whose mass is 80kg walk up a flight of 15 steps (each steps has 20 cm) in 5sec find the power he develops.

Given data to find Power

m = 80kg P = W/t

S = 20 x 15 P = (F x s)/t

= 3000cm = 3m P = (m x g x s)/t (F = ma = mg) t = 5sec P = (80 x 9.81 x 3)/5

P = ? P = 470.4 W or 470.4 x 10^{-3} kW

6) Calculate the power in HP which can lift 100 litres of water from a height of 10m in 8 seconds.

Given data to find Work to find Power

m = 100 litres of water W = F x s P = W/t

S = 10m W = m x a x s P = 9810/8

t = 8sec W = m x g x s P = 1226.25 W

P = ? W = 100 x 9.81 x 10 W.k.t

W = ? W = 9810 J

1HP = 746 Watts

= 1226.25/746

HP = 1.64

7) A space craft of mass 10000kg is moving with velocity of 10^6km/s calculate kinetic energy.

Given Data KE = ½ mv2

m = 10000 kg KE = ½ x 10000x $(10^{9)2}$

v = 10^6 km/s = 10^9 m/s

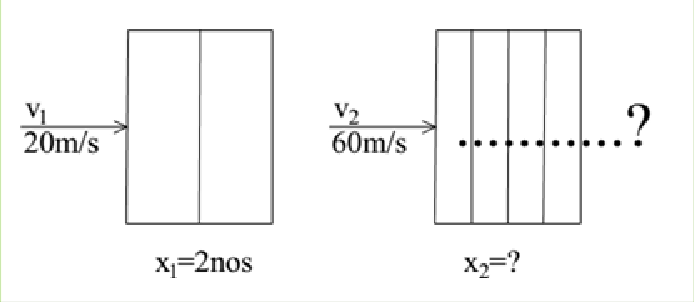
KE =? KE = 5 X 10^{21} J

8) A bullet with velocity 20 m/s can just penetrates2 planks of equal thickness. How many such planks can a bullet with a velocity 60 m/s just penetrate?

To find KE

$KE = ½mv^2 x_2 = ?$

KE α Number of Planks



KE α x

½ mv^2 α x

Then x_1 & x_2 are

½ $mv_1^2 = x_1$ & ½

$mv_2^2 = x_2$ $x_1 \div x_2 = (½\, mv_1^2)/(½\, mv_2^2)$

2 2

$x_1 / x_2 = v_1 / v_2$

$x_2 = (x_1.v_2^2)/ v_1^2$

$x_2 = [2 \times (60)^2]/(20)^2$

$x_2 = 18$ nos.

9) A bullet of mass 50g enters a wooden block with a velocity of 200 m/s & leaves with 100 m/s in 2min.Calculate the work done by the bullet.

Given data to find 'a' to find 'S'

m = 50g = 0.05kg $V = u - at$ $V^2=u^2-2as$

v = 100m/s $a = (u-v) / t$ $S = (u^2-v^2)/2a$

t = 120 seconds $a = (200-100) / 120$ $S = [200^2-100^2]/(2 \times 0.83)$

u = 200m/s $a = 0.83\ m/s^2$ S = 18000m W =?

To find 'W'

W = F x S

W = m x a x S

W = 0.05 x 0.83 x 18000

W = 747 J

10) A body of mass 1kg starts to fall under gravity from a height of 8m. Find the K.E and P.E at the height of 5m above the ground also find total Energy.

Given data

m = 1kg to find 'PE' to find 'V^2'

s or h = 8m P.E = mgh $V^2=u^2+2as$

1

$g = 9.81 m/s^2$ P.E = 1 x 9.81 x 5 $V^2 = 0 + 2(9.81 x 3)$

s or h2 = 5m P.E = 49 J $V^2 = 58.86$ PE = ?

KE =?

To find 'KE' Total Energy

KE = ½ mv^2 T.E = K.E + P.E

KE = ½ x1 x 58.86 T.E = 29.43 + 49

KE = 29.43 J T.E = 78.43J

Exercises

I. Fill In The Blanks

a) Product of force & displacement is.......................

b) The rate of doing work is called...........

c) SI unit of work is.............

d) The capacity for doing work is called................

e) If force & displacement in same direction, then the work is...................

II. Multiple Choice Questions

a) N-m is also indicating as

a) w b) J c) F d) None of these

b) If velocity is zero, then K.E will be a) 1 b) 0 c) 4 d) 5

c) If height is zero, then P.E will be

a) max b) 0 c) 4 d) 5

III. Answer the following Questions

a) Define work? Explain work in special cases

b) Derive KE= ½ mv^2

c) Derive PE=mgh

d) Explain law of conservation of energy in case of Simple Pendulum

e) Explain law of conservation of energy in case of freely falling body

f) A space craft of mass $25x10^3$ kg is moving with velocity of 10^5 km/s calculate kinetic energy.

g) A body of mass 2kg starts to fall under gravity from a height of 10m. Find the K.E and P.E at the height of 7.5m above the ground & also find total Energy.

UNIT 5: HEAT

Heat (Q)

It is a form of energy. Its existence is felt in the form of hotness and coldness.

When heat is entering the body makes it hot and when removed makes it cold.

SI unit – Joule (J)

Temperature (T)

Heat is the cause and the temperature is the effect. The term temperature refers to degree of hotness of the body.

Temperature is directly proportional to heat.

It can be measured by instrument called thermometer units are °C [Celsius], °F [Fahrenheit], °K [Kelvin]

Relation between above Units is,

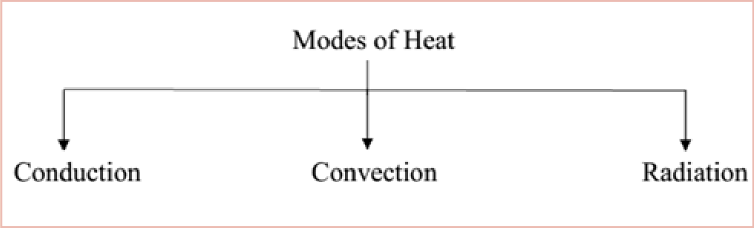
(C/100) = (F-32)/180 = (T-273)/100

Difference between Heat and Temperature

Heat	**Temperature**
✓ Form of energy	✓ It measures degree of hotness
✓ It is a Cause	✓ It is a Effect
✓ Heat flow does not depends on amount of heat energy present	✓ Heat flows from higher temperature to lower temperature by itself
✓ Sum of energies of all molecules	✓ Average Kinetic Energy of the molecules
✓ Measured in Joule	✓ Measured in Kelvin.

Modes of Transfer of Heat

There are 3 types of Modes of transfer of heat



1) **Conduction:** The process of transfer of heat from one point to another point without actual movement of the particles in solid is called Conduction

Ex:

- Copper, aluminum, stainless steel is used to manufacturing cooking utensils, because they are good conductor of heat.
- Wood, plastic, fiber etc.... are used as handles for cooking utensils because they are bad conductor of heat

2) **Convection:** The process of transfer of heat from one point to another point with actual movement of the particles in liquid and gas is called convection.

Ex:

- Ventilators are provided high up walls of rooms and hall to exhaust Co2. At the same time fresh and cold air enters into the room and hall which convection forces takes place.
- While cooking water by vessel, molecules of water moved from bottom to top of vessel due to convection

3) **Radiation:** The process of transfer of heat from one region to another region without affecting intervening medium is called radiation

Ex:

- Steam and hot water pipes are painted black inside the rooms so that the radiate maximum heat into the room. The pipes outside the room are painted white so that they reflect heat with in the pipe and avoid the loss of head into surroundings.
- White cloths are preferred in summer because white color is poor absorber of heat and good reflector of heat.

Heat Insulations:

The process of preventing the flow of heat in any mode is called Heat Insulation & materials used for this purpose is called Heat Insulators.

OR

The substances which do not allow heat to flow through them.

Ex: Sawdust, wools, hairs, wood, plastics etc.

Conductors: The substances which allows heat to flow through them.

Ex: Metals

Specific Heat of Substance (S)

The specific heat of a substance is defined as the amount of heat required to rise temperature of One kg mass of a substance through one-degree Kelvin.

SI unit of [S]: Joule/kg/Kelvin **or** J/kg/k **or** $J.kg^{-1}.\ k^{-1}$

Laws of Thermodynamics

There are two laws:

1st law of Thermodynamic: The amount of heat supplied to the system is partly utilized to measure the internal energy and partly utilized to do external work on the system.

Ex: Diesel and Petrol engine.

2nd law of Thermodynamic: It is impossible for self-acting machine unaided by an external agent to transfer heat from a body at lower temperature to a body at higher temperature.

Ex: Refrigerator.

Solar Energy

Energy received from sun light is called solar energy. The solar energy is used for different purposes in different methods.

Advantages/Uses of solar energy:

1) Solar energy is used in solar cookers & solar Lights.
2) Solar energy is used in solar vegetable dryers & solar water heaters.
3) It is used in solar cells.

Cells are made up of silicon thin layers of 4cm x 2cm x 0. 144mm.Each solar cell can produce 0.5 volt of potential.

To produce sufficient potential many cells are joined. The cells joined together in big panels are placed in sunlight.20000 solar cells can produce 500 watts.

It is a device which converts light energy into electrical energy.

Limitations/Disadvantages

1. Solar energy is used only for generate a small amount of electrical power.
2. It is used for domestic purpose & in automobiles.
3. It cannot be used in large scale industries.
4. Sun light should not have obstructed by clouds.
5. Large amount of useful energy cannot be produced at a time.

Solar energy is non-conventional, renewable, pollution free & eco-friendly energy Because,

- It is freely available in nature.
- It will reduce the cost of fossils like coal, natural gas, petroleum products in power generation.
- It has longer life till sun will be their [billions of years].
- It can be easily released & it is inexhaustible.
- They do not produce carbon compounds [It avoids pollution].

Exercises

I. Fill in The Blanks

a) Heat is a.......................

b) Temperature is an...........

c) SI unit of Heat is.............

d) Wood is an example for................

e) Metal is a good...................

II. Multiple Choice Questions

a) Heat is denoted by

a) T b) Q c) P d) H

b) Temperature is denoted by
   a) q   b) degree   c) hotness   d) T

c) An example for 1st law of Thermodynamics is
   a) Refrigerator   b) TV   c) Petrol engine d) Cooler

IV. Answer the following Questions

a) Explain three modes of Heat Transfer.
b) State laws of thermodynamics.
c) Define Conductors & Insulators.
d) Write the advantages of Solar Energy.
e) Write the Limitations of Solar Energy.

UNIT 6: VECTORS

Introduction

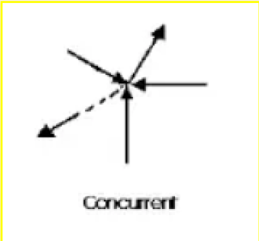
Any physical quantity which is represented by both in magnitude and direction are called vectors.

It is denoted by $\vec{A}$, B or $\vec{V}$

The length of the line indicates Magnitude and arrow head indicates its Direction.

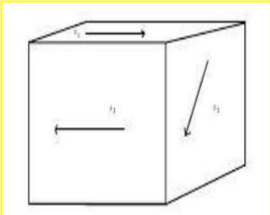
Concurrent Vector (Force)

Forces or vectors which have same initial points are called concurrent vectors.



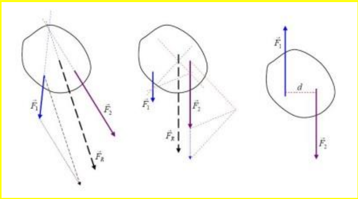
Non Concurrent Vector (Force)

Forces or vectors have different initial points then they are called noncurrent vectors.



Resultant

It is a single effect produced by the body and is equal to the combine effect of number of forces acting on it.



Equilibrium

When two or more forces acting on a body do not produces any effect and resultant of all the forces acting on the body is zero finally the body comes to rest this condition is called equilibrium.

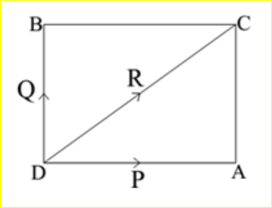
Equilibrant

A force which is equal in magnitude and opposite to the direction of resultant is called equilibrant.

Law of Parallelogram of Forces

Statement:

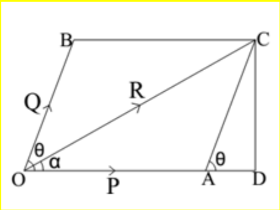
When two forces are acting at a point are represented by both in magnitude and direction by adjacent sides of a parallelogram from that point. Then the resultant is represented by both in magnitude and direction by the diagonal passing through the same point.



Explanation:

Expression for Magnitude of Resultant of Two Forces

Considered two forces P & Q acting at ‘O’ making angle ‘θ’. Let OBCA be the parallelogram. The diagonal OC represented by both in magnitude and direction gives the resultant of 2 forces P &Q. Draw a line CD perpendicular to OA extended.



To find Magnitude (R)

Considered a triangle OCD then,

$OC^2 = OD^2 + CD^2$ ($\therefore$ Pythagoras theorem)

$OC^2 = (OA + AD)^2 + CD^2 (a + b)^2 = a^2 + b^2 + 2ab$

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

From above figure

$R^2 = P^2 + AD^2 + 2(P)(AD) + CD^2$ (1)

From triangle ACD

$\sin\theta = CD/AC$ or $CD = \sin\theta . AC$ {but AC =OB=Q} $CD = Q.\sin\theta$ (2)

& $\cos\theta = AD/AC$ or $AD = AC.\cos\theta$

$AD = Q.\cos\theta$ (3)

Substitute equation (2) & (3) in equation (1)

$R^2 = P^2 + (Q.\cos\theta)^2 + 2P.Q\cos\theta + (Q.\sin\theta)^2$

$R^2 = P^2 + Q^2.\cos^2\theta + 2PQ.\cos\theta + Q^2 \sin^2\theta$ $R^2 = P^2 + Q^2 [\cos^2\theta + \sin^2\theta] + 2PQ.\cos\theta$ $R^2 = P^2 + Q^2 [1] + 2PQ.\cos\theta$

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

This is the expression for magnitude of resultant of two forces.

Direction of Resultant (a)

Let 'α' be the direction of resultant with the force 'P' from triangle OCD, $\tan\alpha = CD/OD$

$\tan\alpha = CD/(OA+AD)$

$\tan\alpha = Q.\sin\theta/(P+Q\cos\theta)$

$\mathbf{\alpha = \tan^{-1} [Q.\sin\theta/(P+Q\cos\theta)]}$

Special Cases

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

a) If P & Q are acting in same direction.

Then $\theta = 0$ $\therefore \cos\theta = \cos(o) =$

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

$R = \sqrt{P^2 + Q^2 + 2PQ}$ from $(a+b)^2 = a^2 + b^2 + 2ab$

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

$R = P+Q$

b) If P & Q are acting in opposite direction

Then θ=180 $\therefore$ cos θ (180) =-1 R = $\sqrt{P^2+Q+2P.Q\,(-1)}$

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

R = $\sqrt{P^2+Q^2-2PQ}$ from $(a-b)^2= a^2+b^2-2ab$ R = $\sqrt{(P-Q)^2}$

R = P-Q

c) If P & Q are perpendicular to each other

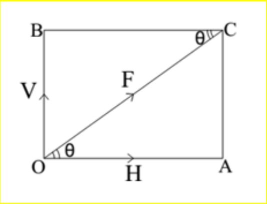
Then θ = 90 $\therefore$ cos θ = cos (90) = 0 R = $\sqrt{P^2+Q^2+2PQ\,(0)}$

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

Resolution of Vectors

The process of dividing into number of components of a given force is called resolution of the force

Expression for rectangular component of a vector



Considered let ‘V’ & ‘H’ be the two forces acting along OB and OA perpendicular to each other from a point ‘O’.

The diagonal OC of rectangular gives the resultant force ‘F’ let ‘θ’ be the angle between the resultant forces which the vertical force ‘V’ as shown in figure.

The resultant force ‘F’ can be revolved into 2 components along x-axis or along y-axis. Resultant component along x –axis can be determined by triangle COA. Cosθ = OA/OC

Cosθ= H/F or H = F.cosθ $\therefore$ this is the expression for horizontal component.

The resultant component along y-axis is given by triangle OCB,

Sinθ = OB/OC Sin θ = V/F

V = F.sinθ $\therefore$ this is the expression for vertical component.

Law of Triangle of Forces:

Statement:

If 3 forces are acting at point equilibrium, then the each of a triangle are represented by both in magnitude and direction when they are taken in order.

Explanation:

Let P, Q & R be the three forces acting at ‘O’ in equilibrium then each force is directly proportional to the magnitude of the same force.

i.e. Pα DE

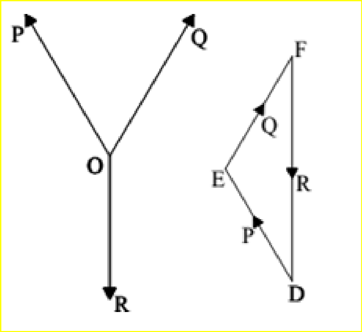
Or P = kDEor

P/DE = k III^{ly},

Qα EF or Q/EF = k Rα FD or R/FD =k

∴ P/DE = Q/EF = R/FD = k

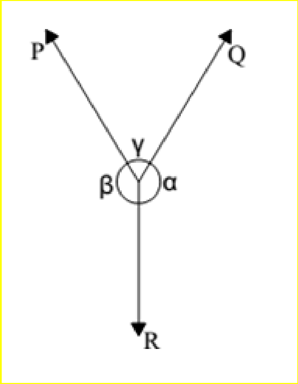
Where ‘k’ is constant this verities law of triangle of force.



Lami’s Theorem

Statement:

When 3 forces are acting at a point in equilibrium then each force is directly proportional to the sine of the angle between other two forces



Explanation

Let P, Q & R be the 3 forces acting a ‘O’ in equilibrium According to Lami’s theorem

P α sinα or P= sinα or P/sinα = k Similarly: Q α sinβ or Q/sinβ= k

R α sinγ or R/sinγ = k

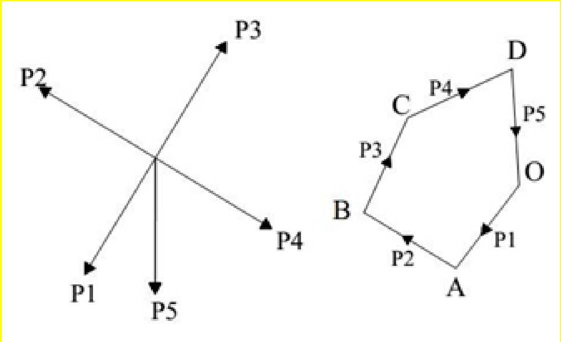
∴ P/sinα = Q /sinβ= R/sinγ = k Where k is constant

This verifies Lami’s theorem.

Law of Polygon of Forces

It states that 'If several concurrent forces acting at a point can be represented both in magnitude and direction by the sides of a polygon taken in order then the forces are in equilibrium.

In this case P_1, P_2, P_3, P_4 and P_5 are forces acting at a point 'O'. They are represented by OA, AB, BC,CD &DO respectively enclosing a pentagon OABCD. The forces are in equilibrium.



Moment of Force:

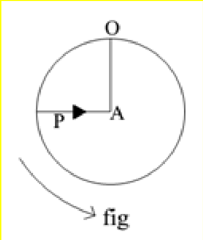
The rotating ability of the force and a point on the body about a fixed point or axis is called moment of force.

Moment of Force = Force x Perpendicular distance. SI Unit: N-m

Positive moment of Force:

If a body rotates in an anti clock wise direction by the force about a fixed point is called Positive moment of force.

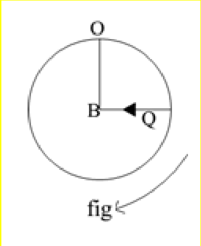
M.F = + (P x OA)



Negative moment of Force:

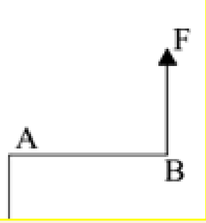
If a body rotates in an clockwise direction by the force about a fixed point is called Negative moment of force.

M.F = - (Q x OB)



Couple: When 2 equal and unlike parallel forces acting at different points on the body about a fixed point rotates the body is called couple.

This rotating effect is known as moment of couple and it is measured by the product of either of the forces and perpendicular distance between 2 forces.

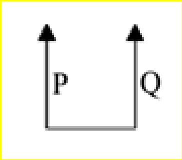


Moment of couple = F x AB Ex: Turning of tap, steering wheel etc.

S.I unit of couple: N-m Dimension: [$L^2 M^1 T^{-2}$]

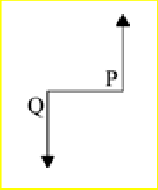
Like and Unlike Parallel Forces

1) **Like parallel forces:**



The number of forces are parallel to each other and acting in the same direction are called like parallel forces

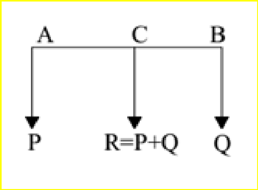
2) **Unlike parallel forces:**



The number of forces is parallel to each other and acting in the opposite direction is called unlike parallel forces.

Resultant of Like Parallel Forces

Let 'P' and 'Q' be two parallel forces acting at 'A' and 'B' as shown in figure.



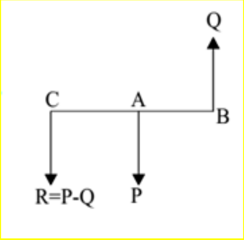
P x AC = Q x BC

The resultant of two such like parallel forces obey following laws.

1) The magnitude of resultant is equal to sum of the two forces.
2) The point of application 'C' of resultant divides AB internally in the inverse ratio of the forces i.e.
3) The resultant force is parallel to either of the two forces
4) The direction of either of the two forces

Resultant unlike Parallel Force

Let 'P' and 'Q' be two unlike parallel forces and 'A' and 'B' as shown in figure.



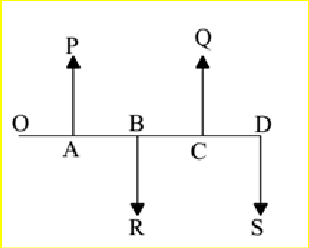
P x AC = Q x BC

It should obey the following laws.

1) The magnitude of the resultant is equal to different between two forces.
2) The point of application 'C' of resultant AB divides externally in the inverse ratio of forces
3) The resultant force is parallel to either of the two forces

The direction of resultant is same as the direction of the greater of the 2 force.

Conditions for equilibrium of co-planer parallel forces



When number of co-planar parallel forces acting on the same plane of a body is called co-planar forces

When not of forces are acting on the body in equilibrium condition. Then there is neither translator motion nor Rotatory motion.

There are two conditions,

a) In equilibrium condition the algebraic sum of forces acting on the plane of a body is equal to 'Zero'

i.e. Sum of upward forces is equal to Sam of downward forces then there is no translator motion.

From fig.

(P+Q) = (R+S)

b) In equilibrium condition the algebraic sum of moment of forces acting on the plane of a body is equal to 'Zero'

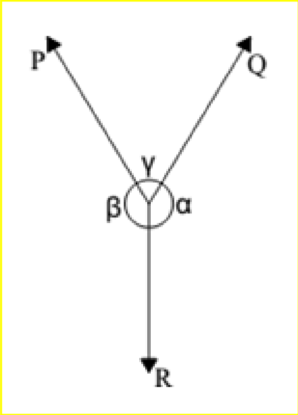
i.e, Sum of the clockwise moment of forces is equal to Sum of the anticlockwise moment of forces, then there is no rotating motion.

From figure. about a point 'O'

(R × OC) + (S × OD) = (P × OA) + (Q × OB)

Problems

1) Three force P, Q & 100 N (R) acting on a body in equilibrium. If the angle opposite to P & Q are 120° & 150° respectively find the value of 'P' & 'Q'.



Given data W.k.t

P =? $\alpha + þ + \gamma = 360°$

Q =? $120° + 150° + \gamma = 360$□

R = 100 N $\gamma = 360$□$- 270° = 90$□

$\alpha = 120°$ According to Lami's Theorem

$\beta = 150°$ $P/\sin\alpha = Q/\sin\beta = R/\sin\gamma$

γ =?

To find P

$P/\sin\alpha = R/\sin\gamma$

$P/\sin 120 = 100/\sin 90$

$P = (100/\sin 90) \sin 120$

$P = 86.60N$

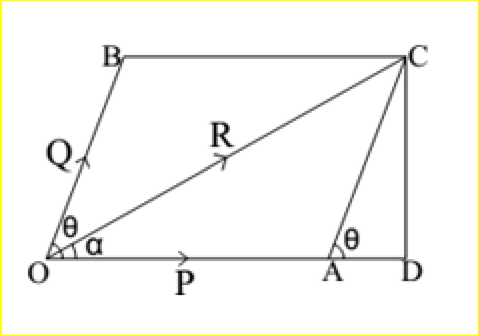
To find Q

$Q/\sin\beta = R/\sin\gamma$

$Q/\sin 150° = 100/\sin 90$

$Q = (100/\sin 90) \times \sin 150°$ $Q = 50N$

2) The forces 7kg weight 15kg & 13kg weight acting on body equilibrium. Find the angle between the first two forces.



Given data we have $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

P = 7Kg

Q = 13kg $R^2 = (\sqrt{p^2 + Q^2\ 2PQ\cos\theta})^2$

R = 15kg $R^2 = P^2 + Q^2 + 2PQ\cos\theta$

$R^2 - P^2 - Q^2 = 2PQ.\cos\theta$ $(R^2 - P^2 - Q^2)/2PQ = \cos\theta$

$\cos\theta = (225 - 49 - 169)/2x7x13$

$\cos\theta = 7/182$

$\cos\theta = 0.038$

$\theta = \cos^{-1}(0.038)$

$\theta = 87.82°$

3) The horizontal & vertical components of a force acting of a point are 7N & 24N respectively. Find the magnitude & direction of the force?

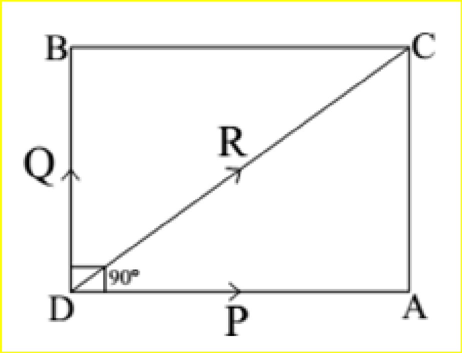
Given data

P = 7N

Q = 24N

R =?

θ = 90° (From diagram)



To find the Magnitude of Resultant

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

$R = \sqrt{7^2 + 24^2 + 2x7x24(0)}$

$R = \sqrt{7^2 + 24^2}$

$R = \sqrt{49+576}$

$R = \sqrt{625}$

R = 25N

To find the Direction

$\alpha = \tan^{-1}$ [(Q-sinθ)/ (P+Q cosθ)]

$\alpha = \tan^{-1}$ [(24-sin90)/ (7+24cosθ)]

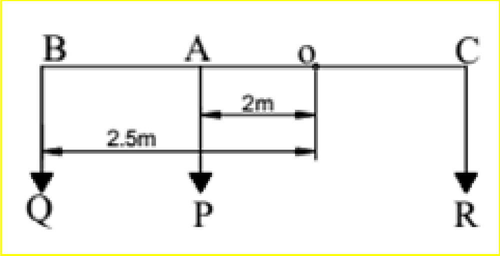
$\alpha = \tan^{-1}$[23/7]

$\alpha = \tan^{-1}$[3.28]

α= 73.04°

4) In a see-saw two children of masses 30 kg & 50 kg are sitting on one side of it at a distance of 2m & 2.5m respectively from the middle.

Where should be a man of 74kg sit to balance it?



Given data from law of moment of force

P = 30kg.wt (P x OA) + (Q x OB) = (R x OC)

Q = 50kg.wt (30 x 2) + (50 x 2.5) = 74 x 0C

OA = 2m 60 + 125 = 74 x OC

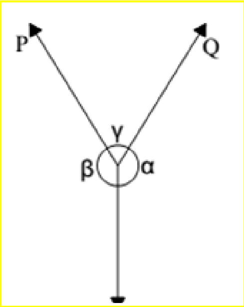
OB = 2.5m

R = 74kg.wt 185 = 74 x OC

OC =? OC = 185/74

OC = 2.5m

5) A steel ball of mass 10kg is suspended by a thin string 'A' attached to the vertical wall. Another string 'B' attached to the balls & it pulls horizontally until the supporting string makes on angle 45° with the vertical. Calculate tensions in strings 'A' & 'B'.



Given Data: m = 10kg

From Lami's theorem

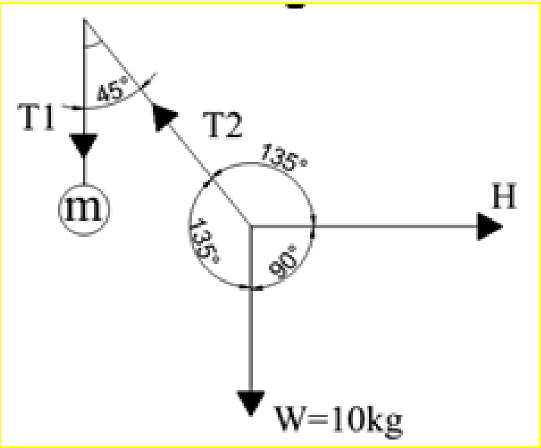
$T_1/\sin\gamma = T_2/\sin\alpha = H/\sin\beta$ (1)

$\alpha + þ + \gamma = 360°$

$90° + 135 + \gamma = 360°$

$\gamma = 360° - 225°$

$\gamma = 135°$



Tension along the string

$T_1 = mg$

$T_1 = 10 \times 9.81$

$T_1 = 98.1N$

From Equation (1)

$T_1 / \sin\gamma = T_2/\sin\alpha 98.1/\sin(135) = T_2/\sin(90)$

T_2 = [98.1x sin (90)\] /sin (135)

T_2 = 138.73N

To find Horizontal Force

T_1 /sin γ = H/sinβ

H =T_1/ {sin (135) x sin (135)}

H = 98.1/sin (135) x sin (135)

H = 98.1N

6) Two forces 3kg weight & 5kg weight at as a point making an angle of 60° with each other. Find the magnitude & direction of the resultant?

Given data | to find magnitude

P = 3kg.wt | R = $P^2 + Q^2 + 2PQ \cos\theta$

Q = 5kg.wt | R = $3^2 + 5^2 + (2x3x5 \cos 60)$

R =?

θ = 60° | R = 9 + 25 + (30x0.5)

R = $\sqrt{9 + 25 + 15}$

R = $\sqrt{49}$

R = 7

Exercises

IV. Fill in The Blanks

a) Forces or vectors which have same initial points are called..................

b) A force which is equal in magnitude and opposite to the direction of resultant is called......................

c) The process of dividing into number of components of a given force is called...........

d) The rotating ability of the force and a point on the body about a fixed point or axis is called.............

e) Any physical quantity which is represented by both in magnitude and direction are called................

V. Multiple Choice Questions

a) SI unit of Couple is

a) N-m b) N c) m d) N-mm^2

b) SI unit of Moment of force is

a) cmb) mm c) kg/mm^2 d) N-m

c) If P & Q are acting in opposite direction, then R=

a) P=Q b) P+Qc) P-Q d) Q-P

VI. Answer the following Questions

a) State the Law of Parallelogram of Forces & Explain

b) Explain rectangular component of a vector

c) State the Law of triangle of Forces & Explain

d) State & Explain Lami's theorem

e) Explain Moment of Force

f) The horizontal & vertical components of a force acting of a point are 10N & 35N respectively. Find the magnitude & direction of the force?

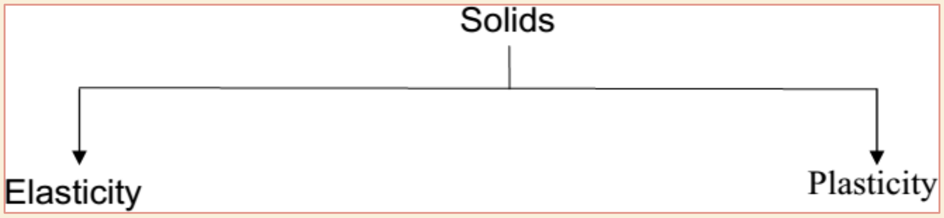
The forces 8kg weight 20kg & 15kg weight acting on body equilibrium. Find the angle between the first two forces.

UNIT 7: PROPERTIES OF SOLIDS AND LIQUIDS

PROPERTIES OF SOLIDS

- ✓ It has definite shape and size
- ✓ Molecules are placed in periodic manner.
- ✓ The melting of solids are very high
- ✓ Density of solid is high

Types of Solids



Elasticity

When force is applied on a body it undergoes deformation it regains its original shape and size after removing force from the body. This kind of property is called Elasticity

Ex: Steel, Iron, Silver, Gold etc.

Plasticity

When force is applied on a body it undergoes deformation it does not regains its original shape and size after removing force from the body. This kind of property is called plasticity.

Ex: Plastic materials.

Stress (a)

It is an internal property of the body it opposes the change in size and shape of the body.

OR

It is defined as the deformation force acting per unit area of a body.

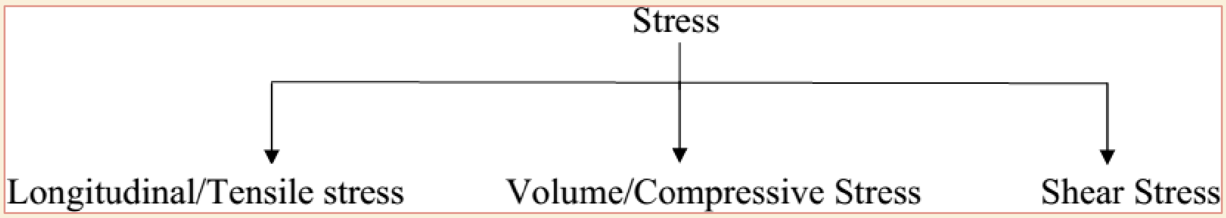
Stress = Force/ Area

$a = F/A$

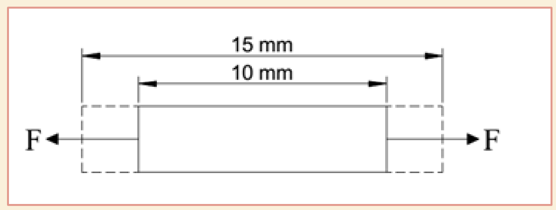
S.I. unit: N/m^2

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

Types of Stress



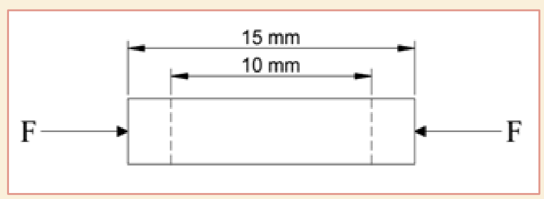
<u>Longitudinal or Tensile Stress:</u>



The stress that changes its length of the body is called longitudinal or tensile stress.

Ex: Bicycle chain, a crane iron rope etc.

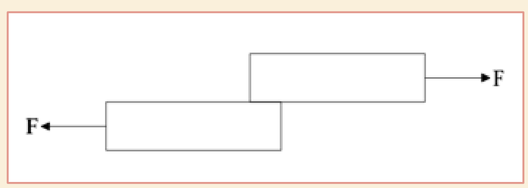
<u>Compressive or Volumetric Stress:</u>



The stress that changes the volume of the body is called compressive stress.

Ex: Springs in Shock absorbers, Legs of chairs etc.

<u>Shear Stress:</u>



The stress that changes shape of the body without changing its volume is called shear stress. It is applied tangentially to the surface of a body.

Ex: Twisting of wet cloths, Scissor cutting a hard sheet etc.

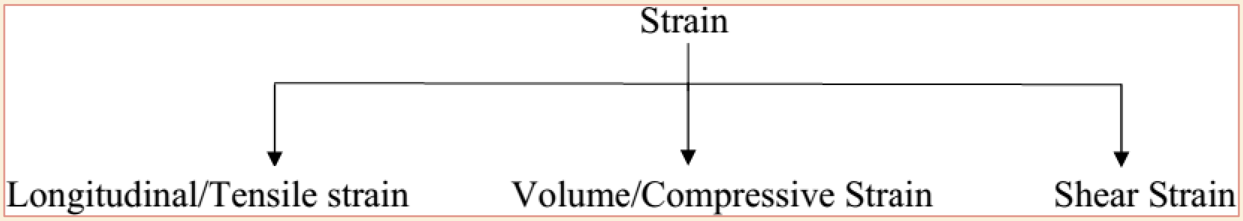
Strain **(ε)**

It is the ratio of change in size to the original size is called strain.

SI Unit = No unit

Dimension = No dimension

Types of strain



Longitudinal or Tensile Strain

It is the ratio of change in length to original length.

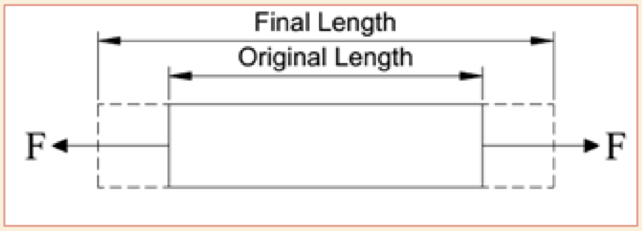
Tensile or longitudinal strain = change in length/original length

Tensile strain = $\Delta L/L_0$

Where,

ΔL = Change in length

L_0 = Original length



Compressive or Volumetric Strain

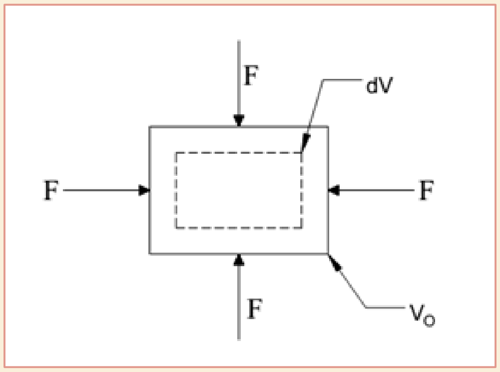
It is the ratio of change in volume to original volume.

Compressive strain = change in volume/ original volume

Compressive strain = $\Delta V/V_0$

Where, ΔV = Change in volume

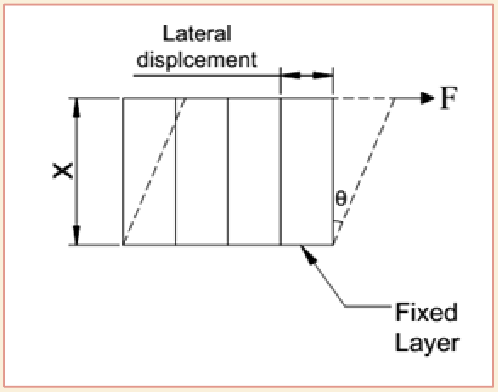
V_0 = Original volume



Shear Strain

It is the ratio of lateral displacement between two layers to the distance between two layers.

$$\text{Shear strain} = \frac{\text{Lateral displacement between two layers}}{\text{Distance between two layers}}$$



From figure let 'θ' be the lateral displacement and 'x' be the distance between top and bottom layers.

Shear strain = θ/x

Let 'L' be the 'θ'

Shear Strain = L/x

Hooke's Law

Statement: The stress is directly proportional to the strain with in elastic limit of the body.

i.e. Stress α strain

$a \propto \varepsilon$

$a = E.\varepsilon$

Stress = E. Strain

Where,

E= constant proportionality or modulus of elasticity or co- efficient or young's modulus.

Then 'E' is defined as ratio of stress to the strain produced within elastic limit and it depends on nature of the material.

$E = a/\varepsilon$ = Stress/strain

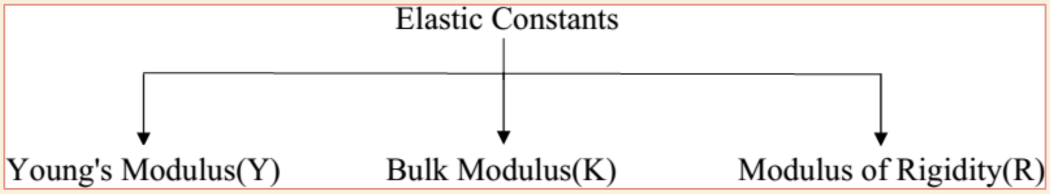
S.I unit: N/m^2

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

Limitations of Hooke's Law

Hooke's law is not valid beyond the elastic limit.

Types of Elastic Constants or Modulus of Elasticity



Young’s Modulus(Y)

It is defined as ratio of longitudinal or tensile stress to the longitudinal or tensile strain within elastic limit.

Young’s Modulus = longitudinal or tensile stress/Longitudinal or tensile strain.

Longitudinal or tensile stress = F/A

Longitudinal or tensile strain = $\Delta L/L_o$

$$Y = (F/A) / (\Delta L/L_o)$$

$$Y = (F/A) \times (L_o/\Delta L)$$

$$Y = (F.L_o)/ (A.\Delta L)$$

S.I unit = N/m^2

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

Bulk Modulus (K)

It is defined as ratio of compressive or volumetric stress to the compressive or volumetric strain within elastic limit.

Bulk modulus (K) = (Compressive or volumetric stress)/ (Compressive or volumetric strain)

Compressive or volumetric stress = F/A

Compressive or volumetric strain = $\Delta V/V_o$

$K = (F/A) /(\Delta V/V_o)$

$K = (F/A) \times (V_o/\Delta V)$ $K = (F.V_o)/ (A.\Delta V)$

S.I unit = N/m^2

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

Modulus of Rigidity (R)

It is defined as ratio of shear stress to the shear strain within elastic limit.

i.e. Modulus of Rigidity (R) = Shear stress / Shear strain

Shear stress = F/A

Shear strain = θ

$R = (F/A)/\ \theta$

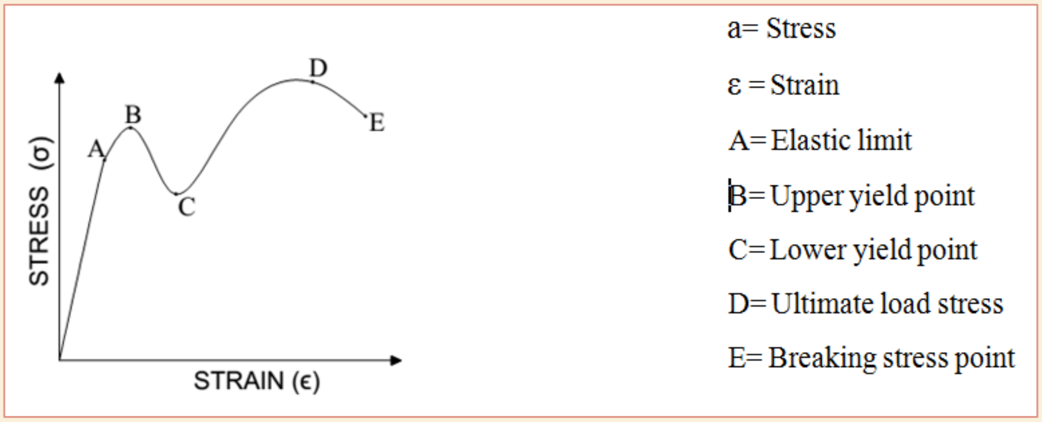
$R = (F/A)/\ (L/x)$ Where $\theta = L/x$

$R = (F.x)/\ (A.L)$

S.I. unit: N/m^2

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

Stress-Strain Graph



- What is the use of Stress-Strain graph?

The stress, strain graph is used to study the nature of elastic material by continuous increase in stress on the body.

- What is Elastic range in Stress-Strain graph?

In stress-strain graph the range ‘OA’ is a straight line and stress is directly proportional to strain.

Hence it obeys ‘Hooke’s law’. The material exhibit elastic property in the range ‘OA’ and is called elastic limit or range.

- What is Yield point in stress- strain graph?

Beyond point ‘A’, the curve slightly bends due to increase in stress and it doesn’t obey the Hooke’s law.

There will be further increase in strain without increasing stress is called ‘Yield point’

B = Upper yield point

C = Lower yield point

- What is plasticity range in stress- strain graph?

Beyond ‘B’ and ‘C’ further increase in stress will cause increase in strain and curve raises till point ‘D’.

Hence material will be deformed permanently.

- What is ultimate stress in stress – strain graph?

Beyond ‘C’ stress will raise till point ‘D’ which material will withstand load & corresponding stress we called it as ultimate stress.

Factor of Safety [FOS]

It is defined as ratio of ultimate stress to the working stress.

Factor of safety = ultimate stress / working stress

SI unit = NIL

Dimension = NIL

Poisson’s Ratio [μ or 1/m]

It is the ratio of lateral strain to the longitudinal [linear] strain Poisson’s ratio, μ or 1/m = (lateral strain) / (longitudinal or linear strain)

SI unit = NIL

Dimension = NIL

Compressibility

When an external force applied on a body normally the body gets compressed due to decrease in space between inter molecules of the body and decrease its volume. This property is called Compressibility.

Compressibility = 1/bulk modulus

Compressibility = 1/ (compressive stress / compressive strain) Compressibility = compressive strain/ compressive stress

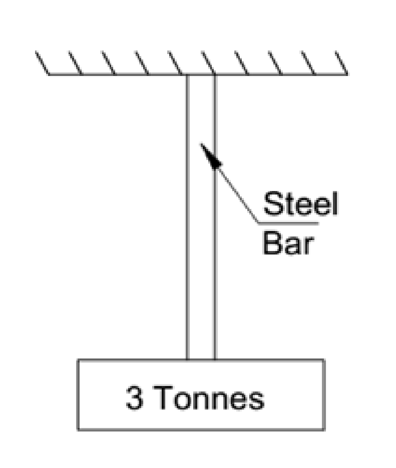
S.I unit = m^2/N

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

Problems

1) A steel bar of length 8m and rectangular cross section 0.66m x 0.03m supports a load of 3 tonnes. What is the change in length of the bar? It is given that Young's modulus?

(Y) For steel is 20×10^{10} N/m^2



Given data,

Length, l = 8m

Area, A = 0.66m X 0.03m = $0.019m^2$

Force, F = 3,000 kg

Young's modulus, Y = 20×10^{10} N/m^2 Change in length ΔL =?

To find force

F = m.g

F= 3000 x 9.81

F = 29430 N

To find ΔL

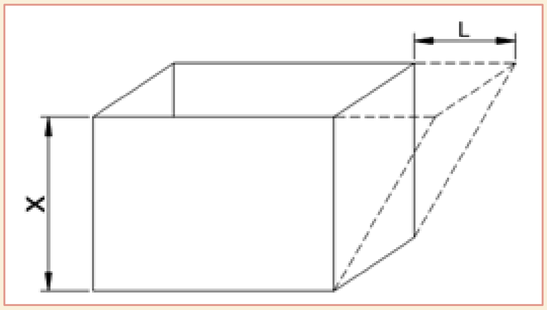
$Y = (F.L_0)/ (A.\Delta L)$

$\Delta L = (F.L_0)/ (A.Y)$

$\Delta L = (29430 \times 8)/ (0.019 \times 20 \times 10^{10})$

$\Delta L = 6.195 \times 10^5 m$

2) A block of rubber 0.5m long 2cm wide and 0.4m height as its lower face fixed and its upper face is subjected to pull of 400N parallel to the face. The upper face found to move 20mm. Relative to lower face. Calculate the modulus of the rubber.



Given data

L_0 = 0.5m

b = 0.02m

h = 0.4m

l = 0.02m F = 400 N

To find rigidity of rubber (shear)

R = Shear stress / shear strain Shear stress = F/A

Shear stress = F/ (L x b)

Shear stress = 400/ (0.02x0.5)

Shear stress = 40000 N/m^2 or 40x10^3 KN/m^2 Shear strain (θ) = l/x

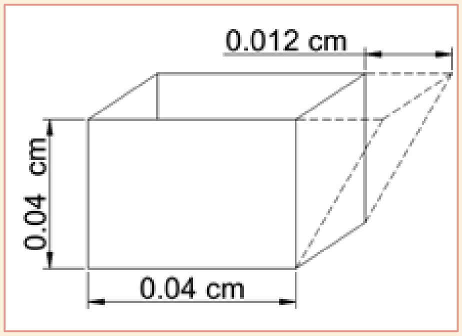
Shear strain = 0.02/0.4 (where x = distance between two layers or faces) Shear strain = 0.05

∴ R = 40000/0.05

R = 800000N/m^2 or 8x10^5 N/m^2

3) An aluminum cube of each side 4 cm is subjected to a tangential force such that top face of the cube is moved by 0.012 cm with respect to the bottom. Find Shear strain, Shear stress, Shear force.

[Rigidity modulus = 2.08x10^{10}N/m^2]



Given data

Cube. **To find shear strain**

L = 0.04m Shear strain = l/x

b = 0.04m Shear strain = (1.2x10^{-4})/ (0.04)

h = 0.04m Shear strain = 0.003

l = 1.2x10^{-4}m **To find shear stress**

R = 2.08x1010N/m2 R = shear stress / shear strain

Shear stress = R x shear strain

Shear stress = (2.08x10^{10}) x (0.003)

Shear stress = 62.4x10^6 N/m^2

To find shear force

Shear stress = F/A

F = shear stress x area

$F = 62.4 \times 10^6 \times 0.04 \times 0.04$

$F = 99.84 \times 10^3 N$

4) A certain steel bar has a maximum stress of 650 N/mm^2 if the area of cross section of bar is $500m^2$.Find the maximum force that the bar can withstand.

Given data

Stress = 650 $N/mm^2 = 650 \times 10^6 \ N/m^2$

Area, A = 500 m^2

To find force

Shear stress = F/ A

F= Shear stress x A

$F = 650 \times 10^6 \times 500$

$F = 650 \times 10^6 \times 500$

$F = 3.25 \times 10^{11}$ N

5) A wire 3m long and 0.625 cm^2 in cross-section is found to stretch 3mm under a tension of 1.2-ton wt. What is the young's modulus of the material of the wire?

Given data

L =3m

A = 0.625 $cm^2 = 6.25 \times 10^{-5} \ m^2$

l = 3mm = 0.003m

m = 1.2 ton = 1.2×10^3 kg

g = 9.81 m/s^2

We know that young's modulus

$Y = (F.L_o)/ (A.\Delta L)$

$Y = (m.g.L_o)/ (A.\Delta L)$ (F = mg)

$Y = (1.2 \times 10^3 \times 9.81 \times 3) / (6.25 \times 10^{-5} \times 0.003)$

$Y = 1.8815 \times 10^{11} \ N/m^2$

6) A stress of 500×10^6 Nm^{-2} produces an extension 0.02m, if the length of wire is 3m, calculate young's modulus.

Given Data

Stress = $500 \times 10^6 N/m^2$

Strain = $L_o / .\Delta L$ = 0.02/3 = 0.0067

Young's modulus, Y = stress/strain

Y= $(500 \times 10^6) / (0.0067) = 7.5 \times 10^{10}$ N/m^2

7) The maximum stress of steel wire is $500 N/m^2$. If the area of cross section of wire is $0.05 m^2$. Calculate force.

W.k.t

Stress = Force/Area

Force = Stress x Area

Force = 500x0.05

Force = 25N

Properties of Liquid

It has No definite shape, but it has shape of the container.

- The atoms or molecules are not fixed to a point and they are moves from one point to another point.
- Density of liquid is low compare to solid. The surface of liquid is always with the same horizontal.

Liquid Thrust

The normal force exerted by the liquid on walls of the container is called liquid thrust.

i.e. Liquid Thrust = Normal Force

S.I unit = Newton [N] Dimension = $[M^1 L^1 T^{-2}]$

Liquid Pressure

The normal force exerted by the liquid per unit area on the walls of the container is called liquid pressure.

i.e. Liquid Pressure = Normal Force/ Area **or** Thrust/ Area

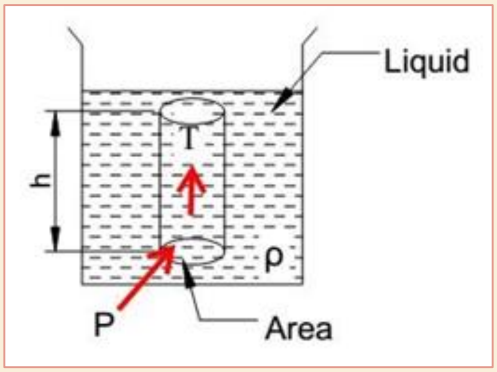
P = F/A or T/A

SI unit: N/m^2

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

Expression for Pressure at any point inside the Liquid at rest

Consider a liquid contain in a beaker. Let 'ρ' (rho) be the density of the water.



Let 'P' be the point at depth (h) from the surface.

Imagine a liquid column at a height 'h' with area of cross section 'A' around 'P' which is at rest as shown in figure.

At 'P' the up thrust 'T' balancing with the weight of the liquid column under balancing condition.

Up thrust of liquid on area 'A' = weight of the liquid column

T = mg {where, m = mass of liquid column}

Density, q = m / v

m = q.v

T = qvg ---------- (1) {v = volume of liquid column}

v = h x A

Substituting 'v' value in equation (1) T = q x (h x A) x g

T/A = q x g x h (2)

By the definition of Liquid Pressure P = T/A

Put 'T/A' value in equation (2)

$P = \rho gh$

This is the expression for pressure at any inside the liquid at rest Note: Density of water, $\rho = 1000$ kg/m^3

Cohesive and Adhesive

Cohesive Force

The force of attraction between same kinds of molecules is called cohesion or cohesive force.

Ex:

- Force between water and water molecules.
- Mercury [Hg] and mercury molecules

Adhesive Force

The force of attraction between different types of molecules is called adhesive force.

Ex:

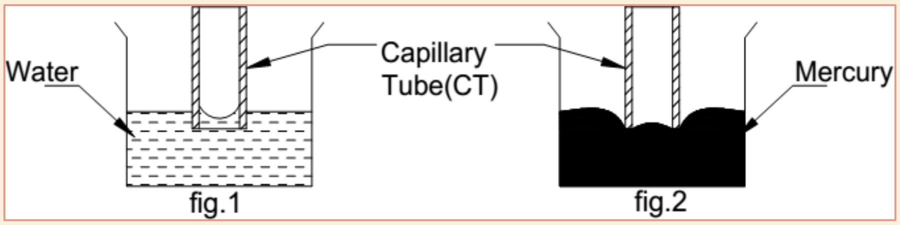
- Force between water and sugar molecules.
- Force between water and glass

Note:

Force of attraction between mercury [Hg] and glass is less.

∴ Hg does not wet the surface of glass.

Capillarity:

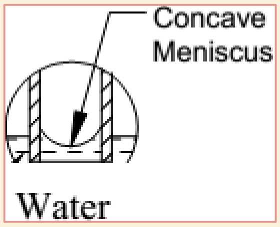


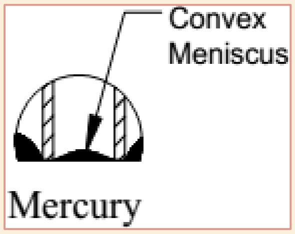
The phenomenon of raising [elevation] or falling [depression] of a liquid in a capillary tube is called as capillarity.

When a capillary tube vertically dipped into the surface of water as shown in figure-1 [capillary rise]. The water rise in a capillary tube because of a strong adhesive force between water and glass.

When a capillary tube is vertically dipped in mercury [Hg] the mercury get depression in capillary tube as shown in figure-2 [capillary fall] . The mercury gets depression in a capillary tube because of a weak adhesive force between mercury and glass.

Nature of Liquid Surface





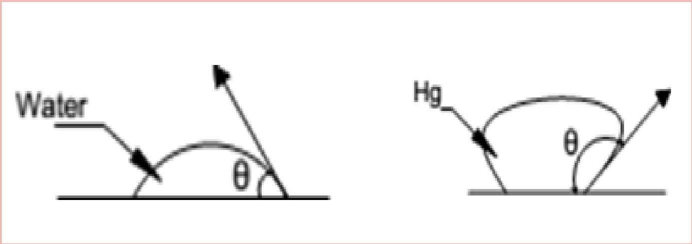
The shape of the surface of liquid in capillary tube is called 'Meniscuses'

The 'meniscuses' is 'concave shape' in the case of water and glass, because of adhesive force is more compared to cohesive force.

The 'meniscuses' is 'convex 'shape' in the case of mercury and glass, because of cohesive force is strong compared to adhesive force.

Angle of Contact

The angle between the tangent drawn from the liquid in contact with the solid and solid surface inside the liquid is called 'Angle of contact'



It is denoted by 'θ'

The angle of contact between glass and water is acute angle [i.e. less than 90]

The angle of contact between glass and mercury is obtuse angle [i.e. greater than 90°]

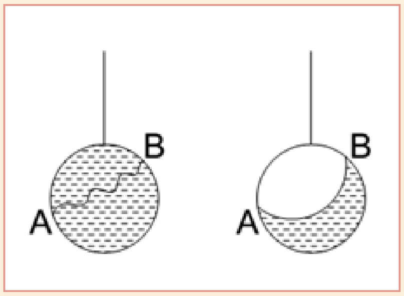
Note:

- The angle of contact between pure water and glass is 'Zero' (0)
- The angle of contact between mercury and glass is 135°

Surface Tension

The surface of liquid is always behaves like a stretched membrane and it is always try to occupy minimum surface area. The property of stretched membrane on the surface on the surface of liquid is called surface tension.

Illustration of surface Tension



A slacked thread tied to the frame of a ring is dipped into soap solution and take out. A thin film formed in the ring the portion one is punctured, then the thread take a form as shown in figure. The portion two tried to occupy minimum surface area became thin film acts like a stretched membrane due to surface tension.

Definition: The force acting per unit length of an imaginary line drawn on the surface of liquid is called surface tension.

i.e, Surface Tension = Force/length.

Surface Tension = F/L

SI unit = N/m

Dimension= $[M^1 L^0 T^{-2}]$

Note:

Surface tension is also defined as amount of work done per unit area of a substance.

i.e. Surface Tension = Work/Area.

Surface tension = W/A

SI Unit = N/m

Dimension = $[M^1 L^0 T^{-2}]$

Expression for surface of water by capillary rise

Surface Tension of water is given by the relation

Surface Tension = $\frac{\rho g h r}{2€os\theta}$

Where,

ρ = Density of water = 1000 kg/m^3
g = Acceleration due to gravity = $9.81 m/s^2$
h = Capillary rise
r = Internal radius of capillary Tube.
θ= Angle of contact

Factors affecting Surface Tension

Surface Tension of liquid depends on,

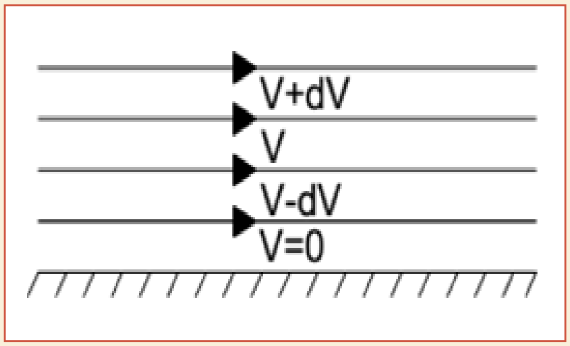
1. Density of the medium
2. Impurities: when impurities are added to the surface of liquid then surface tension is increases.
3. Temperature: As the temperature increases surface tension of liquid is decreases.

Application of Surface Tension

1. The oil rises through wicks of kerosene stove or lamp due to surface tension.
2. In green plants the water transported to leaves through the stem because of surface tension.
3. Burning camphor moves in irregular manner on the surface of water, because the burring camphor experiences imbalanced force due to increased in temperature be decrease in surface tension.

Viscosity (Rate of flow of liquid)

When liquid in stream line flow the velocity is different at different layer but are flow with constant velocity. The maximum velocity is at top and minimum or zero at the bottom of liquid layers.



A force exists between two layers of the liquid when they are in relative motion. The property of force between the layers of liquid is called 'Viscosity'.

Viscous Force

When liquid in stream line flow a force exists between any layer of liquid and upper layer try to accelerate lower layer velocity and lower layer retards upper layer velocity.

This force is always opposite to the direction of flow and is called Viscous Force.

Co-efficient of viscosity

When liquid in stream line flow the viscous force 'F' is,

1. Directly proportional to the change in velocity.
   i.e, $F \alpha\ dv$
2. Directly proportional to the area of cross section of two layers. i.e. $F \alpha\ dv$

3. Inversely proportional to the distance between two layers i.e. $F \alpha\ (1/dx)$

$\therefore F \alpha\ A\ (dv/dx)$

$F = \mu . A\ (dv/dx)$

Where,

'μ' (Constant Proportionality) is called Co-efficient of Viscosity.

SI unit: NS/m^2 Dimension: $[M^1\ L^{-1}T^{-1}]$

Note:

Velocity Gradient: It is the ratio of change in velocity to the distance (thickness) between two layers.

i.e, Velocity Gradient = dv/dx

SI unit: S^{-1}

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

Factors affect viscosity:

1. Density of liquid: If density of liquid increases viscosity is also increases.
2. Temperature: As the temperature of liquid increases the viscosity is decreases.

NOTE:

For Gas: As the temperature increases viscosity of gas also increases.

Applications of viscosity

- Ships and aero planes are designed with aerobic shapes because it reduces the viscosity of water and air.
- Highly viscous lubricants are used in machinery parts to reduce the Friction.
- Circulation of blood through arteries & veins due to property of Viscosity.

Exercises

I. Fill In The Blanks

a) SI unit of stress is..................

b) Ratio of lateral to linear strain is......................

c) SI unit of Surface Tension is...........

d) Shape of the liquid surface is called.............

e) Oil rises through wicks due to.................

II. Multiple Choice Questions

d) SI unit of strain is

a) mm^3 b) N/m^2 c) mm^2 d) No dimension

e) Angle of contact of Pure water is a) 45□ b) 135□ c) 0 d) 90□

f) Meniscus of water surface is

a) Concave shape b) convex shape c) shapeless d) None of these

III. Answer the following Questions

a) Define stress? Explain its Types.

b) Define strain? Explain its Types.

a) Explain stress-strain Graph

b) Define FOS, Poisson's Ratio & Compressibility

c) Define adhesive force, cohesive Force, angle of contact, viscosity & Capillarity.

d) Obtain an expression for the pressure at a point inside a liquid at rest

e) A wire 5m long and 0.625 cm^2 in cross-section is found to stretch 2mm under a tension of 1.5-ton wt. What is the young's modulus of the material of the wire?

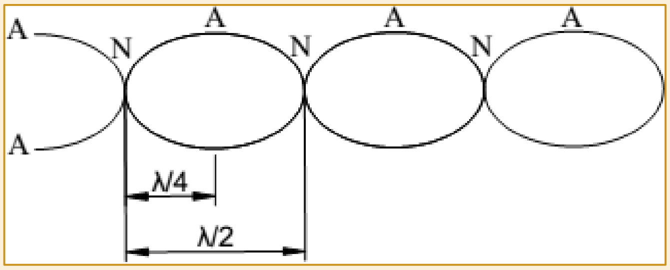
A steel bar of length 6m and rectangular cross section 0.66m x 0.03m supports a load of 2 tonnes. What is the change in length of the bar? It is given that Young's modulus (Y) for steel is 19×10^{10} N/m^2

UNIT 8: WAVE MOTION

Stationary Waves

The stationary waves are formed due to superpose of two progressive waves of equal amplitude (height) and equal frequency travels along a straight line with same velocity but in opposite direction.

These waves are non-progressive waves because there is no transfer of energy from one point to another point.



Characteristics of Stationary Waves

- The stationary waves are formed with number of vibrating segments (Loops)
- The particle in one segment vibrates with same phase, while particles segment vibrates in opposite phase.
- Certain particles in the medium are permanently at rest and are called Nodes (N)
- Certain particles are vibrating with maximum amplitude and are called Antinodes (A)
- The distance between two successive nodes or Antinodes equal to $\lambda/2$
- The distance between a Node and immediate Antinodes is equal to $\lambda/4$
- There is no transfer of energy from one point to another point.

Free Vibration

When a body is displaced from its mean position and left free, it starts vibrating with its own frequency for certain time and is called 'Free Vibration'.

Ex: Vibrating tuning fork, oscillating simple pendulum.

Forced vibration

When a body is said into vibration by an external periodic force, then the body is vibrating with the external force with natural frequency and vibrates as long as external force acting on it. This kind of vibration is called Forced vibration.

Ex: vibrating stringed musical instrument, vibration in resonance air column.

Resonance

If the frequency of the external periodic force applied is equal to the natural frequency of the vibrating body, then the body vibrates with maximum amplitude to produce maximum sound. This condition is called resonance.

Ex:

- Vibrating string in Sonometer
- Vibrating particles in resonance air column
- In T.V receiver signals are tuned by resonance method.
- The vibrating body in moving bus and in Dakota Express makes maximum sound due to resonance.

Beats

The superposition of two slightly difference frequencies (<10Hz) of same nature progressive waves give rise to resultant of waxing (maxima) and waning (minima) is called Beats.

Beat Frequency (f_b)

The number of waxing or waning sound heard per second during beat phenomenon is called Beat Frequency.

Unit: beat per second (b/s).

It is measured by the difference of frequencies of two vibrating bodies.

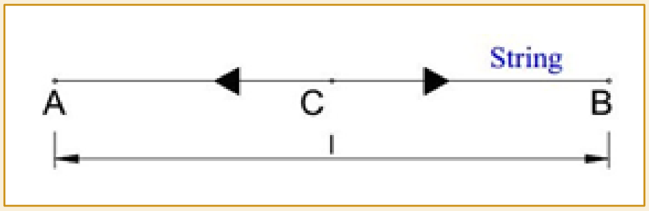
Let F_A and F_B be the frequency of tuning fork A and B respectively then beat frequency is $f_A \sim f_B$

$f_b = f_A \sim f_B$

Uses or Applications of Beats

- It is used to determine unknown frequency of a given tuning fork.
- It is used to tune musical stringed instruments.
- It is used to detect presence of harmful gases in mines.

Transverse vibration of stretched string



Velocity of wave in stretched string Formula

$V=\sqrt{(T/m)}$ (1)

Where,

T =Tension along the string

m = mass per unit length of string in kg/m

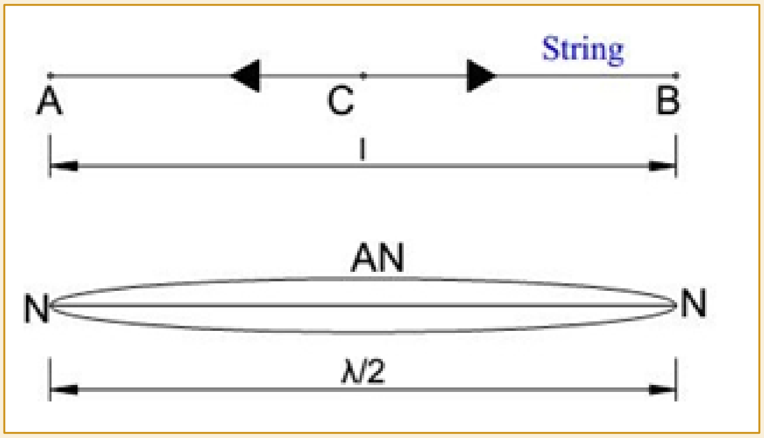
But, m = M/L = mass of the string/Length of the string.

Considered a wire of length 'l' stretched between two fixed point A & B when the string is plucked, transverse waves are travelled along the string and reflected at the fixed end the direct wave superpose with reflected wave and produces transverse stationary waves.

Fundamental Frequency

The body vibrating with lowest possible frequency is called Fundamental Frequency.

In fundamental node of vibration, the string vibrates with single loop. It can form two nodes at fixed ends and antinodes in between.



The frequency is given by

$f = V/\lambda$ [From $v = f.\lambda$]

$f = (1/\lambda).V$ (2)

Equation (1) $V = \sqrt{T/m}$

Put the value of 'V' in equation (2)

$f = (1/\lambda)\times\sqrt{T/m}$

In figure resonating length

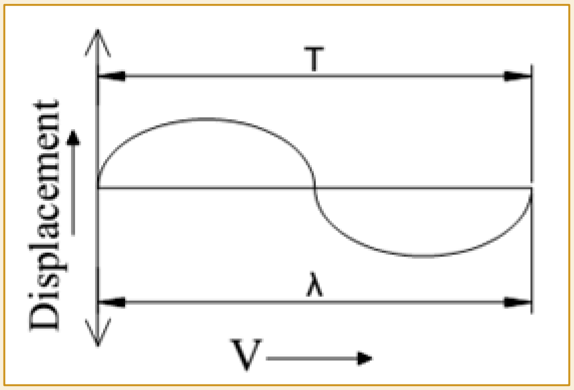
$l = \lambda/2$

$\lambda = 2l$

$\therefore$ **$f = (1/2l)\times\sqrt{T/m}$**

Relation V, f & λ

$V = f.\lambda$



Where,

V= Wave Velocity

f= Frequency= 1/T

λ= Wave Length

T= Time period = 1/f

<u>Laws of stretched strain</u>

We have fundamental frequency

$f = 1/2l \times \sqrt{T/m}$

Where,

L = Resonating length

m = Mass/ unit length

T = Tension along the string.

1st law

Law of Length: The fundamental frequency of a stretched string is inversely proportional to the resonating length, Provides 'Tension' and 'Mass per unit length' are constant.

i.e. f a 1/l

With 'T' and 'm' are constant

2nd law

Law of Tension: The fundamental frequency of a stretched string is directly proportional to the square root of a tension along the string, provides 'Resonating length 'and 'Mass per unit length' are constant.

i.e. f a √T

With 'l' and 'm' are constant.

3rd law

Law of Mass: The fundamental frequency of a stretched string is inversely proportional to the square root of mass per unit length of string provides. 'Resonating length' and 'Tension' are constant.

i.e. f a 1/√m

With 'T 'and 'L' are constant

PROBLEMS

1) At what temperature of hill the velocity of sound in air 'V' doubled of that at 0°c

Given data W.k.t

Velocity of sound in 0°C, T_1 = 273K (V /V) = (T / T)

V1= V0 1 2 1 2

V2 = 2 V0 $V_0/2v_0 = \sqrt{273/T_2}$

T2=? $1/2 = \sqrt{(273/T_2)}$

Squaring on both side,

$(1/2)^2 = [f\ (273/T_2)]^2$

$1/4 = (273/T_2)$

$T_2 = 273 \times 4$

$T_2 = 1092$ K

$T_2 = 1092 - 273$

$T_2 = 819°C$

2) Calculate the time period of vibrating body when the frequency of tuning fork is 500Hz

Given data to find frequency

Frequency of tuning fork, f=500 Hz $f = 1/T$

Time period, T =? $T = 1/f$

$T = 1/500$

$T = 2 \times 10^{-3}$ or 0.002 seconds

3) A wire of length 150cm and mass 0.72g. Is stretched by a load of 20kg. Find the fundamental frequency of a load.

Given data to find mass per unit length

Frequency, f =? $m = M/ L$

Load, T = 20Kg $m = 0.00072/105$

Wire mass, M=0.72g= 0.00072 kgm = 0.00048 kg/m Wire length, L = 1.5 m

To find Tension of wire $T = w \times g$

$T = 20 \times 9.81$ $T = 196.2$ N

Frequency Formula,

$f = 1/2l \times \sqrt{T/n}$ {Where, l = 1.5 m} $f = 1/2l \times \sqrt{196.2/0.00048}$

$f = 1/ (2 \times 1.5) \times (14.007/0.02190)$

$f = 1/3 \times 639.336$

$f = 0.33 \times 639.336$

$f = 212.99$ Hz

4) A Sono meter wire of 0.5m long vibrates in two segments and is stretched by a force of 5kg weight. Calculate the frequency of node emitted ($g= 9.81\ m/s^2$) and density of wire is 0.018 kg/m.

Given data to find Tension,

f =? $T = w \times g$

T =? $T= 5 \times 9.81$

M=5 kg $T = 49.05$ N

$L = 0.5$ m

$g = 9.81$ m/s2

To find frequency

$f = 2/2l \times \sqrt{T/n}$ {where Two Segments} $f = 2/(2 \times 0.5) \times \sqrt{49.05/0.018}$

$f = 2/1 \times (7.00/0.1341)$

$f = 2/1 \times 52.19$

$f = 104.38$Hz

Exercises

I. Fill In The Blanks

a) The distance between two successive nodes or Antinodes equal to.................

b) The body vibrating with lowest possible frequency is called.....................

c) SI unit of beat Frequency is...........

d) SI unit of beat Frequency is.............

e) The distance between a Node and immediate Antinode is equal to................

II. Multiple Choice Questions

a) Frequency is equal to

a) 1/T b) T c) V.T d) V/T

b) Hz is indicate as

a) Cycles b) second c) cycles per second d) minutes

c) In T.V receiver signals are tuned by

a) Sonometer b) Air column c) resonance method d) None of these

III. Answer the following Questions

a) Explain the transverse vibrations of stretched string? With their 3 Laws.

b) Define free vibration & forced vibration.

c) Define resonance, beat & beat frequency

d) Derive $f = (1/2l) \times \sqrt{T/m}$

e) A wire of length 200cm and mass 0.95g. Is stretched by a load of 24kg.

Find the fundamental frequency of a load.

UNIT 9: ENGINEERING CHEMISTRY

Air Pollution

Air pollution is defined as the presence of any form of contaminant in the outdoor atmosphere which is harmful to the public health, safety which a reasonably interference with the comfortable enjoyment of life.

Major air pollutants are:

- **Motor vehicles** which produces Hydrocarbon & Nitrogen dioxide
- **Industries** like chemical plants, fertilizers, paper industries & petroleum refineries.
- **Power plants** burns coal & oil which produces Sulphur dioxide.
- **Radioactive** gases & dusts (pollutants)
- **Agriculture** activities like chemicals spraying.

Effects of Air Pollution

Following are the important harmful effects of an air pollution

1. **Damage to Materials:** It affects metals, building materials, paper, and textiles. The damages include corrosions, abrasion etc.

2. **Damage to Vegetation:** An Air pollutant such as Sulphur dioxide, smog exerts toxic effects on vegetation. It looks like marking, silvering below the leaf and also affects the growth of the plants.

3. **Damage to Farm Animals:** Farm animals are affected by fluorides which make breathing troubles, paralysis and also affect teeth and bones.

4. **Darkening of Sky:** Due to heavy smoke, fog and dust cause darkening of the sky.

Effects on Human Health: It affects human health like blood poisoning, head ache, pain in the eye, sleeplessness and breathing problems.

Acid Rain and its Effects

When rain falls through atmosphere pollutants like Sulphur and nitrogen produce a mixture of sulphuric acid, nitric acid and water is known as Acid Rain.

It will cause following damages

1. Damage to building and structure materials
2. It effects on soils which reduces plants and forest development.
3. It attacks the nutrients from leaves, which effects on growth of plants.
4. It effects on productivity of fishes
5. It effects on reservoirs of drinking water.

Greenhouse and its Effects:

The lower atmosphere around the earth acts like glass in a green house. It means it allows solar radiations to reach the earth but do not allow earth to re-radiate the heat into the space. The gases are transparent to sun light while coming and absorbs radiations which earth sends back has heat. A part of heat reemitted to the earth it will cause heating of earth surface. This phenomenon is called Greenhouse effect.

The main gases responsible for green house effects are Carbon dioxide (co_2), water vapor, chlorofluorocarbon (CFC).

Global Warming: The concentration of greenhouse gases has been continuously increasing because of deforestations, industrialization, increasing burning of fuels and exhaust of automobiles. This traps the heat by the atmosphere which cause rise in temperature of the earth's atmosphere. It is known as Global warming.

Effects of Global warming or Green house.

1. It will cause increase in evaporation of water affecting cloud formation
2. It affects food production all over in the world.
3. It causes heavy floods due to melting of ice caps.
4. It causes rise in sea level from 20cm to 1.5m.

<u>Ozone Layer</u>

Ozone is an important chemical molecular present in stratosphere. It is an height of 30km. It protects the earth from strong ultra violet radiations from the Sun. Due to presence of this layer a very small amount of ultra violet radiation reaches the earth surface.

Due to air pollution ozone in the stratosphere is destroyed. The chlorofluorocarbon (CFC) which are used in refrigerators, air conditioners which produces holes in ozone layer.

The hole in the ozone layer allows strong **Ultraviolet (u.v)** radiations to reach earth surface which cause sun burns and skin cancer

Air Pollution Control

- Preservation of green areas in cities & prevention of deforestation are the major factor in controlling air pollution. This greenery can filter out dust, soot & fly ash from atmosphere. By developing of number of trees will absorbs carbon monoxide which is very harmful to human health.

Industries it should be built chimneys as per the air pollution control board.

If cities, industries & power plants are properly planned then only air pollution is controlled.

- We can control air pollution by controlling vehicles smoke by using filters.
- We can use bio gases in houses to control air pollution.
- We can use solar power to control air pollution.

Water Pollution

Due to the rise in populations & large industrialization water is being constantly polluted.

Cause of water pollution

Major water pollutants are wastes from household, industries & agricultural lands.

- **House hold wastes:** Human excrete, urine, kitchen & laundry waste ect.

- **Industries wastes:** Organic & in organic chemical substance, poisons like lead mercury etc.

- Chemical fertilizers, pesticides etc.

<u>Effect of water pollution:</u>

1. It effects on aquatic animals (oxygen decreased in water)
2. Water hardness increases. (Due to industrial water)
3. Pollution due to household waste may cause typhoid & cholera
4. It also affects photosynthesis in aquatic plants.

Preventive measures [control of water pollution]:

- Keeping ponds clean & unpolluted
- Make use of underground drainage facilities
- New methods for industrial production are undertaken which can discharge harmful wastes.
- Highly polluted water can be use in the production of the biogas
- Adopting of hydrogenation process instead of using sulphuric acid on oil refineries
- Adopt suitable disposal method for waste water or by using safety tanks

Corrosion

Corrosion is defined as gradual destruction of metal when it brought into contact with environment.

Metals like iron & copper undergoes gradual oxidation (oxygen reactions)
Ex:

- Rusting of iron
- Copper covered with green coating
- Surface of grass becoming dull

Electro chemical Theory of Corrosion & its Types:

The corrosion in metals occurs due to electrochemical process. In this case galvanic cells are set up between dissimilar parts of some metal. A galvanic cell is one in which chemical energy is used to produce electric energy. In the case of corrosion two electrodes required are provided by different parts of metals.

According to them the classification has made:

1. **Composition cell:** This cell is usually set up between two dissimilar metals in contact

Ex: Suppose magnesium & platinum are a contact magnesium acts as a cathode. The platinum acts as anode which undergoes corrosion.

2. **Stress cell:** This type of galvanic cell is established between stressed & unstressed areas of the metal.

Ex: In case of nail the head & tip is being stressed which acts as a anode & middle portion is act as a cathode.

3. **Concentration cell:** This cell is established between the clean surfaces & surface of contamination.

Ex: The surface with dirt or contamination has less oxygen supply & behaves like anode.
Whereas, the clean surface acts as a cathode.

Methods of prevention of corrosion

The various protective measures are:

Alloying

By mixing two metals at a suitable ratio, the resistance for the corrosion is increased. Common example is stainless steel [alloy of steel]

Protection by paints

The paints applied to metal surface from thin impermeable layer. This layer prevents oxygen & water coming in contact with the surface. Thus the corrosion is reduced.

cathode or Galvanic protection

In this the metal to be protected from corrosion is made cathode by connecting with it another metal which is higher in electrochemical series of metals. Thus connected anode metal is corroded in preference to the given metal.

To protect iron pipes from corrosion the magnesium metal is connected with it. Thus magnesium is called as sacrificial anode which undergoes corrosion instead of iron pipes.

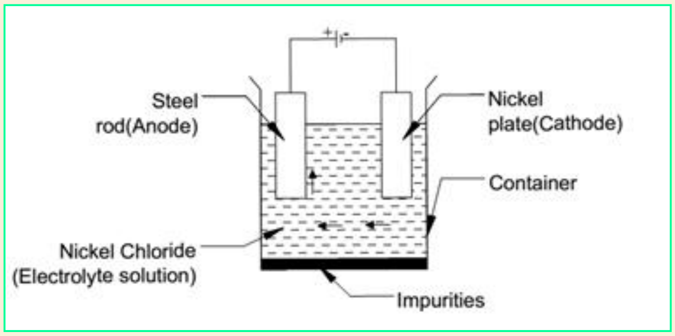
Electroplating

In electroplating work piece [cathode] is plated with a different metal when both are suspended in an electrolyte solution.

Electroplating consist the following process

- The metal ions from the anodes are discharged using electricity
- The metal irons combine with the ions in the solution
- They are deposited on the cathode.

Ex: As shown in the fig steel rod is made as cathode & nickel (pure) as anode both are suspended in a suitable electrolyte like nickel chloride. When passing the current nickel gets deposited in steel rod & impurities are dissolved in solution.



Galvanizing

Galvanizing is the process of coating iron or steel with a thin layer of zinc to prevent them from rusting. It is an anodic coating in which coated metal is anodic to the base metal. When it is exposed to the environment zinc get corroded whereas base metal [Iron or steel] remains protected from corrosion.

Anodizing

Normally aluminum surface is anodized to prevent it from corrosion. In this a coating of aluminum oxide is formed using dilute sulphuric acid, making aluminum surface as anode & passing current.

Thin coating of oxide is formed on it which is achieved by passing steam over it & passing current simultaneously it makes the aluminum has more corrosive resistance.

Exercises

I. Fill in The Blanks

a) Ozone layer is in the height of.................

b) ………is defined as gradual destruction of metal when it brought into contact with environment

c) ………is the process of coating iron or steel with a thin layer of zinc

d) ………will cause rise in sea level from 20cm to 1.5m.

e) Mixture of sulphuric acid, nitric acid and water is known as................

II. Answer the following Questions

a) Explain Air pollution & its effects.

b) Explain Acid rain & its effects.

c) Explain Green house & its effects.

d) Write the methods to prevent corrosion.

e) Explain water pollution & its effects.

f) Explain Electroplating with an example.

UNIT 10: pH VALUE

Acids

The substances which contain $[H^+]$ positive ions in their solution. It is also called Protons.

Properties of Acids

- They are sour to taste
- They turn blue litmus to red
- They donate protons
- They are corrosive in their action
- They react with bases producing salt and water.

Ex: Hcl, H_2SO_4 etc.

Base

The substance which produces hydroxyl $[OH^-]$ when dissolved in water. It also accepts H^+ ions.

Properties of Base

- They are soapy to touch
- They turn red litmus to blue
- They are bitter to taste
- They react with acids to give salt & water.
- When dissolved in water they produce $[OH^-]$ ions.

Ex: Naoh, KoH etc.

Neutralization

A reaction between acid and base produce salt and water is called Neutralization.

Ex: The Sodium Hydroxide reacts with Hydrochloric acid to give Sodium Chloride & water.

$$Naoh + Hcl \quad Nacl + H_2O$$

Ionic Product of Pure Water

- The number of Hydrogen Ions per liter is equal to number of hydroxyl ions per liter.
- It is found to be equal to 10^{-7} gm ions/liter.
- Number of $[H^+]$ ions = 10^{-7} gm ions/at 25˚C
- Number of $[OH^-]$ ions = 10^{7} gm ions/at 25˚C
- $[H^+] \times [OH^-] = 10^{-14}$ gm ions / liter

This product is known as Ionic Product of Pure Water.

Neutral Solution:

If in a solution concentration of H^+ ions and OH^- ions are equal, then it is called Neutral Solution.

For Neutral solution P^H value is always equal to '7'.

Acidic Solution:

If the concentration of H^+ ions is more than 10^{-7}gm/litre such solution is called Acidic Solution.

For Acidic Solution pH value is always less than '7'.

Basic Solution:

If the concentration of H^+ ions is less than 10^{-7}gm/litre such solution is called Basic Solution. For Basic Solution pH value is always more than '7'.

pH of a Solution:

It is defined as negative logarithm to base 10 of Hydrogen ion concentration.

Expressed in gm/Litre

$pH = -\log_{10} [H^+]$ or $pH = \log_{10}[H^+]^{-1}$ or $pH = \log_{10}[1/H^+]$

Ex: For water,

$H^+ = 10^{-7}$gm ions / litre p

$H = \log [1/10^{-7}]$

$pH=7$

The pH Value for Different Fluids.

Fluids	**PH**	**Nature**
Gastric Juice	1.6	Acidic
Lemon Juice	2.4	Acidic
Grape Juice	3.2	Acidic
Tomato Juice	4.3	Acidic
Urine	6.0	Acidic
Cow's Milk	6.4	Acidic
Saliva	5.5 to 7.0	Acidic
Water	7.0	Neutral
Blood Plasma	7.4	Basic
Sea Water	8.5	Basic
Ammonium Hydroxide (0.1N)	11.1	Basic

Applications of pH Value

The pH plays important role in every field.

Ex: In Agriculture, Medicine, Leather Industries, Chemical Industries & also in our day today life.

- **In Agricultural Field**
  - In the choice of fertilizers for the soils the proper value of pH is noted whether it is basic or acidic nature and the values tested initially.

- **In Sugar Industries**
  - During the extraction of Sugar cane, it is always to be maintain pH =7 or Neutral.

  Otherwise it will decompose and giving unwanted products.

- **In Chemical Industries**
  - During the chemical reaction processes the buffer solution is added to maintain the pH level of the given product.

  Buffer solution is which do not change their P^H value for long extent.

- **In Leather Industries**

  The proper pH value reduces the bad odour smell during tanning.

- **In Healthy Body**

For Healthy Body the pH of urine is 5-7 and the pH of blood is 7.4

The milk has pH value 6-7.

This pH value prevents the milk from becoming sour & keeps the freshness.

Exercises

I. Fill In The Blanks

a) Acids are to taste

b) Base is to taste

c) A reaction between acid and base produce salt and water is called...........

d) If the concentration of H^+ ions is more than 10^{-7}gm/litre such solution is called.............

e) Is a negative logarithm to base 10 of Hydrogen ion concentration?

II. Multiple Choice Questions

a) pH value of Water is equal to

a) 7 b) >7 c) < 7 d) 0

a) pH value of sea water is equal to

a) 7 b) 8.4 c) 8.5 d) 8

b) For Acidic Solution P^H value is always less than

a) 6 b) 8 c) 7 d) 7.5

III. Answer the following Questions

a) Define Acid

b) Define Base

c) Write the pH values of fluids.

d) Define pH of a solution. Neutral, Basic, Acidic solution & ionic product of Pure Water

e) Write the application of pH value.

Explain types of zero error in screw Gauge.

Book References:

1. Applied Science Text Book by **Mr. Prakash Yeri**