Previous IPE

SOLVED PAPERS

MARCH-2024 (AP)

PREVIOUS PAPERS

IPE: MARCH-2024(AP)

Time : 3 Hours

JR.PHYSICS

Max.Marks : 60

SECTION-A

I. Answer ALL the following VSAQs: $10 \times 2 = 20$

1. Which of the following has symmetry ? (a) acceleration due to gravity (b) law of gravitation
2. The error in measurement of radius of a sphere is 1%. What is the error in the measurement of volume?
3. State Boyle's law and Charles law.
4. What is the acceleration of a projectile at the top of its trajectory?
5. If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.
6. What is the pressure on a swimmer 10m below the surface of a lake?(Take $g=10ms^{-2}$)
7. Define Viscosity. What are it's units and dimensions?
8. What is latent heat of fusion?
9. The roof of buildings are often painted white during summer. Why?
10. The absolute temperature of a gas is increased 3 times. What will be the increase in rms velocity of the gas molecule?

SECTION-B

II. Answer any SIX of the following SAQs: $6 \times 4 = 24$

11. Two balls are projected from the same point in directions 30º and 60º with respect to the horizontal. What is the ratio of their initial velocities if they (a) attain the same height? (b) have the same range?
12. Show that the trajectory of an object thrown at a certain angle with the horizontal is a parabola.
13. Explain the terms limiting friction, dynamic friction and rolling friction.
14. Define angular acceleration and torque. Establish the relation between angular acceleration and torque.
15. Define vector product. Explain the properties of a vector product with two examples.
16. What is a geostationary satellite? State its uses.
17. Define strain and explain the types of strain.
18. Explain conduction, convection and radiation with examples.

SECTION-C

III. Answer any TWO of the following LAQs: $2 \times 8 = 16$

19. What are collisions? Explain the possible types of collisions? Develop the theory of one dimensional elastic collision.
20. (a) Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is seconds pendulum?
    (b) What is the length of a simple pendulum, which ticks seconds?
21. Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency.

IPE AP MARCH-2024
ANSWERS

SECTION-A

1. Which of the following has symmetry ?
(a) acceleration due to gravity (b) law of gravitation

A: Law of gravitation, because it holds good everywhere in the universe.

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2. The error in measurement of radius of a sphere is 1%. What is the error in the measurement of volume?

A: Error in the radius of sphere, $\frac{dr}{r}\times 100 = 1$

Volume of the sphere, $V = \frac{4}{3}\pi r^3$; $dV = \frac{4}{3}\pi \times 3r^2 dr$

$$\frac{dV}{V} = \frac{\frac{4}{3}\pi \times 3r^2 dr}{\frac{4}{3}\pi r^3} = \frac{3dr}{r}$$

$$\Rightarrow \frac{dV}{V} = 3\frac{dr}{r} \Rightarrow \frac{dV}{V}\times 100 = 3\times\frac{dr}{r}\times 100 = 3\times 1 = 3$$

∴ Error in the measurement of volume is 3%.

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3. State Boyle's law and Charles law.

A: 1) **Boyle's law:** Pressure (P)is 'inversely proportional' to its volume(V),at constant temperature(T). for a given mass of gas. Thus $P \propto \frac{1}{V}$, (T is constant) (or) PV = Constant,

2) **Charles law:** Volume(V) is 'directly proportional' to its absolute temperature(T) , at constant pressure(P) for a given mass of gas.

Thus $V \propto T$, (or) $\frac{V}{T}$ = Constant

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4. What is the acceleration of a projectile at the top of its projectory?

A: 1) At the top of its projectory, acceleration is $9.8 ms^{-2}$.
2) The direction of acceleration is vertically downwards.

5. If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.

A: 1) This is due to the **'law of conservation of momentum'.**

2) When the bomb explodes into two pieces, the two pieces must have equal and opposite momenta. So, the pieces must travel in opposite directions.

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6. What is the pressure on a swimmer 10m below the surface of a lake? (Take $g=10ms^{-2}$)

Sol: Pressure $P = P_a + \rho gh$

Here $P_a = 1.01 \times 10^5$ Pa, $h = 10$ m, $\rho = 1000\ kgm^{-3}$

$P = 1.01 \times 10^5 + 1000 \times 10 \times 10 = 2.01 \times 10^5\ Pa \cong 2$ atm

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7. Define Viscosity. What are it's units and dimensions?

A: **1) Viscosity:** The property of a fluid which opposes the relative motion between different layers is called viscosity.

2) S.I units: pa s (or) Nsm^{-2} **3) Dimensions:** $[ML^{-1}T^{-1}]$

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8. What is latent heat of fusion?

A: **Latent heat of fusion of ice:** The latent heat of fusion of ice is the amount of heat required to convert 'unit mass of water' at 0^0C into ice at 0^0C.

For water the latent heat of fusion is 80 $calgm^{-1}$ (or) $3.33 \times 10^5\ Jkg^{-1}$

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9. The roof of buildings are often painted white during summer. Why?

A: 1) **White paint** is a **good reflector of heat.** Good reflector is a bad absorber of heat.

2) So roof of buildings that are painted white to **'keep cool' during summer.**

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10. The absolute temperature of a gas is increased 3 times. What will be the increase in rms velocity of the gas molecule?

A: 1) Let $T_2 = 3T_1$

2) rms velocity $\Rightarrow C \propto \sqrt{T} \Rightarrow \frac{C_1}{C_2} = \sqrt{\frac{T_1}{T_2}}$ of the gas molecule $= C = \sqrt{\frac{3RT}{M}}$

$$\therefore \frac{C_1}{C_2} = \sqrt{\frac{T_1}{3T_1}} \Rightarrow C_2 = \sqrt{3}C_1$$

3) The r.m.s velocity of the gas molecule becomes $\sqrt{3}$ times of initial rms velocity.

4) Increase in r.m.s velocity of the gas molecule $= C_2 - C_1 = \sqrt{3}C_1 - C_1 = 1.732C_1 - C_1 = 0.732C_1$

5) Percentage increase in rms velocity $= \frac{C_2 - C_1}{C_1} \times 100 = 73.2\%$

SECTION-B

11. Two balls are projected from the same point in directions 30° and 60° with respect to the horizontal. What is the ratio of their initial velocities if they (a) attain the same height? (b) have the same range?

Sol: (a) Let u_1 and u_2 be their initial velocities.

Given, maximum height of 1st body = maximum height of 2nd body

$$\Rightarrow \frac{u_1^2 \sin^2 30^\circ}{2g} = \frac{u_2^2 \sin^2 60^\circ}{2g}$$

$$\Rightarrow u_1^2 \times \frac{1}{4} = u_2^2 \times \frac{3}{4} \Rightarrow u_1^2 \times 1 = u_2^2 \times 3$$

$$\Rightarrow \frac{u_1^2}{u_2^2} = \frac{3}{1} \Rightarrow \frac{u_1}{u_2} = \frac{\sqrt{3}}{1}$$

(b) Range of 1st body = Range of 2nd body

$$\Rightarrow \frac{u_1^2 \sin(2\times 30^\circ)}{g} = \frac{u_2^2 \sin(2\times 60^\circ)}{g}$$

$$\Rightarrow u_1^2 \sin 60^\circ = u_2^2 \sin 120^\circ \Rightarrow u_1^2 \times \frac{\sqrt{3}}{2} = u_2^2 \times \frac{\sqrt{3}}{2}$$

$$\Rightarrow u_1^2 = u_2^2 \Rightarrow u_1 = u_2 \Rightarrow u_1 : u_2 = 1:1$$

12. Show that the trajectory of an object thrown at a certain angle with the horizontal is a parabola.

A: 1) Suppose the object P(x,y) is projected from the origin 'O' with an angle of projection θ. Let its initial velocity is u.

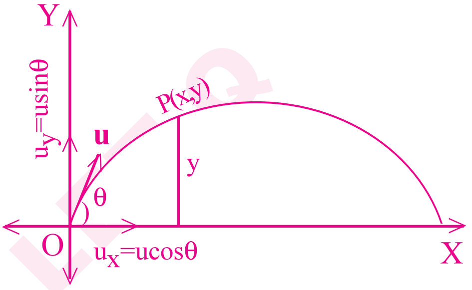
Horizontal component of u is $u_x = u\cos\theta$ and

Vertical component of u is $u_y = u\sin\theta$

2) Motion along horizontal:

Horizontal component of u is $u_x = u\cos\theta$ and $a_x = 0$.

Also Horizontal displacement of P(x, y) is s = x



Now, $s = u_x t + \frac{1}{2} a_x t^2$

$\Rightarrow x = (u\cos\theta)t + \frac{1}{2}(0)t^2 = (u\cos\theta)t$

$\Rightarrow t = \frac{x}{u\cos\theta}$ ....(i)

3) Motion along vertical direction:

Super Sixer 'Q'.
But U get only '4'

Here, Vertical component of u is $u_y = u\sin\theta$ and $a_y = -g$

Also Vertical displacement of P(x,y) is s = y

Now, $s = u_y t + \frac{1}{2} a_y t^2$

$\Rightarrow y = (u\sin\theta)t - \frac{1}{2}gt^2$.......(ii)

4) From (i) & (ii) we get

$$y = \cancel{u}\sin\theta\left(\frac{x}{\cancel{u}\cos\theta}\right) - \frac{1}{2}g\left(\frac{x}{u\cos\theta}\right)^2 = \left(\frac{\sin\theta}{\cos\theta}\right)x - \frac{g}{2}\left(\frac{x^2}{u^2\cos^2\theta}\right)$$

$$\Rightarrow y = (\tan\theta)x - \left(\frac{g}{2u^2\cos^2\theta}\right)x^2$$

This equation is in the form $y = Ax - Bx^2$ .....(iii) where $A = \tan\theta;\ B = \frac{g}{2u^2\cos^2\theta}$

Here, (iii) represents the equation of a Parabola.

So, the Trajectory of a projectile is a Parabola.

13. Explain the terms limiting friction, dynamic friction and rolling friction.

A: 1) **Limiting friction (f_L):** It is the maximum value of static friction between the contact surfaces when the body is just ready to slide over a surface.

2) **Kinetic/Sliding/dynamic friction (f_k) :** The resistive force encountered by a sliding body on the surface is known as kinetic friction (or) sliding friction.

3) **Rolling friction (f_r):** The resistive force encountered by a rolling body on the surface is known as rolling friction.

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14. Define Angular acceleration and Torque. Establish the relation between angular acceleration and torque.

A: 1) **Angular acceleration(α):** Rate of change of angular velocity(ω) is called angular acceleration.

Formula: Angular acceleration, $\alpha = \frac{d\omega}{dt}$ ....(i)

2) **Torque(τ):** The turning effect about an axis of rotation is called torque.

Torque is the rate of change of angular momentum(L).

Formula: Torque, $\tau = \frac{dL}{dt}$ ....(ii)

3) **Relation between angular acceleration(α) and torque(τ):**

If I is moment of inertia of a rotating body with angular velocity 'ω' then its

Angular momentum is $L = I\omega$

4) On differentiating the above equation w.r.t time 't' we get, $\frac{dL}{dt} = I\frac{d\omega}{dt}$

$\therefore$ from (i) & (ii) we get $\tau = I\alpha$

15. Define vector product. Explain the properties of vector product with 2 examples.

A: **1) Vector Product:** The vector product of two vectors $\bar{a}, \bar{b}$ with angle θ between them, is $\bar{a} \times \bar{b} = |\bar{a}||\bar{b}|\sin\theta\, \hat{n}$

Here, $\hat{n}$ is the unit vector normal to the plane of $\bar{a}, \bar{b}$.

2) Properties of Vector Product :

(i) Commutative law is not satisfied: $\bar{a} \times \bar{b} \neq \bar{b} \times \bar{a}$

(ii) Distributive law is satisifed : $\bar{a} \times (\bar{b} + \bar{c}) = (\bar{a} \times \bar{b}) + (\bar{a} \times \bar{c})$

(iii) Vector product of two parallel vectors is null vector.

Ex: $\bar{i} \times \bar{i} = \bar{j} \times \bar{j} = \bar{k} \times \bar{k} = \bar{o}$

(iv) Vector product of two perpendicular unit vectors is unit normal vector.

Ex: $\bar{i} \times \bar{j} = \bar{k}$, $\bar{j} \times \bar{k} = \bar{i}$, $\bar{k} \times \bar{i} = \bar{j}$

3) Examples : Torque $\bar{\tau} = \bar{r} \times \bar{F}$; Velocity $\bar{v} = \bar{\varpi} \times \bar{r}$

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16. What is a geostationary satellite? State its uses.

A: **I) Geostationary satellite :** If the period of revolution of an artificial satellite is equal to the period of rotation of the earth then such a satellite is called geostationary satellite.

II) Uses :

Geostationary satellites can be used to

1) Study the upper layers of the atmosphere.
2) Forecast the changes in the atmosphere.
3) Know the shape and size of the earth.
4) Transmit the T.V programmes to distant places.
5) Identify the minerals and natural resources present inside and on the surface of the earth.

17. Define strain and explain the types of strain. [AP 22, 24] [TS 16]

A: Strain: The ratio of change in the dimension of a body to the original dimension is called strain.

$$\text{Strain} = \frac{\text{Change in dimension}}{\text{Original dimension}}$$

Different types of strain :

i) **Longitudinal strain:** The ratio of the change in length of a body to the original length of the body is called longitudinal strain.

$$\text{Longitudinal strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{e}{l}$$

ii) **Volume strain:** The ratio of the change in volume of a body to the original volume of the body is called volume strain.

$$\text{Volume strain} = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\Delta V}{V}$$

iii) **Shearing strain:** Shearing strain is the ratio of the displacement of a layer to its distance from the fixed layer.

$$\text{Shearing strain } \theta = \frac{x}{l}$$

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18. Explain conduction, convection and radiation with examples.

A: 1) **Conduction:** Transfer of heat from one place to another place **without the actual movement** of the particles is called conduction.

Ex: Heat transfer from the hot end of the rod to the other end.

2) **Convection:** Transfer of heat from one place to another place **with the actual movement** of particles is called convection.

Ex: Sea breeze, Land breeze, Trade wind.

3) **Radiation:** Transfer of heat from one place to another place **without the help of the material** of the medium is called Radiation. Radiation is the quickest mode of heat transmission.

Ex: Transfer of heat energy from the Sun to Earth.

SECTION-C

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

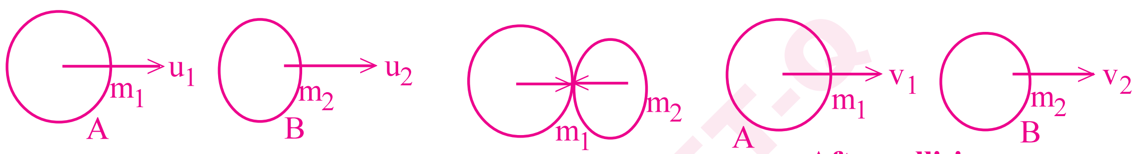
A. 1) **Collision:** It is a strong interaction between bodies, in a very short interval of time, which involves exchange of their momenta. Collisions are of two types.

2) **Elastic collision:** It is the collision in which both Momentum and Kinetic energy are conserved.
Ex: Collision between gas molecules

3) **Inelastic collision:** It is the collision in which only Momentum is conserved but not K.E.
Ex: Collision between a bullet and its target

4) **One dimensional elastic collision:**

Consider two spheres A and B of masses m_1 and m_2 moving with initial velocities u_1 and u_2 undergo an elastic collision . Let v_1 ,v_2 be the velocities after collision .



Before collision **During collision** **After collision**

5) From the law of **conservation of momentum,**
Total momentum before collision = Total momentum after collision.

$\Rightarrow m_1u_1+m_2u_2 = m_1v_1+m_2v_2$ ....(i) $\Rightarrow m_1(u_1-v_1) = m_2(v_2-u_2)$..........(ii)

6) From the law of **conservation of K.E,**
Total K.E before collision = Total K.E after collision.

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

$$\Rightarrow m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2) \text{ -------(iii)}$$

$$\text{Now, } \frac{(iii)}{(ii)} \Rightarrow \frac{m_1(u_1^2 - v_1^2)}{m_1(u_1 - v_1)} = \frac{m_2(v_2^2 - u_2^2)}{m_2(v_2 - u_2)} \Rightarrow \frac{(u_1 + v_1)(u_1 - v_1)}{(u_1 - v_1)} = \frac{(v_2 + u_2)(v_2 - u_2)}{(v_2 - u_2)}$$

$\Rightarrow u_1 + v_1 = v_2 + u_2$. Hence $v_1 = v_2 + u_2 - u_1$ ....(iv). Also $v_2 = u_1 + v_1 - u_2$ .....(v)

7) **To find v_1:** From (i) & (v) we get

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

$$\Rightarrow m_1u_1 + 2m_2u_2 = v_1(m_1 + m_2) + m_2u_1 \Rightarrow v_1(m_1 + m_2) = m_1u_1 - m_2u_1 + 2m_2u_2$$

$$\Rightarrow v_1(m_1 + m_2) = (m_1 - m_2)u_1 + 2m_2u_2 \Rightarrow \boxed{v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2}$$

8) **To find v_2:** From (i) & (iv) we get

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

$$\Rightarrow 2m_1u_1 + m_2u_2 - m_1u_2 = m_1v_2 + m_2v_2 \Rightarrow v_2(m_1 + m_2) = 2m_1u_1 + (m_2 - m_1)u_2$$

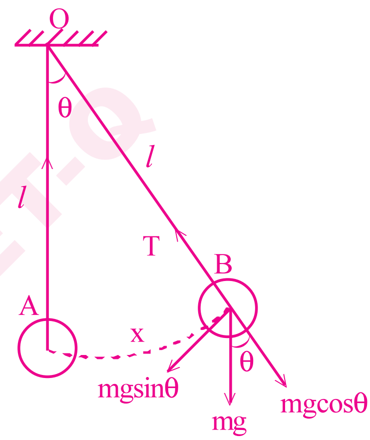
$$\Rightarrow \boxed{v_2 = \left(\frac{2m_1}{m_1 + m_2}\right)u_1 + \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2}$$

20. Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is seconds pendulum?

A: (a) To show that motion of simple pendulum is simple harmonic:

1) Consider a simple pendulum of length 'l', mass 'm' suspended from a rigid support as shown in the figure.
Let the bob makes an angle 'θ' with the vertical at an instant.

2) The weight 'mg' is resolved into two perpendicular components.
One component 'mgcosθ' balances the 'tension(T)'.
The other component 'mgsinθ' provides 'restoring force(F)'.



3) Restoring force is given by $F = -mg\sin\theta$

But we know $F = ma$

$\therefore \cancel{m}a = -\cancel{m}g\sin\theta$

$\Rightarrow a = -g\sin\theta$

$\Rightarrow a = -g\,\theta$ ....(i)[when θ is very small, sinθ=θ]

4) Also $\theta = \dfrac{x}{l}$ $\quad [\because x = r\theta$ as arc length = radius × angle]

From (i), $a = -g\left(\dfrac{x}{l}\right) \Rightarrow a = -\left(\dfrac{g}{l}\right)x$ ....(ii)

5) From (ii), $a \propto -x$, $\left(\because \left(\dfrac{g}{l}\right)\text{ is constant}\right)$

Hence, proved that the motion of the simple pendulum is S.H.M.

(b) Derivation for time period T:

6) If ω is angular velocity of the bob then its acceleration is $a = -\omega^2 x$.............(iii)

Equating (iii) & (ii) we get, $\cancel{-}\omega^2 \cancel{x} = \cancel{-}\left(\dfrac{g}{l}\right)\cancel{x} \Rightarrow \omega^2 = \dfrac{g}{l} \Rightarrow \omega = \sqrt{\dfrac{g}{l}}$.

7) Time period $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{\sqrt{\dfrac{g}{l}}} = 2\pi\sqrt{\dfrac{l}{g}} \qquad \therefore T = 2\pi\sqrt{\dfrac{l}{g}}$

(c) Seconds pendulum:

8) A pendulum with time period **2 seconds** is called seconds pendulum.

P. What is the length of a simple pendulum, which ticks seconds?

Sol: The time period of a simple pendulum is given by $T = 2\pi\sqrt{\dfrac{L}{g}} \Rightarrow T^2 = 4\pi^2\dfrac{L}{g} \Rightarrow L = \dfrac{gT^2}{4\pi^2}$

The time period of a simple pendulum, which ticks seconds is $T = 2s$.
Also $g = 9.8\ ms^{-2}$.

$$\therefore L = \frac{9.8(ms^{-2}) \times 4(s^2)}{4\pi^2} \approx 1\,m$$

21. Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency.

A: **1) Reversible process:** A process that can be 'retraced back' in the opposite direction is called a reversible process.

Ex: Fusion of ice and vaporisation of water.

2) Irreversible process: A process that can not be retraced back in the opposite direction is called an irreversible process.

Ex: Work done against friction.

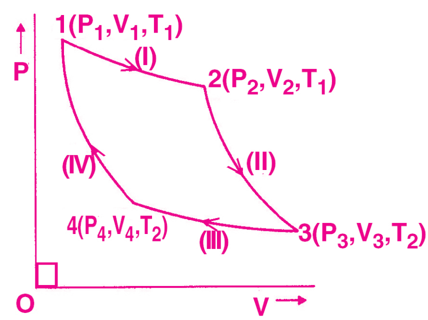
3) Carnot engine: A reversible heat engine operating between two temperatures is called Carnot engine.

Working of Carnot engine: The carnot engine undergoes a cycle of four processes called carnot cycle. It consists of two isothermal processes connected by two adiabatic processes. Ideal gas acts as the working substance in the carnot engine.

4) The 4 steps of Carnot cycle:

a) Step I: Isothermal Expansion(IE) of the gas from $1(P_1,V_1,T_1)$ to $2(P_2,V_2,T_1)$.

Work done by the gas on the environment = Heat(Q_1) absorbed by the gas, from the reservoir, at constant temperature (T_1).



$$W_1 = Q_1 = nRT_1\log_e\left(\frac{V_2}{V_1}\right) \text{ - - - - -(i)}$$

b) Step II : Adiabatic Expansion(AE) of the gas from $2(P_2,V_2,T_1)$ to $3(P_3,V_3,T_2)$.

Work done by the gas in this adiabatic process is $W_2 = \frac{nR}{(\gamma-1)}(T_1 - T_2)$ - - - - (ii)

c) Step III : Isothermal Compression(IC) of the gas from $3(P_3,V_3,T_2)$ to $4(P_4,V_4,T_2)$.

Work done on the gas by the environment = Heat(Q_2) released by the gas to the reservoir, at constant temperature(T_2).

$$W_3 = Q_2 = nRT_2\log_e\left(\frac{V_3}{V_4}\right) \text{ - - - - (iii)}$$

d) Step IV: Adiabatic Compression **(AC) of the gas from 4(P_4,V_4,T_2) to 1(P_1,V_1,T_1).**

Work done on the gas in this adiabatic process is $W_4 = \frac{nR}{(\gamma-1)}(T_1 - T_2)$ ---- (iv)

5) $\therefore$ Total work done by the gas in one complete cycle is

$$W = W_1 + W_2 - W_3 - W_4$$

$$= nRT_1\log_e\left(\frac{V_2}{V_1}\right) + \frac{nR}{(\gamma-1)}(T_1-T_2) - nRT_2\log_e\left(\frac{V_3}{V_4}\right) - \frac{nR}{(\gamma-1)}(T_1-T_2)$$

6) $\therefore W = nRT_1\log_e\left(\frac{V_2}{V_1}\right) - nRT_2\log_e\left(\frac{V_3}{V_4}\right)$

7) The efficiency of the Carnot engine is

$$\eta = \frac{W}{Q_1} = \frac{nRT_1\log_e\left(\frac{V_2}{V_1}\right) - nRT_2\log_e\left(\frac{V_3}{V_4}\right)}{nRT_1\log_e\left(\frac{V_2}{V_1}\right)}$$

$$= \frac{T_1\log_e\left(\frac{V_2}{V_1}\right) - T_2\log_e\left(\frac{V_3}{V_4}\right)}{T_1\log_e\left(\frac{V_2}{V_1}\right)}$$

$$= \frac{T_1\log_e\left(\frac{V_2}{V_1}\right)}{T_1\log_e\left(\frac{V_2}{V_1}\right)} - \frac{T_2\log_e\left(\frac{V_3}{V_4}\right)}{T_1\log_e\left(\frac{V_2}{V_1}\right)}$$

$$= 1 - \left(\frac{T_2}{T_1}\right)\frac{\log_e\left(\frac{V_3}{V_4}\right)}{\log_e\left(\frac{V_2}{V_1}\right)}$$

$\because$ **Step (b) & (d) are adiabatic processes.**

$\therefore TV^{\gamma-1} = \text{constant}$

$\Rightarrow T_1V_2^{\gamma-1} = T_2V_3^{\gamma-1}$ and $T_1V_1^{\gamma-1} = T_2V_4^{\gamma-1}$

Dividing the above two equations, we get

$$\frac{T_1V_2^{\gamma-1}}{T_1V_1^{\gamma-1}} = \frac{T_2V_3^{\gamma-1}}{T_2V_4^{\gamma-1}} \Rightarrow \frac{V_2}{V_1} = \frac{V_3}{V_4}$$

8) $\therefore \eta = 1 - \frac{T_2}{T_1}$

☺ 4 CC ☺
Engine Steps
IE
AE
IC
AC