WORK, POWER AND ENERGY

5.1 Define the terms 1.Work, 2. Power and Energy

5.2 State SI units and dimensional formulae for 1.Work, 2. Power, and Energy

WORK: The work is said to be done on a body when a force displaces a body.

Work = Force x Displacement ⇒ **W = F x S**

In vector form $\boldsymbol{W} = \vec{\boldsymbol{F}} . \vec{\boldsymbol{S}}$

Where **F** is the force, **S** is the displacement, and the angle (**θ**) is the angle between the force and the displacement vector.

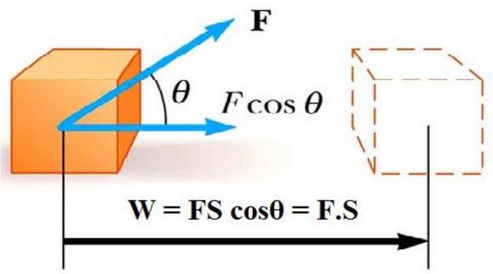
Work is a scalar quantity.

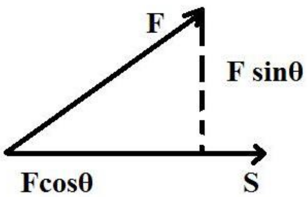
Unit: joule in SI System and erg in C.G.S.

$1\ J = 10^7$ ergs.

Dimensional formula: ML^2T^{-2}

Joule: Joule is the amount of work done when a force of 1 N moves a body through a distance of one meter.





- **Positive Work:** When $0^o < \theta < 90^o$, work done is positive because Cos θ is positive.
  Ex: The work done by the gravitational force on the body is positive.
- **Negative Work:** When $90^o < \theta < 180^o$, work done is negative because Cos θ is negative.
  Ex: The work done by the gravitational force on the body is negative.
- **Zero Work:**
  a) Work is zero if cosθ is zero or $\theta = \pi/2$.
  Ex: As the porter carries the load by lifting it upwards and the moving forward it is obvious the angle between the force applied by the porter and the displacement is 90^o.
  b) Work done is zero when displacement is zero. This happens when a man pushes a wall. There is no displacement of the wall. Thus, there is no work done.

POWER

1) The rate of doing work is called power.

$$Power = \frac{Work}{time} = \frac{W}{T}$$

2) The rate at which energy transformed is called power.

$$Power = \frac{Energy}{time} = \frac{E}{T}$$

3) The dot product of the vectors force and velocity is called power. $\boldsymbol{P} = \vec{\boldsymbol{F}} . \vec{\boldsymbol{V}}$

Unit: watt. 1 watt = 1 joule / second

Dimensional formula: ML^2T^{-3}

Power is a scalar quantity.

Watt: If 1 J work is done in 1 second time, then the power is said to be one watt.

Another unit of power is Horse Power. 1 HP = 746 W

ENERGY

The capacity to do work is called energy. Energy is a scalar quantity.

Unit: joule **Dimensional Formula:** ML^2T^{-2}

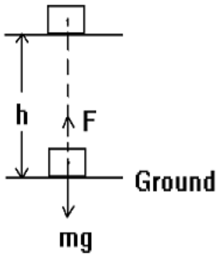
The mechanical energy is two types: 1) Potential Energy 2) Kinetic Energy

5.3 Define potential energy and state examples

The energy possessed by the body by virtue of its position is called potential energy.

Examples:
1. Water stored in the tank has PE.
2. A compressed spring has PE.
3. A raised weight has PE.
4. A stretched rubber has PE.
5. Bullets before they are fired from a gun.

5.4 Derive the expression for Potential energy



1) Consider a body of mass m on the ground. The gravitational force acting on the body is mg.
2) To lift this body a minimum force of **mg** is required.
3) Let the body is lifted to a height h, then the work done is
W = F x S = mg x h = mgh
4) This work is stored in the body as potential energy.
Hence PE = mgh

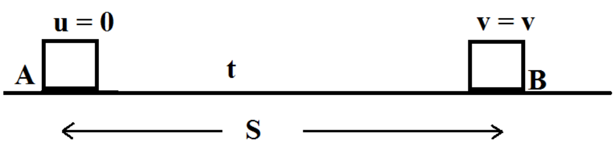
5.5 Define kinetic energy and state examples

The energy possessed by the body by virtue of its motion is called kinetic energy.

Examples:
1) Running man has KE.
2) Moving car has KE.
3) Flowing water has KE.
4) Blowing wind has KE.

5.6 Derive the expression for kinetic energy

Derivation for Kinetic energy:



1) Consider a body of mass **m** which is at rest, at a point A as shown in figure.
2) A force of **F** acting on the body and moves it through a distance S and reaches a point B.

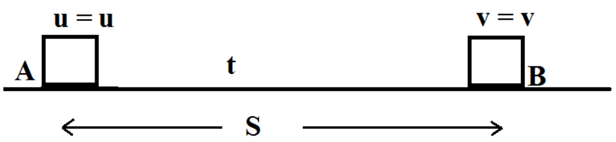
3) Let the velocity of the body at B is V.

4) From equation $v^2 - u^2 = 2as$,wehave
$v = v, u= 0, a = a, s = s \Rightarrow v^2 - 0 = 2as$
$\Rightarrow v^2 = 2as \Rightarrow as = \frac{V^2}{2}$
5) ∴ The work done by the force
W = F x s = ma x s (F = ma)
$= m \times as = m \times \frac{V^2}{2} \Rightarrow W = \frac{1}{2}mv^2$
6) This work is stored in the body as kinetic energy. Hence

$$\boldsymbol{KE = \frac{1}{2}mv^2}$$

5.7 State and derive Work- Energy theorem

Statement: The work done on a body by a constant force is equal to the change in the kinetic energy of the body.



1) Consider a body of mass **m** is moving with a velocity u at a point A as shown in figure.
2) A force of F acting on the body and moves it through a distance S and reaches a point B.
3) Let the velocity of the body at B is V.
4) From equation $v^2 - u^2 = 2as$,wehave
$v = v, u= u, a = a, s = s \Rightarrow v^2 - u^2 = 2as$
$\Rightarrow as = \frac{u^2 - V^2}{2}$
5) ∴ The work done by the force
W = F x s = ma x s (F = ma)
$= m \times as = m \times \left(\frac{u^2 - V^2}{2}\right) = m \times \left(\frac{u^2}{2} - \frac{V^2}{2}\right)$
$\Rightarrow W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$
$\Rightarrow W = KE_f - KE_i$
$\therefore work = change\ in\ kinetic\ energy$
6) Hence work – Energy theorem is verified.

5.8 Derive the relation between Kinetic energy and momentum

1) The product of mass and velocity of a body is called its momentum (p). ∴ $p = mv$
2) The Kinetic energy of the body is

$$KE = \frac{1}{2}mv^2$$

3) From $p = mv$ we have,

$$v = \frac{p}{m} \Rightarrow v^2 = \frac{p^2}{m^2}$$

4) $\therefore KE = \frac{1}{2}m \times \frac{p^2}{m^2} = \frac{p^2}{2m} \Rightarrow \boldsymbol{KE = \frac{p^2}{2m}}$

5.9 State the law of conservation of energy and mention examples

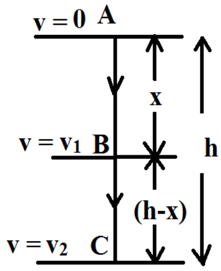
Statement: Energy neither be created nor be destroyed but one form of energy is converted into another form.

Examples of energy transformation:

1) In an electric motor, the electrical energy is converted into mechanical energy.
2) In a dynamo, mechanical energy is converted into electrical energy.
3) In a battery, chemical energy is converted into electrical energy.
4) In a hydroelectric power station, KE of the water is converted into electrical energy.

5.10 Verify the law of conservation of energy in case of a freely falling body

1) Consider a body of mass m freely falls from a height h at a point A as shown in figure.
2) After travelling a distance of x the body reaches the point B and having a velocity v_1.
3) The height of the point B above the ground is (h - x).
4) After travelling a distance of (h-x) from B the body reaches the ground at C and having a velocity v_2.



Freely falling body

At point A:
5) The potential energy of the freely falling body is PE = mgh.
Because, h = h,
6) The Kinetic energy of the freely falling body is
$KE = 0$
Because, $v = 0$
7) The total energy of the freely falling body is
TE = PE + KE
= mgh + 0
∴ TE= mgh.

At point – B:
8) Here h = h - x,
The potential energy of the freely falling body is
⇒ PE = mg (h – x) = mgh - mgx.
9) Here $V = V_1$
The Kinetic energy of the freely falling body is
$\Rightarrow KE = \frac{1}{2}mv_1^2$
From equation $v^2 - u^2 = 2as$,
we have $V = V_1$, u= 0, a = g, s = x
$\Rightarrow v_1^2 - 0 = 2gx \Rightarrow v_1^2 = 2gx$
$\therefore KE = \frac{1}{2}m(2gx) = mgx.$
11) The total energy of the freely falling body is
TE = PE + KE
= mgh - mgx + mgx = mgh.
∴ TE = mgh

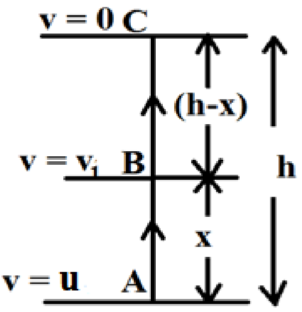
At point – C:
12) Here h = 0
The potential energy of the freely falling body is
PE = 0.
13) Here, $V = V_2$
The Kinetic energy of the freely falling body is
$KE = \frac{1}{2}mv_2^2$
From equation $v^2 - u^2 = 2as$,
we have $V = V_2$, u= 0, a = g, s = h
$\Rightarrow v_2^2 - 0 = 2gh \Rightarrow v_2^2 = 2gh$
$\therefore KE = \frac{1}{2}m(2gh) = mgh.$
14) The total energy of the freely falling body is
TE = PE + KE
= 0 + mgh = mgh.
∴ TE = mgh

Conclusion:

15) The total energy of the freely falling body remains constant from A to C and equals to mgh.
16) The PE of the freely falling body is converted into KE while the body travels from A to C.
17) Hence, the law of conservation of energy in case of freely falling body is verified.

5.10 Verify the law of conservation of energy in case of vertically projected body in the upward direction

1) Consider a body of mass m projected vertically upwards from a point A with a velocity **u** as shown in figure.
2) After travelling a distance of **x** the body reaches the point B and having a velocity V_1.
3) After travelling a distance of (h-x) from B the body reaches the point C (max.height).
4) The velocity of body at C is 0.



Vertically upward projected body

At point A:

5) The potential energy of the body is PE = mgh.

But here, h = 0, ⇒ PE = mg x 0 = 0.

6) The Kinetic energy of the body is $KE = \frac{1}{2}mv^2$

But here, v = u ⇒ $KE = \frac{1}{2}mu^2$

7) The total energy of the body is

TE = PE + KE

$= 0 + \frac{1}{2}mu^2$

$\therefore \boldsymbol{TE = \frac{1}{2}mu^2}$

At point B:

8) The potential energy of the body is

PE = mgx.

Because, h = x

9) The Kinetic energy of the body is

$$KE = \frac{1}{2}mv_1^2$$

Because $v = v_1$

From equation $v^2 - u^2 = 2as$,

We have $v = v_1$, u= u, a = -g, s = x

$$\Rightarrow v_1^2 - u^2 = -2gx \Rightarrow v_1^2 = u^2 - 2gx$$

$$\therefore KE = \frac{1}{2}mv_1^2$$

$$= \frac{1}{2}m(u^2 - 2gx)$$

$$= \frac{1}{2}mu^2 - mgx$$

10) The total energy of the body is

TE = PE + KE

$$= mgx + \frac{1}{2}mu^2 - mgx$$

$$\therefore \boldsymbol{TE = \frac{1}{2}mu^2}$$

At point C:

11) The potential energy of the body is

PE = mgh.

Because, h = h

From equation $v^2 - u^2 = 2as$,

wehave v = 0, u= u, a = -g, s = h

$$\Rightarrow 0 - u^2 = -2gh$$

$$\Rightarrow u^2 = 2gh \Rightarrow gh = gh = \frac{u^2}{2}$$

$$\therefore PE = mgh$$

$$= m\left(\frac{u^2}{2}\right) = \frac{1}{2}mu^2$$

12)The Kinetic energy of the body is

$KE = 0$

Because v = 0

13) The total energy of the body is TE = PE + KE

$$= \frac{1}{2}mu^2 + 0$$

$$= \frac{1}{2}mu^2$$

$$\therefore \boldsymbol{TE = \frac{1}{2}mu^2}$$

Conclusion:

14) The total energy of the vertically upward projected body remains constant from A to C and equals to $\frac{1}{2}mu^2$.
15) The KE of the body is converted into PE while the body travels from A to C.
16) Hence, the law of conservation of energy in case of vertically upward projected body is verified.

Conventional energy sources and non - Conventional energy sources:

Conventional energy sources:

The sources of energy which are used from ancient days are called Conventional energy sources (or) Non – renewable energy sources.

Ex: Oil, Coal, Firewood,………

Non - Conventional energy sources:

The sources of energy which are used from recent days are called Non-Conventional energy sources (or)Renewable energy sources.

Ex: Wind energy,Solar energy,Tide energy,………..

SIMPLE HARMAONIC MOTION

6.1 Define Simple harmonic motion

The to and fro motion of a body such that its acceleration is always directed towards a fixed point and is proportional to its displacement from that point is said to be SIMPLE HARMONIC MOTION.

6.2 Give examples for Simple harmonic motion

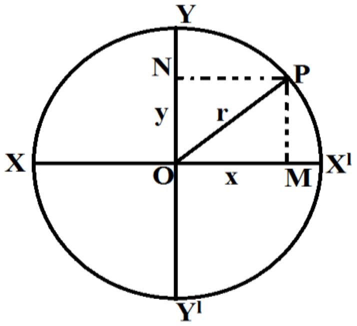
1) Motion of the objects on water waves.
2) Motion of a fall a concave surface.
3) Vibrations of violin string.
4) Motion of the prongs of vibrating tuning fork.
5) Oscillations of simple pendulum.

6.3 State the conditions of Simple harmonic motion

1) Motion should be periodic.
2) To and fro motion.
3) Restoring force must be act on the body.
4) Acceleration always directed towards the mean position.
5) Acceleration proportional to its displacement.
6) Acceleration and displacement always opposite to each other.

6.4 Explanation of SHM in terms of projection of circular motion on any one of the diameters of the circular path

1) Consider a particle **P** moving along the circumference of a circle in anti clockwise direction as shown in figure.
2) The radius of the circle is **r** and the velocity of particle P is **v**.
3) **O** is the centre of the reference circle.
4) **PM** is the perpendicular drawn from P to horizontal diameter XX[l] .
5) **PN** is the perpendicular drawn from P to vertical diameter YY[l] .



6) When **P** starts from X, **N** starts from O.
7) As **P** moves from $X \rightarrow Y$, **N** moves from $O \rightarrow Y$.
8) As **P** moves from $Y \rightarrow X^{/}$, **N** moves from $Y \rightarrow O$.
9) As **P** moves from $X^{/} \rightarrow Y^{/}$, **N** moves from $O \rightarrow Y^{/}$
10) As **P** moves from $Y^{/} \rightarrow X$, **N** moves from $Y \rightarrow O$.
11) As the particle **P** completes one revolution its projection **N** completes one oscillation along YY[l].
12) Hence, the particle executing uniform circular motion, its projection executes simple harmonic motion.

6.5 Derive expression for displacement

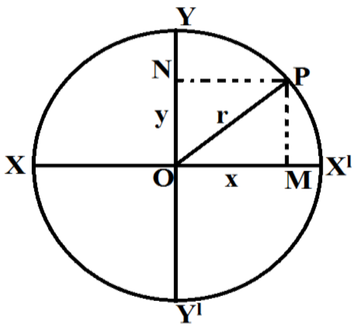
Definition: The distance of the particle in SHM from its mean position at any instant is called its displacement.

From ΔOPM we have $sin\theta = \frac{PM}{OP}$

$But\ PM = y, OP = r\ and\ \theta = \omega t \Rightarrow sin\omega t = \frac{y}{r}$

Therefore, the displacement of the particle

y = rsinωt



Amplitude: The maximum displacement of the vibrating particle on either side of the mean position is called its amplitude.

In displacement y = rsinωt, **r** is the amplitude.

6.6 Derive expression for velocity

Definition: The rate of change in displacement of a vibrating particle is called its velocity.

1) The displacement of the particle **y = rsinωt**.

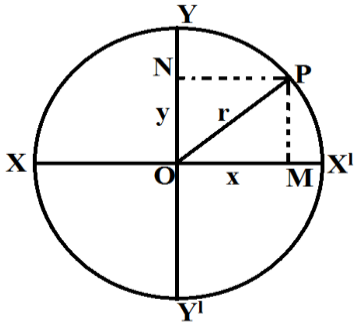
2) But velocity $v = \frac{dy}{dt}$

$$= \frac{d}{dt}(rsin\omega t)$$

$$= r\frac{d}{dt}(sin\omega t)$$

$$\boldsymbol{v = r\omega cos\omega t}$$

$$\left(since \frac{d}{dt}(sin\omega t) = \omega cos\omega t\right)$$



3) We have, $cos^2\theta = 1 - sin^2\theta$.
$Similarly\ cos^2\omega t = 1 - sin^2\omega t$

4) From $y = rsin\omega t$, we get $sin\omega t = \frac{y}{r}$.

5) Therefore, $cos^2\omega t = 1 - sin^2\omega t$

$$= 1 - \left(\frac{y}{r}\right)^2$$

$$= 1 - \left(\frac{y^2}{r^2}\right)$$

$$= \frac{r^2 - y^2}{r^2}$$

$$\Rightarrow \cos\omega t = \frac{\sqrt{r^2 - y^2}}{r}$$

$$\therefore v = r\omega cos\omega t \Rightarrow \boldsymbol{v = \omega\sqrt{r^2 - y^2}}$$

6) If $y=0$, i.e., at mean position 'v' is maximum

$$v_{max} = \omega\sqrt{r^2 - 0} = r\omega \Rightarrow \boldsymbol{v_{max} = r\omega}$$

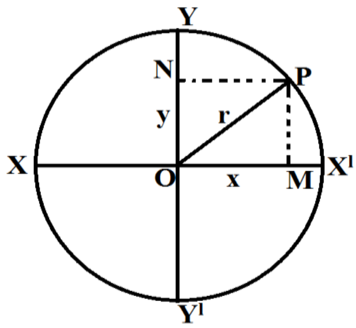
7) If $y = r$, i.e., at extreme position 'v' is minimum

$$v_{min} = \omega\sqrt{r^2 - r^2} = 0 \Rightarrow \boldsymbol{v_{min} = 0}$$

6.7 Derive expression for acceleration

Definition: The rate of change in velocity of a vibrating particle is called its acceleration.

1) The displacement of the particle $y = rsin\omega t$ and velocity $v = r\omega cos\omega t$



2) But acceleration $a = \frac{dv}{dt}$

$$= \frac{d}{dt}(r\omega cos\omega t)$$

$$= r\omega\frac{d}{dt}(cos\omega t)$$

$$\boldsymbol{a = -r\omega^2 sin\omega t}$$

$$\left(since \frac{d}{dt}(cos\omega t) = -\omega sin\omega t\right)$$

3) And also, $a = -\omega^2(rsin\omega t) = -\omega^2 y \Rightarrow$ **$a = -\omega^2 y$**

4) Here the negative sign indicates that acceleration and displacement always opposite to each other.

5) If $y=0$ i.e., at mean position 'a' is minimum.

$\therefore a_{min} = \omega^2(0) \Rightarrow \quad a_{min} = 0.$

6) If $y=r$, i.e., at end position 'a' is maximum.

$\therefore a_{max} = \omega^2(r) \Rightarrow \quad a_{max} = r\omega^2.$

6.8 Derive expression for Time period and frequency of S H M

Time period:

1) The time taken by the particle in SHM to complete one oscillation is called its time period(T).
2) $Time\ period\ (T) = \frac{angular\ displacement(2\pi)}{angular\ velocity(\omega)}$

$$\Rightarrow T = \frac{2\pi}{\omega}$$

3) But $a = \omega^2 y \Rightarrow \omega^2 = \frac{a}{y} \Rightarrow \omega = \sqrt{\frac{a}{y}} \Rightarrow \frac{1}{\omega} = \sqrt{\frac{y}{a}}$
4) $T = \frac{2\pi}{\omega} = 2\pi \times \frac{1}{\omega} \Rightarrow \boldsymbol{T = 2\pi\sqrt{\frac{y}{a}}}$

Frequency:

1) The no.of oscillations made by the particle in SHM in one second time is called its frequency(n).

2) $Frequency = \frac{1}{Timeperiod}$

$$\Rightarrow n = \frac{1}{T}(or) \Rightarrow n = \frac{\omega}{2\pi}$$

3) But $a = \omega^2 y \Rightarrow \omega^2 = \frac{a}{y} \Rightarrow \omega = \sqrt{\frac{a}{y}}$

$$\therefore \textbf{Frequency (n)} = \frac{\mathbf{1}}{\mathbf{2\pi}}\sqrt{\frac{\boldsymbol{a}}{\boldsymbol{y}}}$$

6.9 Define phase of S H M and explain from the expression of displacement

1) The state or condition of the particle in SHM as regards to its position and direction of motion at any given instant is called its phase.

2) We have, y= r sinωt. Here **ωt** is called phase of motion of the particle.

3) The phase at t = 0 is called initial phase (or) phase constant (or) epoch.

6.10 Define Ideal simple pendulum and derive expression for Time period of simple pendulum

Ideal simple pendulum:

A heavy point mass suspended by a light inextensible torsion less string is called an ideal simple pendulum. Practically it is not possible to attain this ideal concept.

Expression for period of simple pendulum

1) Consider a simple pendulum of length ***l*** suspended from a fixed point O as shown in figure.

2) Let **m** be the mass of the bob.

3) When the bob is at A (mean position) two forces are acting on the bob (i) tension force (T) and
(ii) gravitational force (mg).Both are balanced. $\therefore T=mg$.

4) When the bob is at B (at any time t) three forces are acting on the bob (i) tension force (T) ,
(ii) gravitational force (mg) and (iii) restoring Force (F).

5) Now ***mg*** can be resolved into two components $mgsin\theta$ and $mgcos\theta$ as shown in figure.

6) The component $mgcos\theta$ is balanced by T and $mgsin\theta$ is balanced by $-F$ as shown in figure.

$$\therefore T = mgcos\theta \ and$$
$$F = -mgsin\theta.$$
$$ma = -mgsin\theta$$
$$\Rightarrow a = -gsin\theta$$

When *'θ'* is small then $sin\theta \approx \theta \Rightarrow a = -g\theta$.

7) But $\theta = \frac{arc}{radius}$ .But here arc = y and radius = $l \Rightarrow \theta = \frac{y}{l}$

8) $\therefore a = -g\left(\frac{y}{l}\right) = -\left(\frac{g}{l}\right)y \Rightarrow a \propto -y$

9) ***Hence the oscillations of simple pendulum are in SHM.***

11) Comparing $a = -\left(\frac{g}{l}\right)y$ with

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

$$we\ get\ \omega^2 = \frac{g}{l} \Rightarrow \omega = \sqrt{\frac{g}{l}}$$

12) The period of oscillation of a body in S.H.M is given by

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{g}{l}}} \Rightarrow T = 2\pi\sqrt{\frac{l}{g}}$$

13) This is the expression for the time period of a simple pendulum.

6.11 State the laws of motion of simple pendulum and mention formulae

The time period of a simple pendulum is given by

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

1. Time period does not depend on shape, size and mass of the bob.
2. Time period is directly proportional to square root of the length of the pendulum.

$$T \propto \sqrt{l} \text{ (when } \mathbf{g} \text{ is constant)}$$

3. Time period is inversely proportional to square root of the acceleration due to gravity.

$$T \propto \frac{1}{\sqrt{g}} \text{ (where } \boldsymbol{l} \text{ is constant)}$$

Seconds pendulum:

A pendulum whose time period is two seconds is called seconds pendulum. The seconds pendulum gives correct time Hence it is arranged in wall clocks

Length of the pendulum:

The distance between point of suspension and centre of oscillation of a simple pendulum is called the length of the pendulum.

Point of suspension - point from which the bob is suspended.

Centre of oscillation - Centre of gravity of the bob.

HEAT AND THERMODYNAMICS

HEAT: Heat is a form of energy it transforms from one body to another body or system.

TEMPERATURE: Temperature is the thermal condition of a body and measures its relative hotness or coldness.

7.1 Explain the concept of expansion of gases

1. The Temperature of gas changes both volume and pressure of a gas. thus in case of gases there are 3 variables. (i) Volume(V) (ii) pressure(P) (iii) temperature(T)
2. These variable are depends on each other. If one of these variables kept constant we get a gas laws that connect the other two.

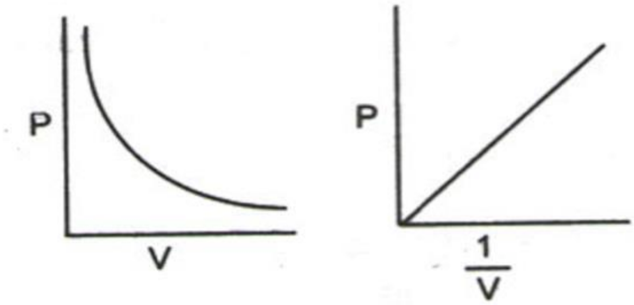
7.2 State and explain Boyle's law and also express it in terms of density

BOYLE'S LAW (in terms of P and V):

STATEMENT: At constant temperature the volume of a given mass of gas is inversely proportional to its pressure.

$$V \propto \frac{1}{P} \Rightarrow V = (constant)\frac{1}{P} \Rightarrow PV = constant.$$

1) If P_1, P_2 are the pressures and V_1, V_2 are the correspondent volumes then $\mathbf{P_1V_1=P_2V_2}$
2) This law holds good for any gas at high temperature and low pressure only.



BOYLE'S LAW (in terms of P and d):

Statement: At constant temperature the density of a given mass of gas is directly proportional to its pressure.

1)According to Boyle's law we have V∝1/p ----(1)

But, mass (m) = Volume (V) x density (d)

$$\Rightarrow m = V \times d \Rightarrow V = \frac{m}{d} \Rightarrow V \propto \frac{1}{d} \text{ -----(2)}$$

2) From eq (1) & (2) we can write $P \propto d$

$$\Rightarrow Pd = \text{Constant.}$$

3) If P1 & P_2 are the pressure and d1 & d2 are the corresponding densities then $P1d1=P2d2$
4) This law holds good for ideal gas at any temperature and any pressure.
5) This law holds good for real gas at high temperatures and low pressures only.

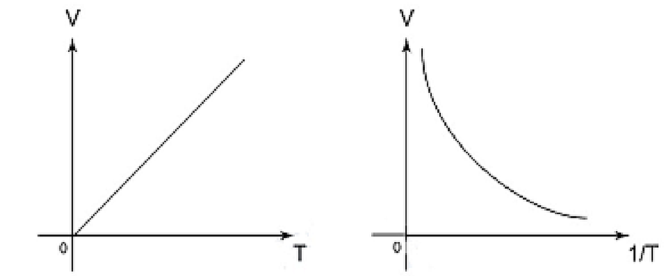
7.3 State Charles laws in terms of absolute temperature and explain

Charle's first law (or)Charle's law at constant pressure:

Statement: At constant pressure the volume of given mass of gas is directly proportional to its absolute temperature.

$$V \propto T \Rightarrow V = (constant)T \Rightarrow \boldsymbol{\frac{V}{T} = constant}$$

1) If V_1& V_2 are the volume and T_1 & $T_2$are the corresponding absolute temperatures then $\boldsymbol{V_1T_1 = V_2T_2}$
2) This law holds good for ideal gas at any temperature and any pressure.
3) This law holds good for real gas at low temperatures and high pressures only.



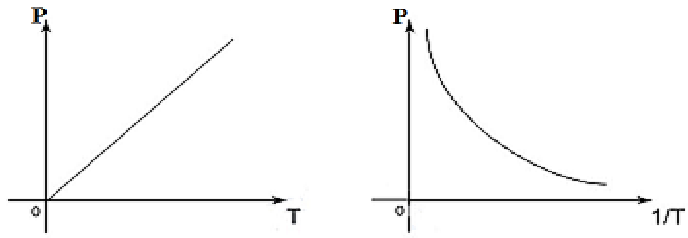
(i) T - V Graph (ii) V- 1/T Graph

Charle's second law (or) Charles law at constant volume:

Statement :- At constant volume the pressure of given mass of gas is directly proportional to its absolute temperature.

$$P \propto T \Rightarrow P = (constant)T \Rightarrow \frac{P}{T} = \text{Constant}$$

1) If P_1 and P_2 are the volume and T_1 and T_2 are the corresponding absolute temperatures then $P_1T_1= P_2T_2$
2) This law holds good for ideal gas at any temperature and any pressure.
3) This law holds good for real gas at low temperatures and high pressures only.



(i) P - T Graph (ii) P - 1/T Graph

7.4Define absolute zero temperature

Absolute Zero: The temperature (-273˚c) at which the pressure and volume of a given mass of a gas becomes zero is called absolute zero temperature (or) absolute zero.

7.5 Explain absolute scale of temperature

A scale which has -273˚c as zero and the size of the degree as that of centigrade scale is called absolute scale of temperature (or) Kelvin scale of temperature.

T=t+273(or) t=T-273.

Here T- temperatures in Kelvin scale

t- temperature in Centigrade scale

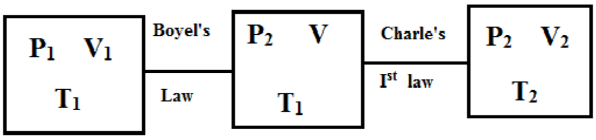
7.6 Define ideal gas and distinguish from real gas

Ideal Gas	Real Gas
1. Ideal gas has no definite volume.	**1.** Real gas has definite volume.
2. Ideal gas has no mass.	**2.** Real gas has mass.
3. Collision of ideal gas particles is elastic.	**3.** Collision of real gas particles is non – elastic.
4. Pressure is high in ideal gas compared to real gas.	**4.** Pressure is low in real gas compared to ideal gas.
5. Ideal gas follows the equation PV=nRT	5. Real gas follows the equation $(P + aV^2)(V – b) = nRT$

Ideal Gas: The gas which obeys the gas laws at any temperature and any pressure is called an ideal gas. The molecules of the gas are point size with no attraction or repulsion between them.

7.7 Derive Ideal gas equation

1. Consider an ideal gas enclosed in a container. Let the gas have a pressure P_1 and volume V_1 at absolute temperature T_1.
2. Suppose that pressure of a gas increased from P_1 to P_2 by keeping temperature constant.
3. According to Boyle's law its volume changes and let volume be V. Now, the gas has a pressure P_2, volume V temperature T_1.



4. By applying Boyle's law we get $P_1V_1=P_2V_2$

$$\text{here } V_2 = V$$
$$\Rightarrow P_1V_1=P_2V$$
$$\Rightarrow V = \frac{P_1V_1}{P_2}$$

5. Now suppose that the temperature of gas is raised from T1to T2 by keeping its pressure constant.
6. According to Charle's first law the volume changes and let the volume be V2, now the gas at pressure P2, volume V2 and temperature T2.
7. By applying Charle's law at constant pressure we get.

$$V_1T_1= V_2T_2$$
$$\text{here} V_1=V$$
$$\Rightarrow VT_1=V_2T_2$$
$$\Rightarrow V = \frac{V_2T_2}{T_1} \text{ ………… (2).}$$

8.Comparing eq (1) & (2) we get

$$\frac{P_1V_1}{P_2} = \frac{V_2T_2}{T_1}$$

$$\Rightarrow \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$
$$\Rightarrow \frac{PV}{T} = Constant$$

9. If we consider the volume occupied by one gram mole of gas at NTP, then constant is R.

$$\Rightarrow \frac{PV}{T} = R$$
$$\Rightarrow \mathbf{PV=RT}$$

10. This equation is called an ideal gas equation, here R is universal gas constant and its value is 8.31 J/mol/K.

7.8 Define Specific gas constant and Universal gas constant

Specific gas constant(r):

1. The value of $\frac{PV}{T}$ when the volume of. 1gram of gas is considered at NTP is called specific gas constant(r).
2. SI unit $J/kg/K$
3. Dimensional formula $M°L^2T^{-2}K^{-1}$

Universal gas constant(R):

1. The value of $\frac{PV}{T}$ when the volume of 1gram mole of gas is considered at NTP is called universal gas constant(R).
2. SI unit J/mol/K
3. Dimensional formula $ML^2T^{-2}K^{-1}mol^{-1}$.

7.9 Explain why universal gas constant is same for all gases

From ideal gas equation, we have $\frac{PV}{T} = Constant.$

- If we consider gas equation the volume occupied by the 1gm mole of gas at NTP, the constant is 'R' ∴ $\frac{PV}{T} = R$
- According to Avogadro's hypothesis every 1gm mole of gas occupy the same volume at NTP. Therefore, the value of 'R' is same for all gasses.

7.10 State SI unit and dimensional formula of universal gas constant

Unit of universal gas constant is **J/mol/K**

Dimensional formula of universal gas constant: $R = \frac{PV}{nT}$

$$R = \frac{ML^{-1}T^{-3} \times L^3}{mol \times K} = ML^2T^{-2}K^{-1}mol^{-1}$$

7.11 Calculate the value of universal gas constant

At N.T.P. for 1 gr.mole of gas has

Pressure (P) = 76 cm of Hg = 76 X 13.6 X 98 N/m^2 Volume (V) = 22.4 liters = 22.4 X 10^{-3} m^3

Absolute temperature (T) = 0^0 C = 273 K

$$Universal\ gas\ constan(R) = \frac{PV}{T}$$
$$= \frac{76 \times 13.6 \times 98 \times 22.4 \times 10^{-3}}{273} = 8.31$$
$$\therefore R = 8.31\ J/mol/k$$

7.12 State the gas equation in different forms (as a function of density and mass)

1. Form ideal gas equation we have

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T2} \text{ …………(1)}$$

But, we have $volume = mass$ x $density$

$$\Rightarrow V_1 = m \text{ x } d_1\ and$$
$$V_2 = m \text{ x } d_2$$
$$\Rightarrow \frac{P_1}{T_1d_1} = \frac{P_2}{T_2d_2}$$
$$\Rightarrow \frac{\boldsymbol{P}}{\boldsymbol{Td}} = \boldsymbol{Constant.}$$

This is the ideal gas equation in terms of density.

2. If we take the volume occupied by 1gram of gas at NTP, then $\frac{PV}{T} = r \Rightarrow PV = rT$. Here 'r' is gas constant.
3. If we consider the volume occupied by 'n' gram mole of gas at NTP, then the ideal gas equation is **PV = nRT** here 'n' is number of moles.
4. But $n = \frac{mass\ of\ thegas(m)}{molecularweight(M)} \Rightarrow PV = \frac{m}{M}RT$

$$\Rightarrow PV = m\left(\frac{R}{M}\right)T$$
$$\mathbf{PV = m\,rT}\ \left(\mathbf{r} = \frac{\mathbf{R}}{\mathbf{M}}\right)$$

7.13 Distinguish between r and R

Gas Constant (r)	Universal gas constant(R)
1.The value of PV/T when the volume of. 1gr. of gas is considered at NTP is called gas constant(r).	1. The value of PV/T when the volume of 1gr. mole of gas is considered at NTP is called universal gas constant(R).
2. Its value varies from gas to gas.	2.Its value is constant for all gases.
3.SI unit J/kg/K	3.SI unit J/mol/K
4.Dimensional formula $M°L^2T^{-2}K^{-1}$	4. Dimensional formula $ML^2T^{-2}K^{-1}mol^{-1}$.
5. It depends upon mass of the gas.	5. It depends upon gram molecular weight of gas.

THERMODYNAMICS

INTERNAL ENERGY:

- The molecules of the gases have KE and PE and they move always randomly. The KE and PE are always changing because of their random motion.
- The total KE and PE of all molecules in the gas is called its internal energy.
- It is impossible to calculate the internal energy of the gas. But we can estimate the change in internal energy because. It brings the change in temperature.

Thermal equilibrium: If two systems are at same temperature, then they are said to be at thermal equilibrium.
Isothermal Process: The change in pressure and volume of a gas taking place at constant temperature is called isothermal process.
Adiabatic Process: The change in pressure and volume of a gas taking place in thermal isolated system is called Adiabatic process..
Isobaric Process: A process in which the pressure of the system remains constant is called isobaric process.
Isochoric Process: A process in which the volume of the system remains constant is called isochoric process.
Work done in thermodynamic process:
In a thermodynamic process the work done is
$W = P(V_2-V_1)$.
If $V_2 > V_1$, then work is done by the system. This work is called external work.
If $V_2 < V_1$, then work is done on the system. This work is called internal work.
Entropy: The thermal property of a body which remains constant during an adiabatic process is called as entropy. The calculation of entropy of a substance is not possible; we can only measure the change in entropy as the substance moves from one state to another. It is denoted by '**S**' (or) '$\emptyset$'.
UNIT – J/K.
Dimensional Formula: $ML^2T^{-2}K^{-1}$.

7.14 State and Explain Isothermal process

Statement: The change in pressure and volume of a gas taking place at constant temperature is called isothermal process.
1. It is a slow process.
2. Heat exchange is possible in this process. So, it is conducted in good conducting vessel. ∴ $dQ \neq 0$.
3. The temperature of the system is constant. Hence $dU = 0$.
4. Internal energy is constant because in this process temperature is constant.
5. Boyle's law is holds Good.PV = constant. ∴ dU=0
6. When gas is expanded the work done in isothermal process is $W = 2.303RT\log_{10}\left(\frac{V_2}{V_1}\right)$ (or)

$$W = 2.303RT\log_{10}\left(\frac{P_1}{P_2}\right)$$

7.15 State and Explain adiabatic process

Statement: The change in pressure and volume of a gas taking place in thermal isolated system is called adiabatic process.
1) It is a quick process.
2) Heat exchange is not possible in this process. So, it is conducted in a non - conducting vessel. ∴ $dQ = 0$.
3) The temperature of the system is changes. Hence $dU \neq 0$.
4) Entropy is constant because in this process heat energy is constant.
5) PV^{γ}= constant is holds good in this process.
6) When gas is expanded the work done in adiabatic process is $W = \frac{1}{\gamma-1}(P_1V_1 - P_2V_2)$.
7) There is no change in heat energy the molar specific heat is zero. ($C = \frac{dQ}{dT}$)

7.16 Distinguish between isothermal and adiabatic processes

Isothermal Process	Adiabatic Process
1) The change in pressure and volume of a gas taking place at constant temperature is called isothermal process.	1) The change in pressure and volume of a gas taking place in thermal isolated system is called adiabatic process.
2) Heat exchange is possible.	2) Heat exchange is not possible.
3) Internal energy is constant.	3) Heat energy is constant.
4) Conducted in good conducting vessel.	4) Conducted in Non-conducting vessel.
5) It is a slow process.	5) It is a Quick process.
6) PV = constant, is holds Good.	6) PV^{γ}= constant, is holds Good.
7) Here dU=0 and $dQ \neq 0$.	7) Here $dU \neq 0$ and dQ= 0.

7.17 State first and second laws of thermodynamics and state applications

First law of thermodynamics
Statement: The heat energy (dQ) Supply to a system is equal to the sum of the increase in internal energy (dU) and the external work (dW) done by the system.

$$dQ = dU + dW.$$

EX: Working of diesel, petrol and steam engines are based on this law.
Applications:
(1) Isolated system : If a system is completely cut-off from the surroundings is called an isolated system.
For isolated system heat energy and internal energy is constant. dQ = 0 and dU = 0.

$$dQ = dU + dW$$
$$\Rightarrow 0 = 0 + dW$$
$$\Rightarrow dW = 0.$$

(2) Isothermal Process: For isothermal process internal energy is constant. ⇒ dU=o.
But we have, $dQ=dU + dW$
$\Rightarrow dQ=0+dW$
$\Rightarrow dQ = dW$.
Hence, the total heat energy supplied to the system is used to do external work.
(3) Adiabatic Process: For adiabatic process heat energy is constant. ⇒dQ=0,
But $dQ=dU + dW$
$\Rightarrow 0=dU + dW$
$\Rightarrow dU= -dW$.
The adiabatic compression always causes heating and the adiabatic expansion always causes cooling.
(4) Cycliic Process: For cyclic process the system returns to initial state.Therefore,the internal energy is constant.
⇒ dU =o.
But we have, $dQ=dU + dW$
$\Rightarrow dQ=0+dW$
$\Rightarrow dQ = dW$.

Hence, the total heat energy supplied to the system is used to do external work.

Second law of thermodynamics

Statement: Heat by itself cannot transmit from a body at low temperature to a body at high temperature without aid of an external agent.

Ex: working of refrigerators, water coolers, ac etc are based on this law.

Applications:

1. This law gives the concept of temperature.
2. From this law it is impossible to convert the total heat energy of a system into work.

7.18 Define specific heats & molar specific heats of a gas and differentiate them

Specific heat of gas at constant volume (cv):

At constant volume the amount of the heat energy is required to increase the temperature of 1gram of gas through 1° is called specific heat of a gas at constant volume (Cv).

SI unit –J/kg/K

Dimensional formula: $M^{\circ}L^2T^{-2}K^{-1}$

Specific heat of gas at constant pressure (cp):

At constant pressure the amount of the heat energy is required to increase the temperature of 1gram of gas through 1° is called specific heat of a gas at constant pressure (Cp).

SI unit –J/kg/K

Dimensional formula: $M^{\circ}L^2T^{-2}K^{-1}$

Molar Specfic Heat Of Gas

Molar specific heat of gas at constant volume (Cv):

At constant volume the amount of the heat energy is required to increase the temperature of 1gram mole of gas through 1° is called molar specific heat of a gas at constant volume(Cv).

SI unit –J/mol/K

Dimensional formula: $ML^2T^{-2}K^{-1}mol^{-1}$

Molar specific heat of a gas at constant pressure (Cp):

At constant pressure the amount of the heat energy is required to increase the temperature of 1gram mole of gas through 1° is called molar specific heat of a gas at constant pressure (Cp).

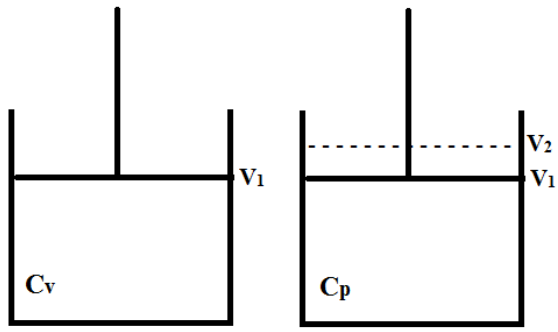
SI unit – J/mol/K Dimensional formula: $ML^2T^{-2}K^{-1}mol^{-1}$

Differences between cp and cv:

Specific heat of gas at constant volume(cv)	**Specific heat of gas at constant pressure(cp)**
1.At constant volume, the amount of heat energy required to increase the temperature of 1gram of gas through 1° is called specific heat of gas at constant volume(cv).	1.At constant pressure, the amount of heat energy required to increase the temperature of 1gram of gas through 1° is called specific heat of gas at constant pressure(cp).
2. External work done by the gas is zero.	2. External work done by the gas is not zero.
3. The heat supplied is utilized to increase the internal energy of gas only.	3. The heat supplied is utilized to increase the internal energy and to do external energy.
4. cv is less than cp.	4. cp is greater than cv.
5.SI unit –J /kg/ K.	5.SI unit –J /kg/ K.
6. Dimensional formula: $M^{\circ}L^2T^{-2}K^{-1}$	6. Dimensional formula: $M^{\circ}L^2T^{-2}K^{-1}$

7.19 Derive the relation Cp – Cv = R
(Mayer's Equation)

1. Consider 1gram mole of an ideal gas enclosed in a cylinder as shown in figure. Let the volume, Pressure and temperature of the gas are V_1, P and T respectively.
2. First let us suppose that a heat energy Cv is supplied to the gas. Now, the volume of the gas remains constant and temperature is (T+1).
3. By the definition of Cv we can write Cv = dU…… (1)
4. Now suppose that a heat energy Cp is supplied to the gas at temperature T, and volume V_1.
5. Now, the volume increased from V1 to V2 and temperature is T to (T+1).



6. By the definition of Cp, we can write

$$Cp = dU + dW.$$
$$\Rightarrow Cp = Cv + dW.$$
$$\text{But, } dW = P(V_2 - V_1).$$
$$\therefore Cp = Cv + P(V_2 - V_1) \ldots\ldots (2)$$

7. From ideal gas equation, we have, PV=RT.

$PV_1 = RT$ ------ before supplied Cp.

$PV_2 = R(T+1)$ -------after supplied Cp.

$\Rightarrow PV2 = RT+R$

$= PV_1 + R$

$\Rightarrow PV_2 - PV_1 = R$

$\Rightarrow P(V_2 - V_1) = R.$

$\therefore Cp = Cv + R$

Cp - Cv =R.

This equation is known as Mayer's equation.

8. For 1gram of gas the above equation can be written as

cp - cv = r

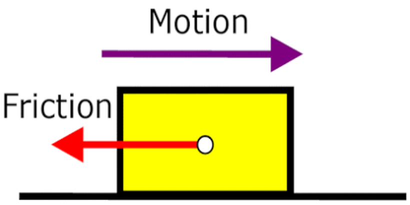
Why Cp is greater than Cv:

1. When a gas is heated at constant volume the heat energy supplied to the gas is utilized to increase the internal energy of the gas only. i.e. Cv = dU
2. But, when a gas is heated at constant pressure, the heat energy supplied to the gas is utilized to
 (i) for increasing internal energy. (ii) To do ext at work .
 i.e.: Cp = dU + dW
3. Therefore, Cp is for all greater than Cv.

FRICTION

4.1 Define friction

Def: The force which always opposes the motion of one body over the other body in contact with it is called the friction.

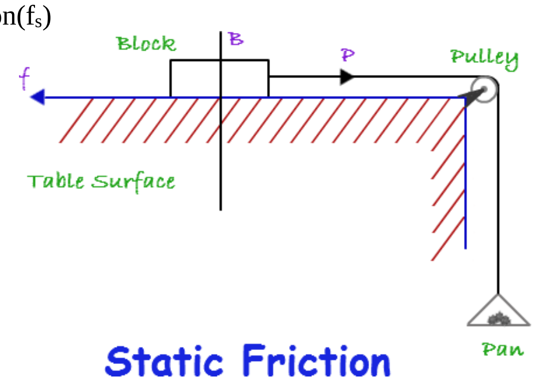


Examples of friction in daily life:
Friction plays an important role in our daily life. Some examples are given below:
1) Safe walking on the floor is possible because of friction.
2) Friction helps the fingers to hold the objects.
3) Nails and screws are held in the walls and wooden boards due to friction.
4) Vehicles move on the roods without slipping due to friction.
5) We can light the match stick due to friction.

4.2 Classify the types of friction

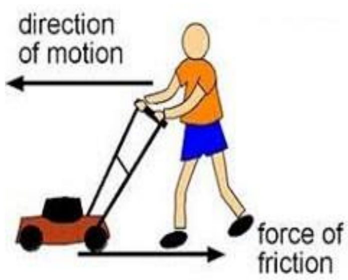
The force of friction is 3 types, namely
(1) Static friction (2) kinetic (or) dynamic friction
(3) Rolling friction.

Static friction:
The frictional force which is present when a body just tends to slide over the surface of another body is called “static friction(f_s)



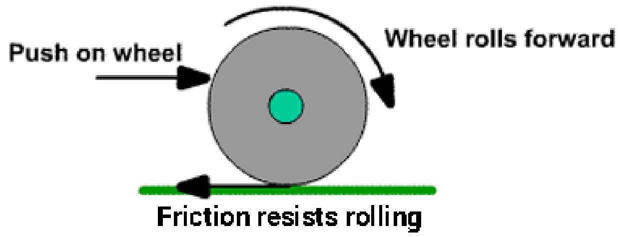
- Static friction is equal to the applied force and opposite in direction. If the applied force increases, the static frictional force also increases and becomes maximum.
- The maximum static frictional force is called as “limiting friction(f_L).”. At this state the body tends to slide without any acceleration.

Kinetic friction:
The frictional force which comes into play after the motion has started is called ‘Kinetic friction ((f_k)’.



Kinetic friction is equal to the force required to keep a body to slide over another body with uniform velocity opposite to the direction of motion.

Rolling friction:
When a body like a wheel, cylinder rolls over the surface of another body the friction is called rolling friction (f_R).
In rolling friction the body deforms the surface on which the body rolling and the body also deformed. These deformations produce the frictional force.

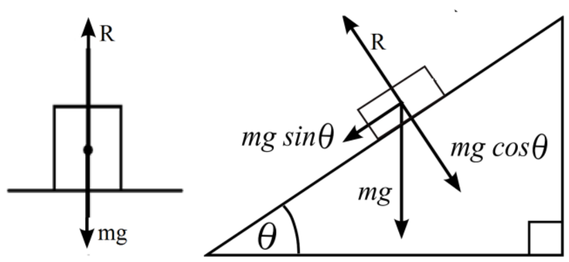


In these three types the static friction is greater than and rolling friction is less than in the remaining.
$f_S > f_K > f_R$.

4.3 Explain the concept of Normal reaction

Def: When the body rests on another, the force acting on the bottom surface of the upper body is called the normal reaction(R). It is perpendicular to the bottom surface.
1) Normal reaction acts perpendicular to the plane, Whether the body lies on a horizontal plane or inclined plane.
2) If a body of mass ‘m’ lies on a horizontal surface, the normal reaction is ‘mg.’ R=mg.
3)If a body of mass ‘m’ lies on an inclined plane of inclination ‘θ’

$$R=mg\cos\theta$$



4.4 State the laws of friction

(1) Friction opposes the relative motion between two surfaces in contact and is always a parallel to the surfaces of contact.
(2) Friction depends on the nature of the two surfaces in contact.
(3) Friction is independent of area of contact between the Friction is directly proportional to the normal reaction acting on the body.
(4) Friction is directly proportional to the normal reaction.

$$f \propto R$$

Laws of static friction:
(1) Static friction is always acts in a direction, opposite to the direction of the body tends to move.
(2) The static frictional force is independent of area of contact.
(3) The magnitude of static friction is always equal to the applied force.
(4) The value of limiting friction is directly proportional to the normal reaction. $f_L \propto R$

Laws of kinetic friction:

(1) Kinetic friction is always acts in a direction, opposite to the direction of motion of the body.
(2) It is independent of area of contact.
(3) Kinetic friction is independent of velocity of the body.
(4) Kinetic friction is directly proportional to the normal reaction. $\mathbf{f_K \alpha\ R}$

Laws of rolling friction:

(1) Rolling friction is always acts in a direction, opposite to the direction of the rolling of the body.
(2) It is directly proportional to the area of contact.
(3) Rolling friction is inversely proportional to the radius.
(4) Rolling friction is directly proportional to normal reaction. $\mathbf{f_R \alpha\ R}$

4.5 Define coefficients of friction

Coefficient of static friction:

The ratio between limiting friction and normal reaction is called coefficient of static friction(μ_s).

we know that $f_L \alpha$ R.

$\Rightarrow f_L = \mu_S R$

$\Rightarrow \mu_S (or)\ \mu_L = \frac{f_L}{R}$

Where $\mu_s$is known as static friction.

Coefficient of kinetic friction:

The ratio between kinetic friction and normal reaction is called coefficient of kinetic friction(μ_k).

We know that, $f_k \alpha$ R

$\Rightarrow f_k = \mu_k R$

$\Rightarrow \mu_k = f_k/R$.

Where μ_k is known as coefficient of kinetic friction.

$\mu_S > \mu_K$ (Since $f_L > f_K$)

Coefficient of rolling friction:

The ratio between rolling friction and normal reaction is called coefficient of rolling friction (μ_R).

We know that, $f_R \alpha$ R

$\Rightarrow f_R = \mu_R R$

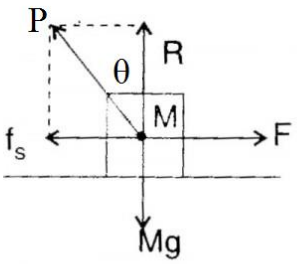
$\Rightarrow \mu_R = f_R/R$

Where μ_R is known as coefficient of rolling friction.

$\mu_S > \mu_K > \mu_R$(Since $f_L > f_K > f_R$)

4.6 Explain the Angle of friction

Def: The angle between the normal reaction and the resultant of normal reaction and limiting friction is called as angle of friction(θ).



From the fig, we have.

$\tan\theta = \frac{PR}{OR} = \frac{f_s}{R}$ (∵from ΔOPR)

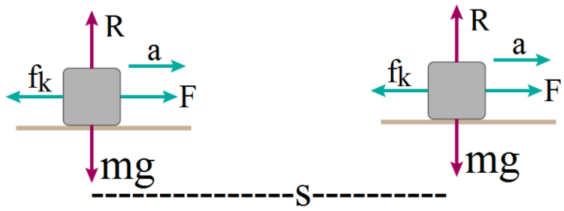
But $\mu_s = \frac{f_s}{R}$.

$\therefore \tan\theta = \mu_s$.

That is the tangent of the angle of friction is numerically equal to the coefficient of limiting friction.

4.6 Derive an expression for acceleration of a body on a rough horizontal surface

1) Friction always opposes the motion of the body. Hence it acts as a retarding force producing negative acceleration.
2) Consider a body of mass **m** moving along rough horizontal surface with a velocity **u**. Due to friction the body will come to reset after a time **t** and travelled a distance **s**.



3) For horizontal surface, normal reaction R=mg.
4) The force of friction between the surfaces is given by

$f_K = \mu_K R$

$= \mu_K mg$.

5) ∴Acceleration of the body $= -\frac{F}{m}$

$= -\frac{f_k}{m}$

$= -\frac{\mu_k mg}{m}$

$\mathbf{a = -\mu_k g}$

4.8 Derive an expression for the displacement and time taken to come to rest over a Rough horizontal surface

Displacement:

6) Here we have,

$u = u$,

$v = 0$,

$a = -\mu_k g$,

$s = s$.

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

$0 - u^2 = 2(-\mu_k g)s$

$\Rightarrow -u^2 = -2\mu_k gs$

$\Rightarrow \mathbf{S = \frac{u^2}{2\mu_k g}}$

This is expression for distance travelled by the body before coming to rest.

Time taken to come to rest:

7) Here we have

$u = u$,

$v = 0$,

$a = -\mu_k g$,

$t = t$.

We have , $v = u + at$

$0 = u + (-\mu_k g)t$

$\Rightarrow \mu_k g\, t = u$

$\Rightarrow \mathbf{t = \frac{u}{\mu_k g}}$

This is the expression for time taken by body to come to rest.

Work done by the frictional force:

8) The work done by the frictional force is

$W = F \times S$

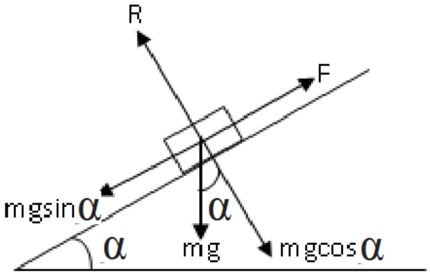
$= f_k \times S$

$= \mu_K mg \times \frac{u^2}{2\mu_k g}$

$W = \frac{1}{2} m v^2$

4.9 Define Angle of repose

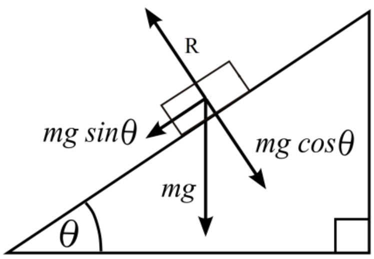
Def: The minimum angle of inclination of an inclined plane at which the body over it tends to slide down is called angle of repose (α)



4.10 Derive expressions for acceleration of a body on a smooth inclined plane (up and down)

When the body is sliding up:

1. Consider a body of mass 'm' which is projected up with a velocity 'u' on a smoothinclined plane, inclined at an angle 'θ' with the horizontal.
2. As the inclined plane is smooth the force of friction is negligible.



Acceleration:

3. The net retarding force acting on the body is mgsinθ.

$$F = mg\sin\theta.$$

$$\text{acceleration (a)} = -\frac{F}{m}$$

$$= -\frac{mg\sin\theta}{m}$$

$$\Rightarrow \mathbf{a = -g\sin\theta}$$

Distance:

4. Suppose that the distance travelled by the body before its velocity becomes zero is 'S'.

We know that

$$u = u,$$
$$v = 0,$$
$$a = -g\sin\theta$$
$$S = S.$$

We have $v^2 - u^2 = 2as$,

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

$$\Rightarrow S = \frac{0^2 - u^2}{2(-g\sin\theta)}$$

$$\Rightarrow \mathbf{S = \frac{u^2}{2g\sin\theta}}$$

Time:

5. Suppose that the time taken by body for its velocity becomes zero be't'.

We know that, $u = u$,
$v = 0$,
$a = -g\sin\theta$
$t = t$.

We have $v = u + at$,

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

$$= \frac{0 - u}{(-g\sin\theta)}$$

$$= \frac{u}{g\sin\theta}$$

$$\Rightarrow \mathbf{t = \frac{u}{g\sin\theta}}$$

Work:

7.Suppose that the work done by the body on travelling a distance's is w.

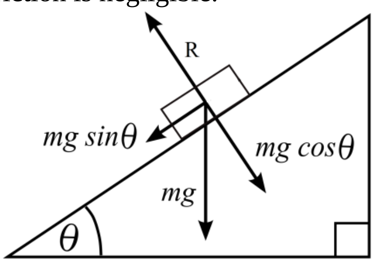
$$W = F \times S$$

$$\Rightarrow W = mg\sin\theta \times S$$

$$\mathbf{W = mgS\sin\theta}$$

When the body is sliding down:

1. Consider a body of mass 'm' which is sliding down on a smooth inclined plane, inclined at an angle 'θ' with the horizontal As the inclined plane is smooth the force of friction is negligible.



Acceleration:

The net force acting on the body is

$$F = mg\sin\theta.$$

$$\text{acceleration (a)} = \frac{F}{m}$$

$$= \frac{mg\sin\theta}{m}$$

$$\Rightarrow \mathbf{a = g\sin\theta}$$

Time:

Suppose that, the time taken by the body to reach the bottom of the plane be't'.

We know that,

$$S = l,$$
$$u = 0,$$
$$a = g\sin\theta,$$
$$t = t.$$

We have $S = ut + \frac{1}{2}at^2$,

$$l = (0)t + \frac{1}{2} \times g\sin\theta \times t^2$$

$$\Rightarrow t^2 = \frac{2l}{g\sin\theta}$$

$$\Rightarrow \mathbf{t = \sqrt{\frac{2l}{g\sin\theta}}}$$

Velocity on reaching bottom of the plane:

Suppose that the velocityof the body on reaching the bottom of the plane be v.
we know that,

$u = 0,$
$s = l,$
$a = g\sin\theta,$
$v = v$

We have $v^2 - u^2 = 2as,$

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

$v^2 = 0^2 + 2(g\sin\theta)l$

$$\Rightarrow V = \sqrt{2gl\sin\theta}$$

Work:
Suppose that the work done by the body on reaching the bottom of the plane be 'W'.

$W = F \times S$

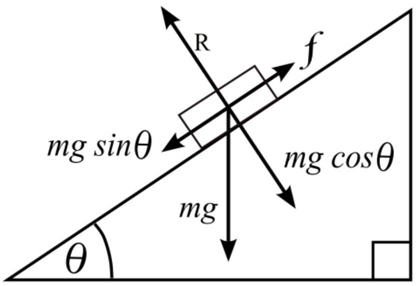
$\Rightarrow W = mg\sin\theta \times l$

$\Rightarrow$ **$W = mgl\sin\theta$.**

4.11 Derive expressions for acceleration of a body on a rough inclined plane (up and down)

When the body is sliding up

- Consider a body of mass 'm' which is projected up with a velocity 'u' on a rough inclined plane, inclined at an angle 'θ' with the horizontal.
- As the inclined plane is rough the force of friction is considerable.



1) *ACCELARATION:*

Acceleration:
The net retarding force acting on the body is mgsinθ.

$F = mg\sin\theta + \mu_k mg\cos\theta$

acceleration (a) = $-\frac{F}{m}$

$= -\frac{(mg\sin\theta + \mu_k mg\cos\theta)}{m}$

$$\Rightarrow a = -g(\sin\theta + \mu_k\cos\theta)$$

Distance:
Suppose that the distance travelled by the body before its velocity becomes zero is 'S'.
We know that

$u = u,$
$v = 0,$
$a = -g(\sin\theta + \mu_k\cos\theta)$
$S = S.$

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

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

$\Rightarrow S = \frac{0^2 - u^2}{-2g(\sin\theta + \mu_k\cos\theta)}$

$$\Rightarrow S = \frac{u^2}{2g(\sin\theta + \mu_k\cos\theta)}$$

Time:
Suppose that the time taken by body for its velocity becomes zero be't'.
We know that,

$u = u,$
$V = 0,$
$a = -g(\sin\theta + \mu_k\cos\theta)$
$t = t.$

From $v = u + at,$

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

$= \frac{0 - u}{-g(\sin\theta + \mu_k\cos\theta)}$

$= \frac{u}{g(\sin\theta + \mu_k\cos\theta)}$

$$\Rightarrow t = \frac{u}{g(\sin\theta + \mu_k\cos\theta)}$$

Work:
Suppose that the work done by the body on travelling a distance's is w.

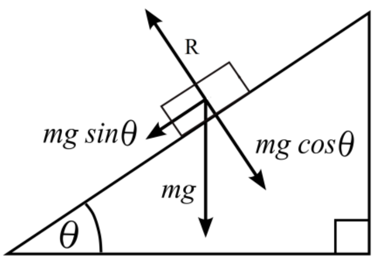
$W = F \times S$

$\Rightarrow W = (mg\sin\theta + \mu_k mg\cos\theta) \times S$

$$\Rightarrow W = mgS(\sin\theta + \mu_k\cos\theta)$$

When the body is sliding down:

- Consider a body of mass 'm' which is sliding down on a rough inclined plane, inclined at an angle 'θ' with the horizontal.
- As the inclined plane is rough the force of friction is negligible.



Acceleration:
The net force acting on the body is

$F = mg\sin\theta - \mu_k mg\cos\theta$

$= mg(\sin\theta - \mu_k\cos\theta).$

acceleration (a) = $\frac{F}{m}$

$= \frac{mg(\sin\theta - \mu_k\cos\theta)}{m}$

$$\Rightarrow a = g(\sin\theta - \mu_k\cos\theta)$$

Time:
Suppose that, the time taken by the body to reach the bottom of the plane be't'.
We know that,

$s = l,$
$u = 0,$
$a = g(\sin\theta - \mu_k\cos\theta),$
$t = t.$

From $S = ut + \frac{1}{2}at^2$, we get

$l = 0 + \frac{1}{2}g(\sin\theta - \mu_k\cos\theta)t^2$

$\Rightarrow t^2 = \frac{2l}{g(\sin\theta - \mu_k\cos\theta),}$

$$\Rightarrow t = \sqrt{\frac{2l}{g(\sin\theta - \mu_k\cos\theta)}}$$

Velocity on reaching bottom of the plane:
Suppose that the velocityof the body on reaching the bottom of the plane be v.

we know that, $u=0$,

$s = l$,

$a = g (\sin\theta - \mu_k \cos\theta)$,

$v = v$

From $v^2 - u^2 = 2as$, we get, $v^2 = u^2 + 2as$

$v^2 = 0 + 2g (\sin\theta - \mu_k \cos\theta) l$

$$\Rightarrow \mathbf{v} = \sqrt{2gl\,(\sin\theta - \mu_k \cos\theta)}$$

Work:
Suppose that the work done by the body on reaching the bottom of the plane be 'W'.

$W = F \times S$

$\Rightarrow W = mg (\sin\theta - \mu_k \cos\theta) \times l$

$$\Rightarrow \mathbf{W} = mgl\,(\sin\theta - \mu_k \cos\theta)$$

4.12List the Advantages and Disadvantages of friction

Friction plays a main role in our daily life. Without friction we are handicap.

1. Safe walking on the floor is due to friction.
2. Fix nails and screws in the wooden board or wall due to friction.
3. Because of friction we can hold the objects with fingers.
4. Writing with pen on the paper due to friction.
5. Friction helps in applying the brakes.
6. Lighting match stick is due to friction.

DISADVANTAGES OF FRICTION

1. It opposes the motion.
2. Reduces the efficiency of our vehicles
3. Some useful energy is wasted as heat energyin various parts of machines due to friction.
4. Due to friction we have to consume more power in machines.
5. Due to friction, noise is also produced in machines.
6. Due to friction, engines of automobiles consume more fuel which is a money loss.

4.13 Mention the methods of minimizing friction

There are a number of methods to reduce friction in which some are discussed here.

1) **Using lubricants:** The parts of machines which are moving over one another must be properly lubricated by using oils and lubricants of suitable viscosity.
2) **Using grease:** Proper greasing between the sliding parts of machine reduces the friction.
3) **Using ball bearings:** In machines where possible, sliding friction can be replaced by rolling friction by using ball bearings.
4) **Design Modification:** Friction can be reduced by changing the design of fast moving objects. The front of vehicles and airplanes made oblong to minimize friction.