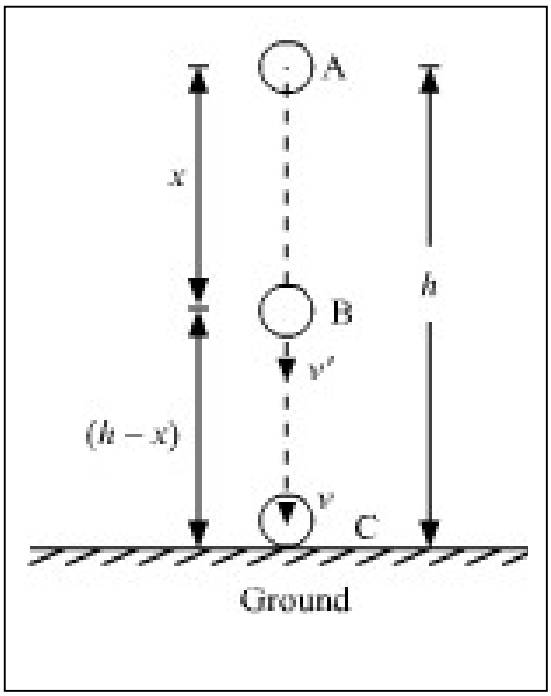
LAQ:1. State and prove law of conservation of energy in case of freely falling body.

1) Law of conservation of energy: Energy can neither be created nor be destroyed Total energy remains constant in a given system

2) Proof: Consider a freely falling body of mass 'm' released from a point 'A'. The acceleration of the body is a= +g



3) At Point A: Let the height of the body from the ground is **'h'**.

$\therefore$ Potential Energy $P.E = mgh \quad \ldots.(1)$

$at\ A$ Velocity $V_A = u = 0$

$\therefore$ Kinetic Energy $K.E = \frac{1}{2}mV_A{}^2 = \frac{1}{2}(0)^2 = 0 \ldots.(2)$

From (1) & (2) Total Energy

$\boldsymbol{TE = PE + KE = mgh + 0 = mgh} \ldots (\boldsymbol{A})$

4) At Point B:

Let the body travels a displacement and reaches the point B.

So height of the body from the ground is (h-x)

$\therefore PE = mg(h - x) = mgh - mgx \ldots\ldots.(3)$

$At\ B, displacement \quad s = x, u = 0, V = V_B\ and\ a = +g$

We know that $V^2 - U^2 = 2as \Rightarrow V_B{}^2 = 2gx$

$\therefore K.E = \frac{1}{2}mV_B{}^2 = \frac{1}{2}m(2gx) = mgx \ldots\ldots\ldots(4)$

From (3) & (4) $\boldsymbol{TE = PE + KE = mgh - mgx + mgx = mgh} \ldots (\boldsymbol{B})$

5) At Point C: Let the body hits the ground at C, So height of the body h=0

$\therefore PE = mgh = mg(0) = 0 \ldots\ldots.(5)$

$At\ C, displacement \quad s = h,\ u = 0, V = V_C\ and\ a = +g$

We know that $V^2 - U^2 = 2as \Rightarrow V_C{}^2 = 2gh$

$\therefore \boldsymbol{K.E = \frac{1}{2}mV_C{}^2 = \frac{1}{2}m(2gh) = mgh} \ldots\ldots\ldots(\boldsymbol{6})$

From (5) & (6) $\boldsymbol{TE = PE + KE = 0 + mgh = mgh} \ldots (\boldsymbol{C})$

From (A). (B), (C) it is clear that the total energy T.E is always constant Hence, the law of conservation of energy is proved.

LAQ:2. Develop the notions of work and kinetic energy show that it leads to work - energy theorem?

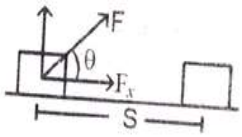
A. **Work**: Work is defined as the product of force in the direction of displacement and magnitude of the displacement.

Consider a body of mass 'm' undergoing a displacement's' by applying a force 'F' making an angle 'θ' with the horizontal.

Work, W = (F cos θ) S= FS cos θ

The work done by a force, can be either positive, negative or zero.

If $0^0 < \theta < 90^0$ Then work done is positive. If $\theta = 90^0 <$ then work done is zero.



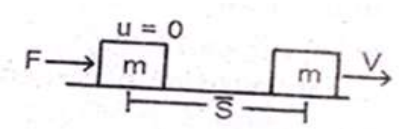
If $90^0 < \theta < 180^0$ then work done is negative.

Kinetic energy : is the energy processed by a body by virtue of its motion.

Consider a body of mass 'm' at rest. By applying force 'F' on it, its attains a velocity 'v'

Then work done on the body is, W = FS cos θ = FS cos (0) = FS ($\because \theta = 0^0 \Rightarrow \cos 0 = 1$)

$\Rightarrow$ W = maS…….. (1) ($\because$ F= ma)



According to $V^2 - U^2 = 2aS$,

$V^2 = 2aS \Rightarrow aS = \frac{v^2}{2}$ …… (2) ($\because$ U = 0)

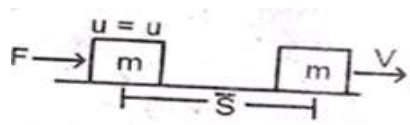
From equation (1) and (2), W $= m\left(\frac{v^2}{2}\right) = \frac{1}{2}mv^2$

This work done on the body to move it with a velocity v is equal to its Kinetic energy.

$\therefore$ Kinetic energy, K.E $= \frac{1}{2}mv^2$

Work - Energy Theorem: The work done on a body by the net force is equal to change in its Kinetic energy.

Consider a body of mass 'm' moving with a initial velocity 'u'. By applying a force 'F' on it, it attains a velocity 'v'. Then



Work done, $W = FS\cos\theta = FS\cos(0) = FS$

$\Rightarrow$ $W = maS$.....(1) $(\because F = ma)$

From $V^2 - U^2 = 2aS$ $\Rightarrow$ $aS = \dfrac{V^2 - U^2}{2}$.....(2)

From equation (1) and (2), we get,

$$W = m\left(\frac{V^2 - U^2}{2}\right) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 \quad \Rightarrow W = K.E_f - K.E_i$$

LAQ:3. What are collisions? Explain the possible types of collisions? Develop the theory of one dimensional elastic collision.

Ans: Collision: Collision is the interaction between two or more bodies that results in sudden change in momentum.

Types of Collisions:

(i) Elastic Collision (ii) Inelastic collision

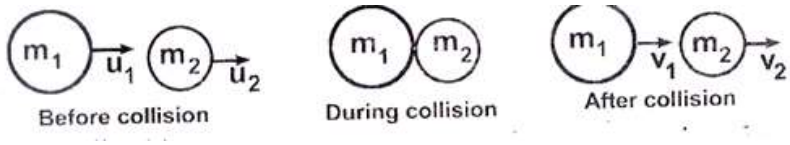
Elastic Collision: The collision in which both momentum and kinetic energy are conserved is called elastic collision.

Examples:
Collision between hard billiard balls, Collision between fundamental particles etc.

Inelastic Collisions:
The collision in which, momentum alone is conserved, is called inelastic collision.

Examples:
Collision between any two vehicles.

One Dimensional Elastic Collision:



Consider two bodies 'A' and 'B' of masses m1 and m2 are moving along the same straight line in the same direction. Let u1, u2 be their velocities before collision (u1 > u2) and V1, V2 be the velocities after collision. According to law of conservation of linear momentum,

Total momentum before collision = Total momentum after collision

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad \Rightarrow m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$

$\Rightarrow m_1(u_1 - v_1) = m_2(v_2 - u_2)$.....(1)

According to law of conservation of kinetic energy

$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \quad \Rightarrow m_1u_1^2 + m_2u_2^2 = m_1v_1^2 - m_2v_2^2$

$\Rightarrow m_1u_1^2 - m_1v_1^2 = m_2v_2^2 - m_2u_2^2 \quad \Rightarrow m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$

$\Rightarrow m_1(u_1 + v_1)(u_1 - v_1) = m_2(v_2 + u_2)(v_2 - u_2)$.....(2)

On dividing equation (2) with equation (1) we get

$\frac{m_1(u_1 + v_1)(u_1 - v_1)}{m_1(u_1 - v_1)} = \frac{m_2(v_2 + u_2)(v_2 - u_2)}{m_2(v_2 - u_2)} \quad \Rightarrow u_1 + v_1 = v_2 + u_2 \Rightarrow u_1 - u_2 = v_2 - v_1$.....(3)

$\therefore$ Relative velocity of approach = Relative velocity of separation

To Find v_1: From equation (3), $v_2 = u_1 - u_2 + v_1$ .....(4)

From equation (4) and (1), we get, $m_1(u_1 - v_1) = m_2(u_1 - u_2 + v_1 - u_2)$

$\Rightarrow m_1u_1 - m_1v_1 = m_2(u_1 - 2u_2 + v_1) \quad \Rightarrow m_1u_1 - m_1v_1 = m_2u_1 - 2m_2u_2 + m_2v_1$

$\Rightarrow m_1u_1 - m_2u_1 + 2m_2u_2 = m_2v_1 + m_1v_1 \quad \Rightarrow (m_1 - m_2)u_1 + 2m_2u_2 = v_1(m_1 + m_2)$

$\Rightarrow \left(\frac{(m_1 - m_2)}{(m_1 + m_2)}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2 = v_1$

To find v_2: From equation (3), $v_1 = v_2 - u_1 + u_2$ ..... (5)

From equation (5) and (1), we get, $m_1(u_1 - v_2 + u_1 - u_2) = m_2(v2 - u_2)$

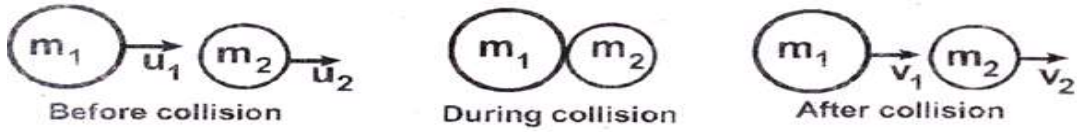
$\Rightarrow m_1(2u_1 - v_2 - u_2) = m_2v_2 - m_2u_2 \quad \Rightarrow 2m_1u_1 - m_1u_2 + m_2u_2 = m_2v_2 + m_1v_2$

$\Rightarrow 2m_1u_1 - (m_2 - m_1)u_2 = (m_2 + m_1)v_2$

$\Rightarrow \left(\frac{2m_1}{(m_1 + m_2)}\right)u_1 + \left(\frac{(m_2 - m_1)}{m_1 + m_2}\right)u_2 = v_2$

LAQ:4. Show that in case of one dimensional elastic collision, the relative velocity of approach of two colliding bodies before collision is equal to the relative velocity of separation after collision.

A.



Consider two bodies of masses m1 and m2 which are moving on a straight line in same direction with velocities u1 and u2 undergo collision. Let v1 and v2 be the velocities of bodies after collision. According to law of conversation of linear momentum,

Total momentum before collision = total momentum after collision

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad \Rightarrow m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$

$\Rightarrow m_1(u_1 - v_1) = m_2(v_2 - u_2)$.....(1)

According to law of conservation of kinetic energy,

kinetic energy before collision = kinetic energy after collision

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \qquad \Rightarrow \frac{1}{2}m_1u_1^2 - \frac{1}{2}m_1v_1^2 = \frac{1}{2}m_2v_2^2 - \frac{1}{2}m_2u_2^2$$

$$\Rightarrow m_1\left(u_1^2 - v_1^2\right) = m_2\left(v_2^2 - u_2^2\right)$$

$$\Rightarrow m_1(u_1 + v_1)(u_1 - v_1) = m_2(v_2 + u_2)(v_2 - u_2).....(2)$$

On dividing equation (2) with equation (1) we get,

$$\Rightarrow u_1 + v_1 = v_2 + u_2 \quad \Rightarrow u_1 - u_2 = v_2 - v_1$$

$\therefore$ Relative velocity of approach before collision is equal to relative velocity of separartion after collision.

LAQ:5. State Newton's second law of motion. Hence derive the equation of motion f = ma from it.
b) A body is moving along a circular path such that its speed always remains constant should there be a force acting on the body

A. **a) Newton's second law of motion:** The rate of change of momentum of a body is directly proportional to the net force acting on the body and it takes place in the direction of force.

To derive F = ma:

Consider a body of mass 'm' moving with velocity 'v'. Let its velocity be increased by 'dv' in a time interval dt due to an external force F. in the direction of velocity. Let 'dv' is the chane in velocity in a time interval 'dt' From second law of motion ,

$$F \propto \frac{dp}{dt} \Rightarrow F \propto \frac{d}{dt}(mv)(\because P = mv) \Rightarrow F = k.\frac{d}{dt}(mv)$$ (K is proportionality constant)

$$\Rightarrow F = k.m\frac{d}{dt}(v) \Rightarrow F = kma\left(\because \frac{dv}{dt} = a\right)$$

Now, the units of forces are selected so that K becomes unit.
i.e., if m = 1, a=1 and F=1 then K=1.
Where k is proportionality constant

Unit Force:
A force which produces a unit acceleration in a body of unit mass is called a unit force.

F = ma

b) Motion in a Circular Path:

yes, a force is acting on the body. When moving in circular path with constant speed, the tangent drawn at any point on the circular path represents the dirction of velocity speed of the body at the point. The velocity of this body changes at every point due to change in its direction. So body will have centripetal acceleration and the corresponding force is called centripetal force.

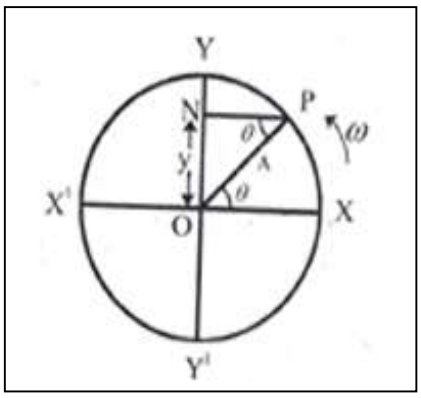
LAQ:6. Define Simple Harmonic Motion? Show that the projection of uniform circular motion on any diameter is simple harmonic.

A. **Definition:** A body is said to be in S.H.M, if it moves to nad fro about its mean position such that , any point its acceleration is directly proportional to its displacement in magnitude but opposite in direction and is directed always towards the mean position''.

Motion of projection of a particle in uniform circular motion, on any diameter is simple harmonic : Consider a particle moving on the circumference of a circle of radius 'A' with uniform angular velocity 'ω'. Let 'O' be the centre of the circle and XX^1 and YY^1 are two mutually perpendicular diameters of the circle as shown in figure. Let PN be perpendicular drawn to the diameter YY^1 from 'P'.

As 'P' moves on the circumference of the circle, foot of the perpendicular N moves to and fro about the center 'O' on the diameter YY^1.

Let us consider a particle present at point 'P' at any instant of time 't' during its oscillation, The angular displament of the particle is, $\theta = \omega t$ .....(1) From OPN, $\sin\theta = \frac{ON}{OP}$



$$\Rightarrow ON = (OP)\sin\theta = A\sin\theta$$

$\therefore$ Displacement of N executing simple Harmonic motion, ON = Y = A Sin θ

$$\Rightarrow Y = A\sin\omega t \qquad (\because \theta = \omega t) \text{ ..... (2)}$$

On differentiating displacement equation (2) with respect to time't' we get velocity.

$\therefore$ Velocity of N executing simple harmonic motion, $V = \frac{dy}{dt}$

$$\Rightarrow V = \frac{d}{dt}(A\sin\omega t) = A\ \omega\cos\omega t \text{ ..... (3)}$$

On differentiating velocity equation (3) with respect to time't' we get acceleration.

$\therefore$ Acceleration of N executing simple harmonic motion, $a = \frac{dv}{dt}$

$\Rightarrow a = \frac{d}{dt}(A\omega \cos\omega t) = -A\omega^2 \sin\omega t = -\omega^2 y$

$\therefore$ Acceleration of 'N' is, $a = -\omega^2 y$.....(4) $\Rightarrow a \propto -y$ ($\because \omega$ is Constant)

Acceleration of 'N' is directly proportional to displacement 'y' in magnitude but in opposite in direction and acting towards the fixed point 'O'.

Hence motion of 'N' is simple harmonic.

Thus the projection of a particle performing uniform circular motion on a diameter is simple harmonic.

LAQ:7. Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is second's pendulum?

A. **Time period of simple pendulum**: consider a simple pendulum of length 'L' having a metal bob of mass 'm'.

Let 'θ' be the angle made by string of pendulum with the vertical

$\therefore$ Angular displacement, $\theta = \frac{arc}{radius} = \frac{x}{L}$.....(1)

The weight of the metal bob (mg) can be resolved into two components (mg sin θ) and (mg cos θ).

The component 'mg cosθ' is balanced by the tension in the string and the component 'mg sin θ' provides restoring force.

$\therefore$ Restoring force, F = - mg sin θ

$\Rightarrow$ ma = -mg sin θ ($\because$ F = ma)

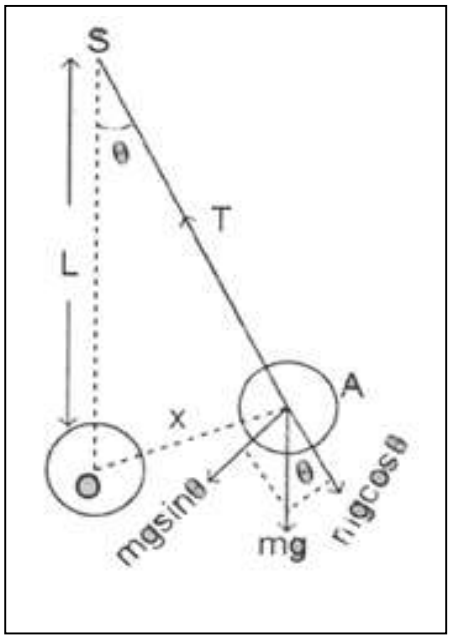
$\Rightarrow$ a = - g sin θ

As 'θ' is very small sin θ $\cong$ θ

$\therefore$ Acceleration of the bob, $a = -g\theta = -g\left(\frac{x}{L}\right)$

$\Rightarrow a = -\left(\frac{g}{L}\right)x$.....(3)

$\Rightarrow a \propto -x$ $\left(\because \frac{g}{L} \text{ is constant}\right)$



Here acceleration is directly proportional to displacement 'x' in magnitude but in opposite in direction and acting towards mean position. Hence motion of bob is simple harmonic

Comparing the equation (3) with general equation of acceleration of simple harmonic Oscillator, $a = -\omega^2 x$.

We get, $\omega^2 = \frac{g}{L} \Rightarrow \omega = \sqrt{\frac{g}{L}}$

$$\Rightarrow \frac{2\pi}{T} = \sqrt{\frac{g}{L}} \left(\because \omega = \frac{2\pi}{T}\right)$$

$\therefore$ Time period of simple pendulum, $T = 2\pi\sqrt{\frac{L}{g}}$

Seconds Pendulum: A pendulum whose time period is 2 seconds is called seconds pendulum.

LAQ:8. Derive the equation for the Kinetic energy and potential energy of simple harmonic Oscillator and show that the total energy of a particle in simple harmonic motion is constant at any point on its path.

A. **Kinetic Energy** :

The displacement of a simple harmonic Oscillator is, $Y = A \sin \omega t$ .....(1)

On Differentiating above equation with respect to time't' we get velocity

$\therefore$ Velocity of simple harmonic oscillator, $V = \frac{dy}{dt} = \frac{d}{dt}(A \sin \omega t)$

$$\Rightarrow V = A\omega \cos \omega t = A\omega\sqrt{1 - \sin^2 \omega t}$$

$$\Rightarrow V = A\omega\sqrt{1 - \frac{y^2}{A^2}} = \omega\sqrt{A^2 - y^2} \text{ .....(2)}$$

$\therefore$ Kinetic energy of simple harmonic oscillator, $KE = \frac{1}{2}mv^2$

Where m is mass of Oscillator

$$\Rightarrow KE = \frac{1}{2}xmx\left(\omega\sqrt{A^2 - Y^2}\right)^2 = \frac{1}{2}m\omega^2\left(A^2 - Y^2\right) \text{ .....(3)}$$

Potential Energy : Work done against restoring force to produce a displacement of 'Y' in simple harmonic Oscillation is equal to its potential energy.

Work done, W = Average force x Displacement

$$\Rightarrow w = \frac{F}{2}xY\left(\because \text{Average force} = \frac{O + F}{2} = \frac{F}{2}\right)$$

$$\Rightarrow w = \frac{ma\,x\,y}{2}(\because F = ma)$$

$$\Rightarrow w = \frac{m\,x\,y}{2}\left(\omega^2 y\right)\left(\because a = \omega^2 y\right) \quad \Rightarrow W = \frac{1}{2}m\omega^2 y^2$$

This work done is stored in the form of its potential energy

$\therefore$ Potential energy of simple harmonic oscillator, $PE = \frac{1}{2}m\omega^2 y^2$ .....(4)

Total Energy:

Total energy of simple harmonic oscillator, TE = KE+ PE

$$\Rightarrow TE = \frac{1}{2}m\omega^2 y^2 + \frac{1}{2}m\omega^2\left(A^2 - Y^2\right)$$

$$\Rightarrow TE = \frac{1}{2}m\omega^2 y^2\left(Y^2 + A^2 - Y^2\right) = \frac{1}{2}m\omega^2\ A^2 \text{ ....(5)}$$

$\Rightarrow TE = \text{Constant}$ ($\therefore$ m, ω and A are constant)

From above equation we can say total energy of a simple harmonic oscillator is constant.

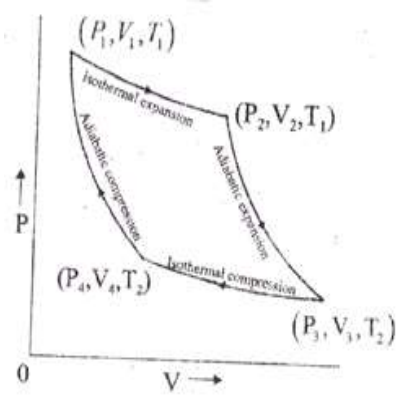
LAQ:9. Explain reversible and irreversible processes. Describe the working of a Carnot engine.

A. **Reversible Process:** A process that can be retraced back in the opposite direction is called reversible process.

EX: Fusion of ice and vaporization of water.

Irreversible process: A process that cannot be retracted back in the opposite direction is called irreversible process.

EX: Diffusion of gases.



Cannot Engine: A reversible heat engine operating between two temperatures is called a Carnot engine.

Working of Carnot engine: The Carnot engine undergoes a cycle of process called Carnot cycle. It consists of two isothermal processes connected by two adiabatic processes. Ideal gas act as a working substance in cannot engine.

Isothermal expansion (step 1 $\rightarrow$ 2): In isothermal expansion **state** of ideal gas changes from (P_1, V_1, T_1) to (P_2, V_2, T_2). In this process, heat absorbed by the gas (Q_1) from the source at temperature (T_1) is equal to work done by the gas on the environment.

$\therefore$ Work done by the gas on the environment, $W_1 = Q_1 = \mu RT_1 \text{ in } \left(\frac{V_2}{V_1}\right)$ .....(1)

Adiabatic expansion (step 2 $\rightarrow$ 3) : In isothermal compression, state of ideal gas changes from (P_2, V_2, T_1) to (P_3, V_3, T_2)

$\therefore$ Work done by the gas, $W_2 = \frac{\mu R}{\gamma - 1}(T_1 - T_2)$ .....(2)

Isothermal Compression (step 3 $\rightarrow$ 4): In isothermal compression **state** of ideal gas changes from (P_3, V_3, T_2) to (P_4, V_4, T_2). In this process, heat released by the gas reservoir at temperature T_2 is equal to work done by the gas on the environment.

$\therefore$Work done by the gas on the environment,

$$W_3 = Q_2 = \mu RT_2 \text{ In } \left(\frac{V_4}{V_3}\right) = -\mu RT_2 \text{ in } \left(\frac{V_3}{V_4}\right) \text{..... (3)}$$

Adiabatic Compression (Step 4 $\rightarrow$ 1) : In adiabatic compression, state of ideal gas changes from (P_4, V_4, T_2) to (P_1, V_1, T_1)

$\therefore$ Work done on the gas, $W_4 = \frac{\mu R}{\gamma - 1}(T_1 - T_2) = -\frac{\mu R}{\gamma - 1}(T_1 - T_2)$.....(4)

$\therefore$ Total work done by the ideal gas in one complete cycle is , $W = W_1 + W_2 + W_3 + W_4$

$$\Rightarrow W = \mu RT_1 \text{ In}\left(\frac{V_2}{V_1}\right) + \frac{\mu R}{\gamma - 1}(T_1 - T_2) - \mu RT_2 \text{ In}\left(\frac{V_3}{V_4}\right)\frac{\mu R}{\gamma - 1}(T_1 - T_2)$$

$$\Rightarrow W = \mu RT_1 \text{ In}\left(\frac{V_2}{V_1}\right) - \mu RT_2 \text{ In}\left(\frac{V_3}{V_4}\right) \text{.....(5)} \qquad \Rightarrow W = Q_1 - Q_2 \text{.....(6)}$$

$\therefore$ Efficiency of Carnot engine,

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} \Rightarrow \eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{\mu RT_2 \ln\left(\frac{V_3}{V_4}\right)}{\mu RT_1 \ln\left(\frac{V_2}{V_1}\right)} = 1 - \frac{T_2 \text{ In}\left(\frac{V_3}{V_4}\right)}{T_1 \text{ In}\left(\frac{V_2}{V_1}\right)} \text{.....(6)}$$

For Adiabatic expansion, $T_1V_2^{\gamma-1} = T_2V_3^{\gamma-1} \quad \Rightarrow \left(\frac{V_2}{V_3}\right)^{\gamma-1} = \left(\frac{T_2}{T_1}\right)$.....(7)

For Adiabatic Compression, $T_2V_4^{\gamma-1} = T_1V_1^{\gamma-1} \quad \Rightarrow \left(\frac{V_1}{V_4}\right)^{\gamma-1} = \left(\frac{T_2}{T_1}\right)$.....(8)

From equation (7) and (8), $\left(\frac{V_2}{V_3}\right)^{\gamma-1} = \left(\frac{V_1}{V_4}\right)^{\gamma-1} \quad \Rightarrow \frac{V_2}{V_3} = \frac{V_1}{V_4} \Rightarrow \frac{V_3}{V_4} = \frac{V_2}{V_1}$.....(9)

From equation (6) and (9), efficiency of Carnot engine

LAQ:10. State second law of thermodynamics. How is heat engine different fromrefrigerator?

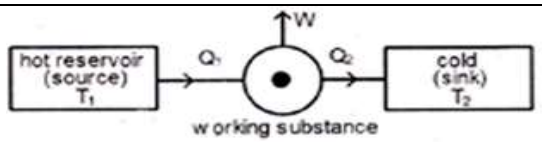
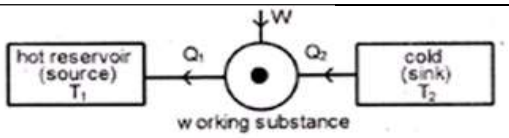
a. **Classis Statement:**

It is impossible for a self acting machine unaided by an external agency to transfer heat from a body at lower temperature to another at a higher temperature.

Kelvin Statement:

It is impossible to construct a heat engine operating in a cycle to convert the heat energy completely into work without any change of working system.

The second law always states that the heat flows from a body at higher temperature to a body at lower temperature. Also it is impossible to construct any heat engine with 100% efficiency.

Heat Engine	Refrigerator
 1.Heat engine will absorb heat energy from source and reject heat energy to the sink. 2. Heat engine converts heat energy into work. 3. In heat engine external work done by the working substances. 4. Efficiency of heat engine is, $\eta = 1 - \frac{Q_2}{Q_1}$ 5. Efficiency of heat engine can never be unity	 1. Refrigerator will extracts heat energy from sink and with the help of external work it delivers heat energy to source. 2. Refrigerator is a heat pump which is reverse of heat engine. 3. In refrigerator external work done on the working substances 4. Coefficient of performance of refrigerator is, $\alpha = \frac{Q_2}{Q_1 - Q_2}$ 5. Coefficient of performance can never be infinite.

LAQ:11. State and explain Newton's Law of cooling. State the conditions under which Newton's Law of cooling is applicable. A body cools down from 60ºC to 50ºC in 5 minutes and to 40ºC in another 8 minutes. Find the temperature of the surroundings.

A. **Newton's law of cooling :** Rate of loss of heat is directly proportional to the difference in temperature between the body and its surroundings provided the difference in temperature is small and the nature of the radiating surface remains same.

Let 'T' be the temperature of hot body, 'Ts' be the temperature of surroundings and dQ/dt be the rate of loss of heat by the hot body, then

$$\frac{dQ}{dt} \alpha (T - Ts) \Rightarrow \frac{dQ}{dt} = -b (T - Ts) \text{ ..... (1)}$$

Here 'b' is called proportionality constant. The value of 'b' depends on nature, shape and area of cooling surface.

Temperature, the $\frac{dQ}{dt} = mc\left(\frac{dT}{dt}\right)$ ..... (2)

On comparing equations (1) and (2) , we get

$$-b\,(T - Ts) = mc\left(\frac{dT}{dt}\right)$$

$$\frac{dT}{dt} = -b/mc\,(T - Ts)$$

Here $\frac{b}{mc}$ is constant and –ve sign indicates that for T > Ts, $\frac{dT}{dt}$ is negative and temperature decreases with time.

Conditions : Newton's law of cooling is applicable when

i. Loss of heat is negligible by conduction and only when it is due to convection.
ii. Loss of heat occurs in a streamlined flow of air.
iii. Temperature of the body is uniformly distributed over it.
iv. Temperature differences are moderate.

Problem: In first case : Initial temperature, $T_1 = 60^0C$; final temperature, $T_2 = 50^0C$

Time of cooling, t = 5 minutes = 5 x 60 = 300 sec.

From Newton's law of cooling, $\frac{dT}{dt} = K\left(\frac{T_1 + T_2}{2} - T_s\right)$

$$\Rightarrow \frac{60-50}{300} = K\left(\frac{50+40}{2} - T_s\right) \quad \Rightarrow \frac{10}{300} = K\,(55-T_s) \quad \Rightarrow \frac{1}{30} = K\,(55 - T_s) \text{.....} (1)$$

In second case : Initial temperature, $T_1 = 50^0$ C; final temperature, $T_2 = 40^0$ C

Time of cooling, t = 8 minutes = 8 x 60 = 480 sec.

From Newton's law of cooling, $\frac{dT}{dt} = K\left(\frac{T_1 + T_2}{2} - T_s\right)$

$$\Rightarrow \frac{dT}{dt} = K\left(\frac{T_1 + T_2}{2} - T_s\right) \quad \Rightarrow \frac{10}{480} = K\,(45 - T_s) \quad \Rightarrow \frac{1}{48} = K\,(45 - T_s) \text{ ..... } (2)$$

From equation (1) and (2)

$$\Rightarrow \frac{48}{30} = \frac{55 - T_s}{45 - T_s} \quad \Rightarrow 2160 - 48\,T_s \quad \Rightarrow 1650 - 30\,T_s \quad \Rightarrow T_s = \frac{510}{18} = 28.3^0\text{ C}$$

Temperature of surroundings, $T_s = 28.3^0$ C