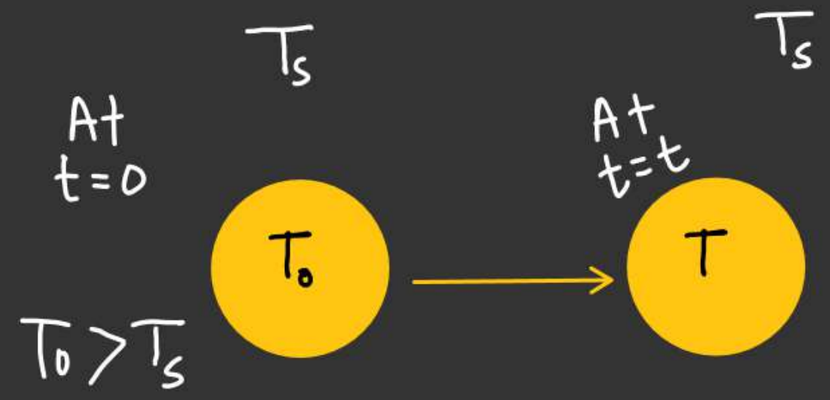
Nishant Jindal

Newton's Law of Cooling



$$-\frac{dT}{dt} = K(T - T_s)$$

$$-\int_{T_0}^{T} \frac{dT}{T - T_s} = K \int_0^t dt$$

$$-\ln\left[T - T_s\right]_{T_0}^{T} = Kt$$

$$\ln\left(\frac{T - T_s}{T_0 - T_s}\right) = -Kt$$

$$T - T_s = (T_0 - T_s)e^{-Kt}$$

$$\boxed{T = T_s + (T_0 - T_s)e^{-Kt}}$$

$\underline{T = T_s}$ when $t \to \infty$.

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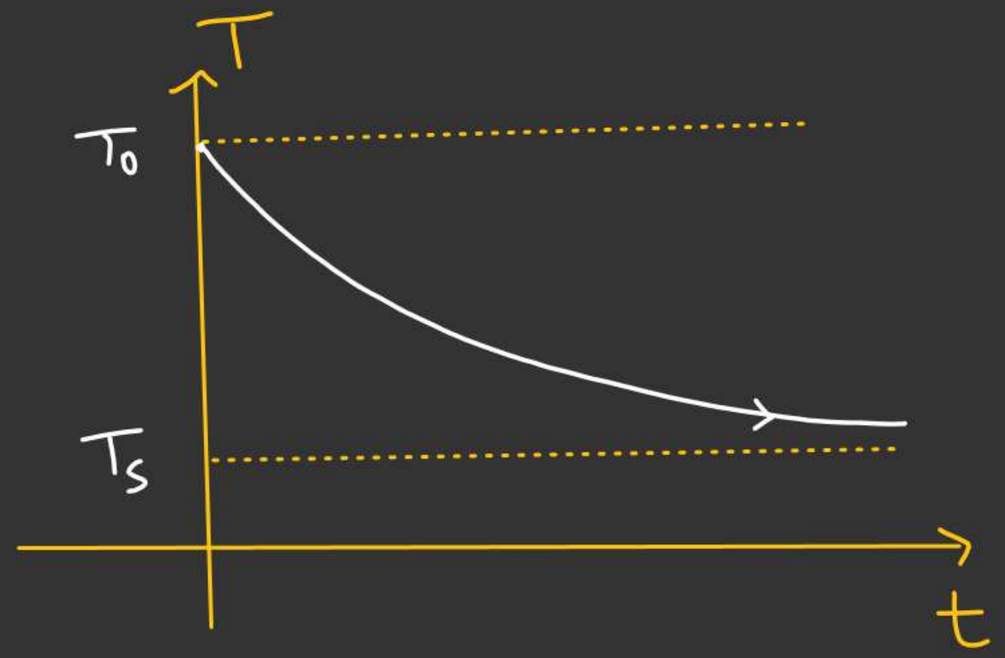
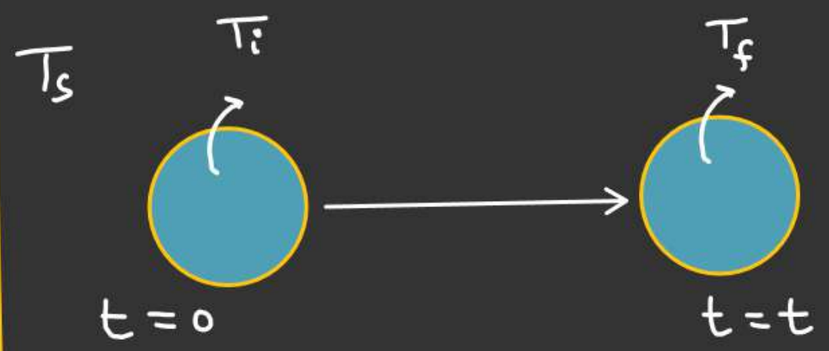


Avg form of Newton's Law of Colling



$$-\frac{dT}{dt} = K(T - T_s)$$

$$T = \left(\frac{T_i + T_f}{2}\right)$$

$dT \to \Delta T$

$dt \to t$

$$-\frac{\Delta T}{t} = K\left(\frac{T_i + T_f}{2} - T_s\right)$$

$$\frac{T_i - T_f}{t} = K\left(\frac{T_i + T_f}{2} - T_s\right)$$

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$$\boxed{\frac{T_i - T_f}{t} = K\left(\frac{T_i + T_f}{2} - T_s\right)}$$

Avg. Method.

#

$T_s = 16^\circ C$

$$40^\circ C \xrightarrow{t = 5\,min} 36^\circ C \xrightarrow{t = ??} 32^\circ C$$

M-1

Integration Method. , At $t = t$, body temp be T

$$-\frac{dT}{dt} = K(T - T_s)$$

$$-\int_{40}^{36} \frac{dT}{T - T_s} = \underset{??}{K} \int_{0}^{5} dt \rightarrow$$

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$T_s = 16^\circ C.$

$$-\int_{40}^{36} \frac{dT}{T-T_s} = K \int_0^5 dt \rightarrow$$

$$-\ln\left[T-T_s\right]_{40}^{36} = 5K$$

$$-\ln\left[\frac{20}{24}\right] = 5K$$

$$-\ln\left(\frac{5}{6}\right) = 5K$$

$$K = \frac{1}{5}\ln\left(\frac{6}{5}\right) \checkmark$$

$36^\circ C \xrightarrow{t = ??} 32^\circ C$

$$-\int_{36}^{32} \frac{dT}{T-T_s} = K \int_0^t dt$$

$\Downarrow$

$t = ??$ ✓

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M-2

Avg. Method.

$$dT \rightarrow \frac{T_i - T_f}{t} = K\left[\left(\frac{T_i + T_f}{2}\right) - T_s\right]$$

T

$dt \leftarrow t$

$$\left(\frac{40-36}{5}\right) = K\left[\left(\frac{40+36}{2}\right) - 16\right]$$

$$K = \frac{0.8}{22}\ \text{min}^{-1}$$

$$K = \frac{8}{220} = \frac{2}{55}\ \text{min}^{-1}$$

$$40^\circ C \xrightarrow{t = 5\,\text{min}} 36^\circ C \xrightarrow{t = ?} 32^\circ C$$

$$\frac{36-32}{t} = \left(\frac{2}{55}\right)\left(\frac{36+32}{2} - 16\right)$$

$t = ??$ ✓

$t = 6.1\,\text{min}$ ✓

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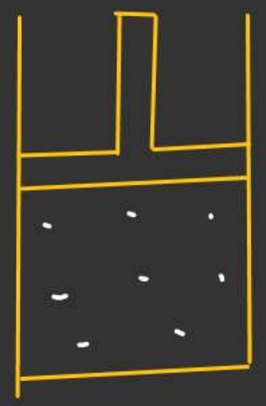
THERMODYNAMICS

- System & Surrounding

System → (The part under observation)

Surrounding → (Other than System is surrounding)



→ (Cylinder + piston) ⇓ System

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THERMODYNAMICS

Thermodynamic Variables

⇒ By the help of which we can defined state of any process

⇒ P, V, T, → Three major thermodynamic Variables.
(ΔU, ΔH)

⇒ Thermodynamic Variables are of two type → State function / Path function

⇒ Variables which only depends on initial & final positions are called state function. Ex:- ΔU,

⇒ Variables which depends on the path. Ex → ΔW

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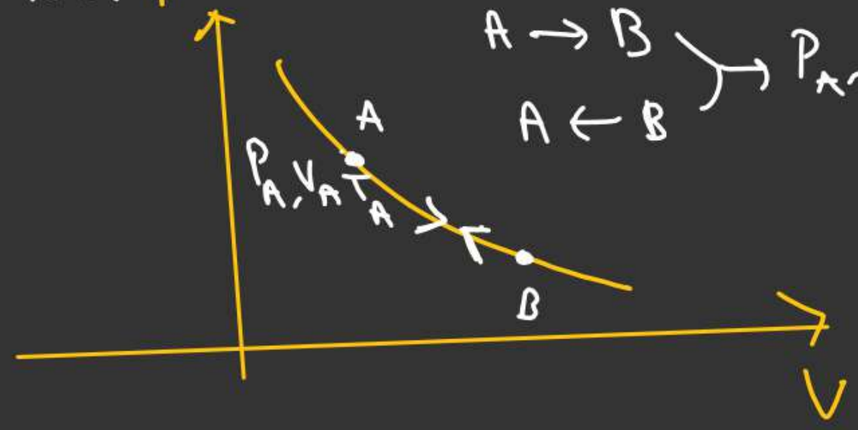
THERMODYNAMICS

Reversible process

- Process occur very slowly
- In Reversible process system is always in equilibrium with surrounding.
- In Reversible process we can again reachive the thermodynamic variables.



$A \rightarrow B$
$A \leftarrow B$ $\rightarrow$ P_A, V_A, T_A $\rightarrow$ doesn't change.

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THERMODYNAMICS

Internal Energy & Change in internal energy

[Internal Energy of gas molecules is the sum of all the energy possess by gas molecules in the form of translational K.E, Rotational K.E & Vibrational energy]

[Internal Energy of a gas Molecules is function of temperature].

$$\Delta U = (U_f - U_i) \rightarrow (\text{State function})$$

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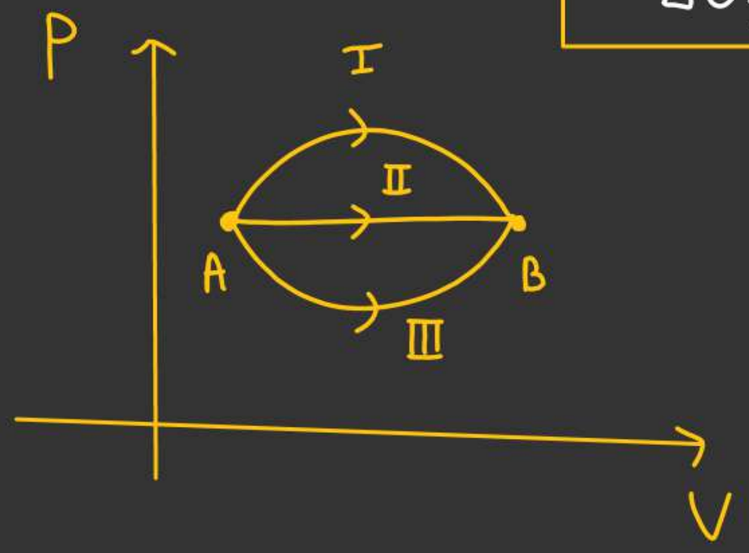
THERMODYNAMICS



$$\boxed{\Delta U_{I} = \Delta U_{II} = \Delta U_{III}}$$

$$\Downarrow$$

$\Delta U \rightarrow$ (state function)

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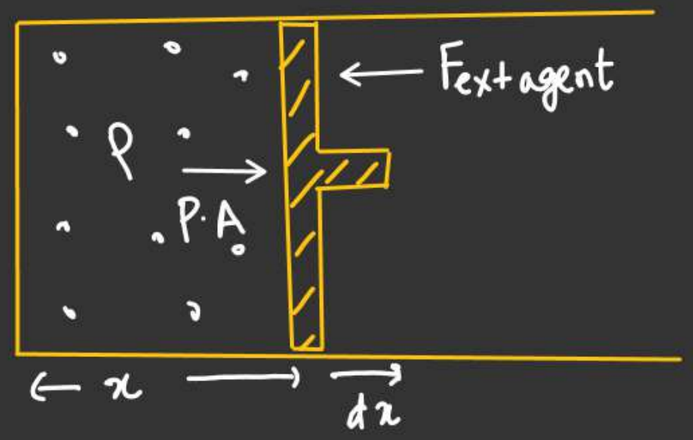
THERMODYNAMICS

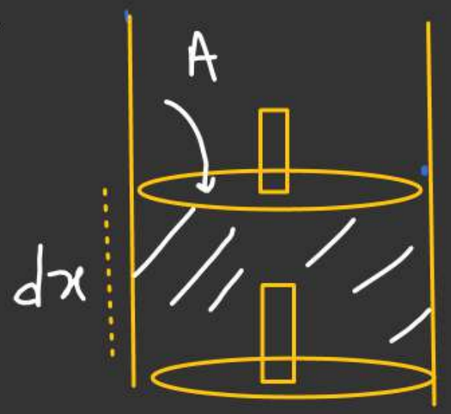
Work done (For reversible process)



$$\int dW_{gas} = \int P\underbrace{A\,dx}_{dV}$$

$dV \rightarrow$ Change in Volume

$$\boxed{W_{gas} = \int P\,dV}$$



$A\,dx = dV$

Since process is reversible

So, $P.A = F_{ext\,agent}$

$$W_{ext\,agent} = \int F_{ext\,agent} \cdot dx \cos\pi$$

$$= -\int P\,A\,dx = -\int P.dV$$

Sign-Convention

$W_{by\ the\ gas}$	$\rightarrow$ +ve
$W_{on\ the\ gas}$	$\rightarrow$ −ve

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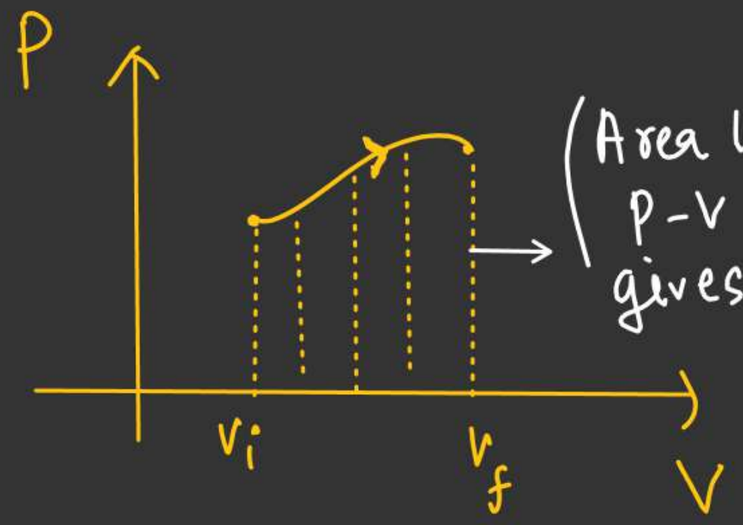
THERMODYNAMICS

$$W = \int_{V_i}^{V_f} P.dV$$



(Area Under P-V Curve gives work done)

(*) During Expansion

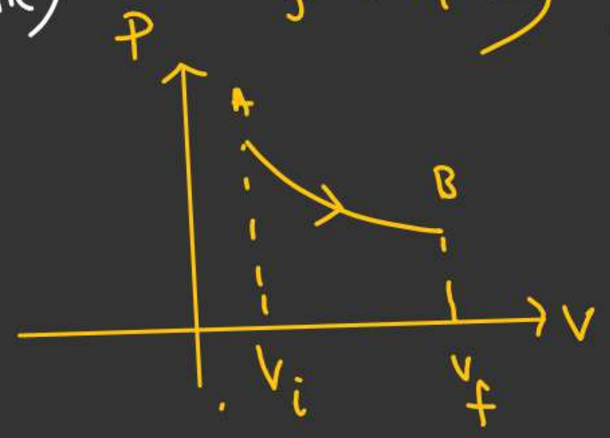
$V_f > V_i \Rightarrow$ gas is doning work

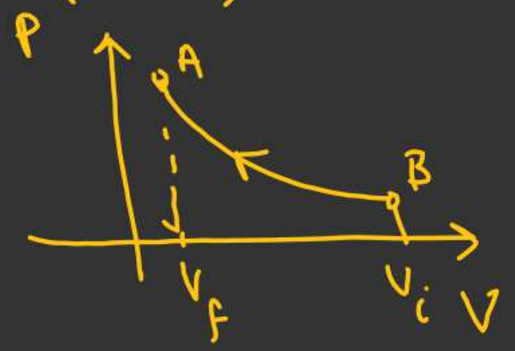
or

Work done by the gas → +ve.

(*) During Compression

$V_f < V_i \Rightarrow$ Work done on the gas (−ve)





$V_f > V_i \Rightarrow W \rightarrow +ve$

$V_f < V_i \Rightarrow W = -ve$

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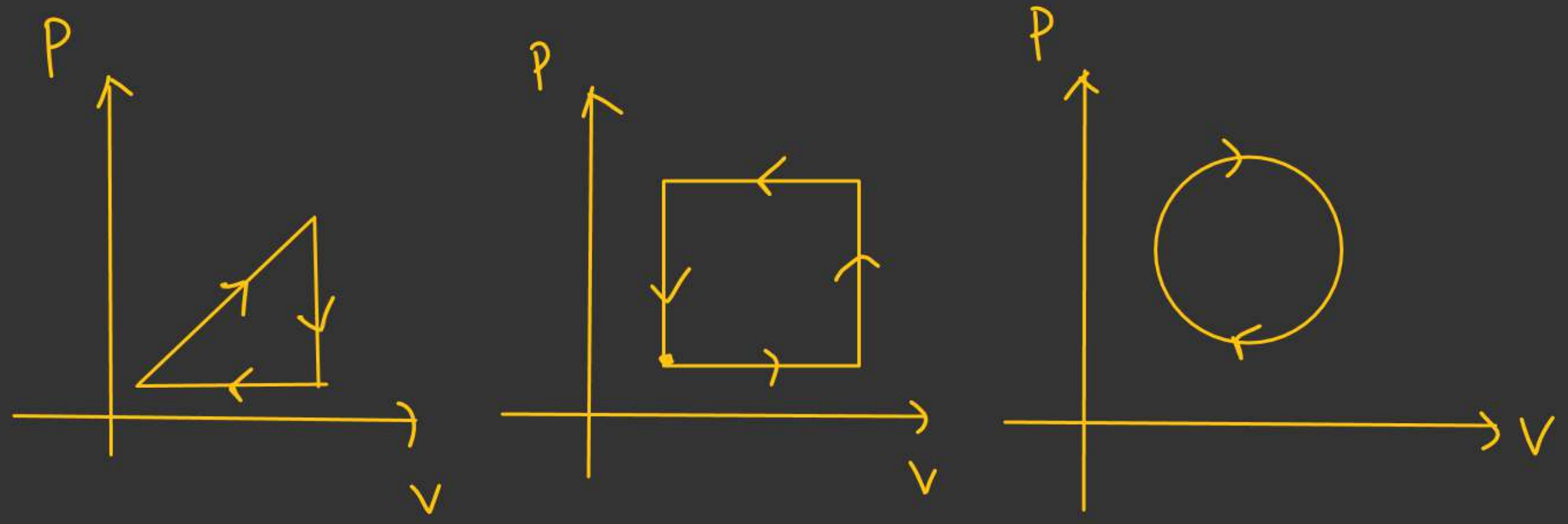
THERMODYNAMICS

Work done in a Cyclic process



$\Rightarrow$ ΔU for all the cyclic process is zero.

(As its initial & final state is same)

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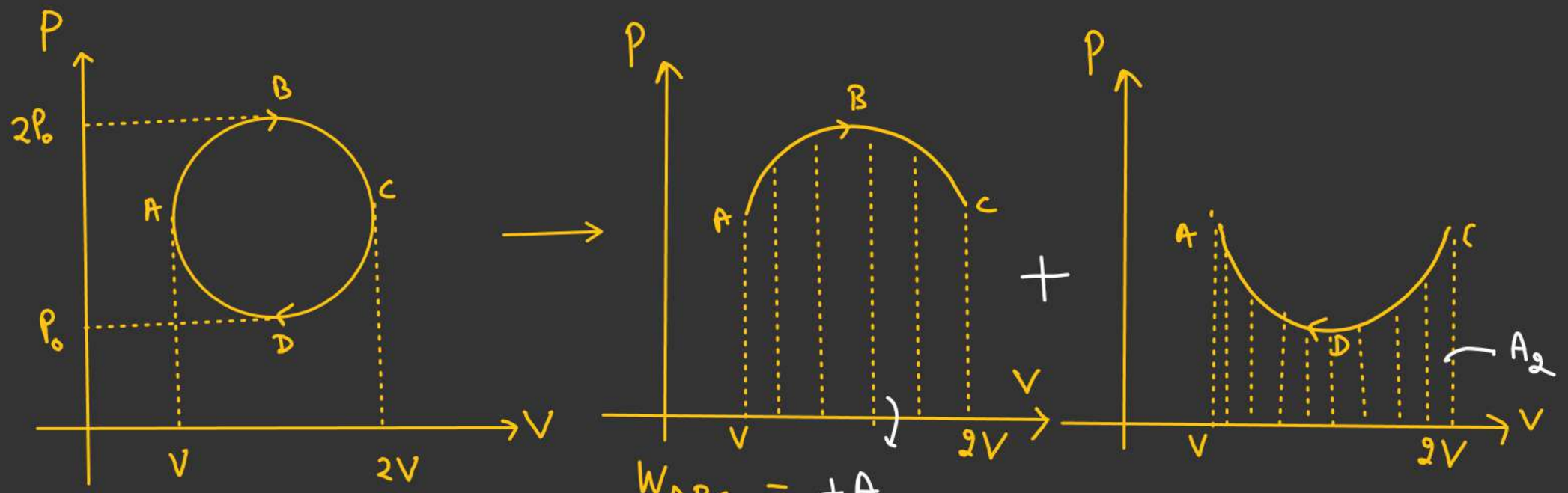
THERMODYNAMICS



$W_{ABC} = +A_1$

⇓

Work done by the gas

$W_{CDA} = -A_2$

⇓

Work done on the gas.

$$W_{net} = (A_1 - A_2) = (\text{Area of Cyclic fig})$$

$W_{net} > 0 \Rightarrow$ If Cycle is Clockwise.

$W_{net} < 0 \Rightarrow$ If Cycle is anticlockwise

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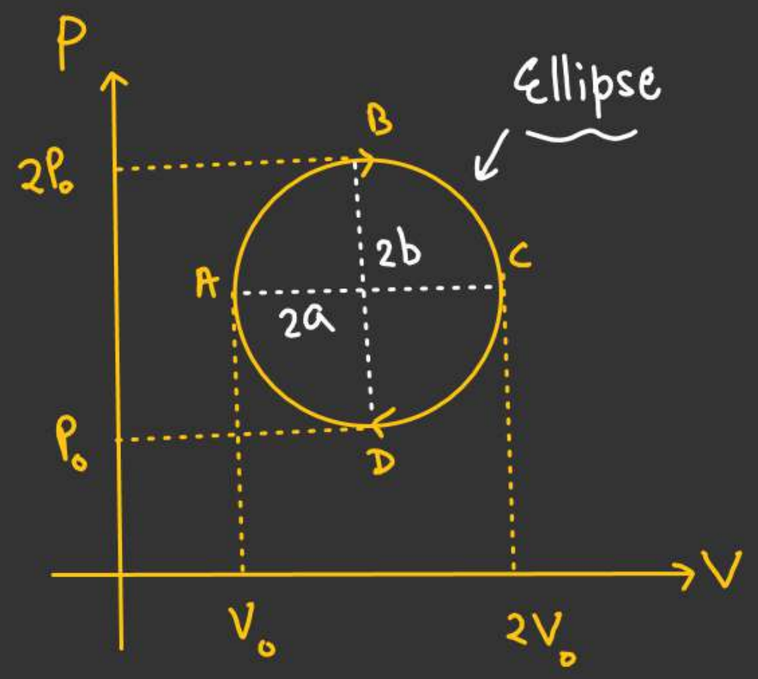
THERMODYNAMICS



$$W_{net} = \text{Area of Cyclic fig.}$$
$$= \text{Area of Ellipse}$$
$$= \pi a b$$
$$= \oplus\left(\frac{\pi P_0 V_0}{4}\right) \checkmark$$

(Cycle is clockwise)

$2a = V_0$ | $2b = P_0$

$a = \frac{V_0}{2}$ | $b = \frac{P_0}{2}$

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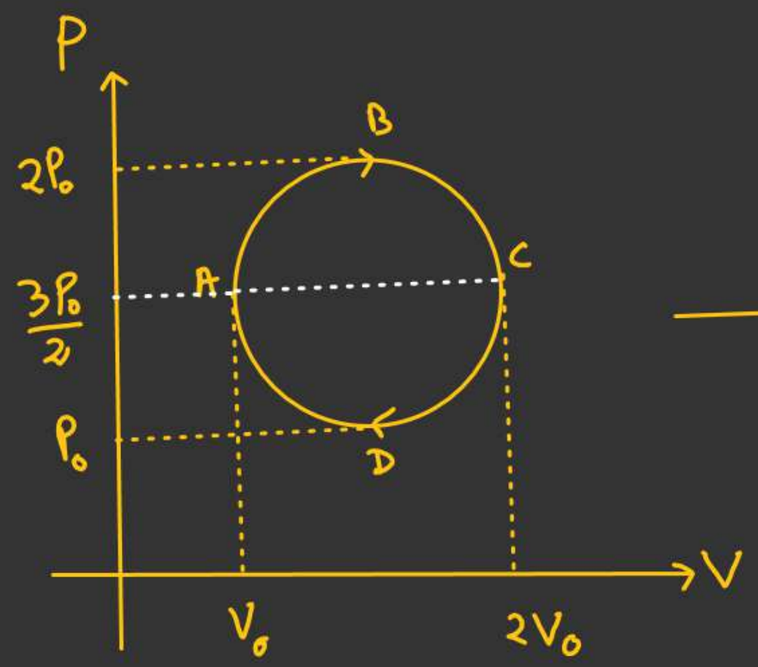
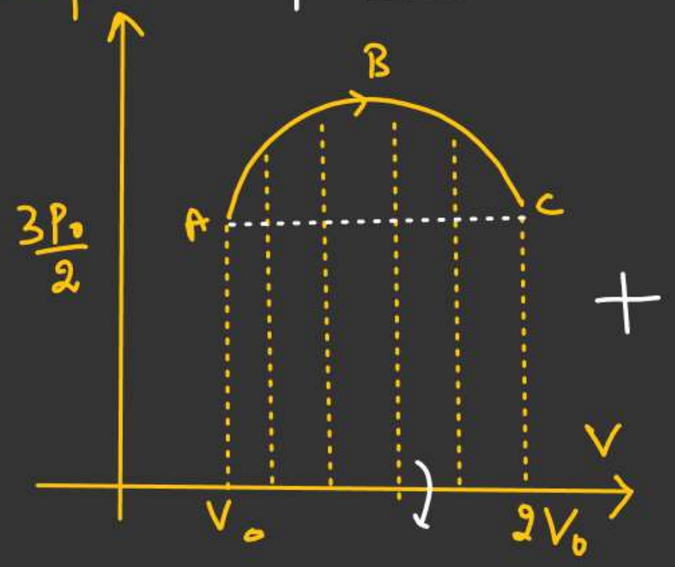
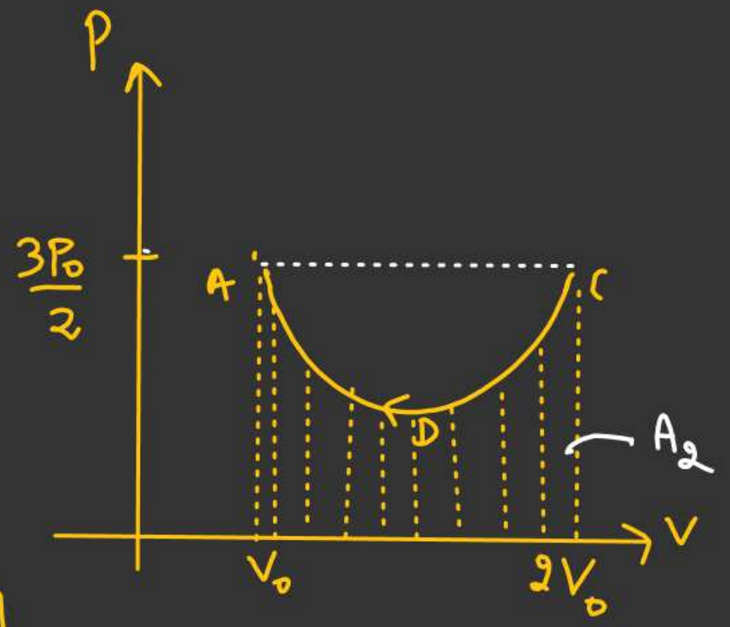
THERMODYNAMICS



Expansion



+



$W_{\text{expansional work}} = \left[\begin{array}{c}\text{Area of Semiellipse} \\ + \\ \text{Area of rectangle}\end{array}\right]$

+ve

$$= \frac{1}{2}\left(\frac{\pi P_0 V_0}{4}\right) + \left(\frac{3P_0V_0}{2}\right)$$

$W_{\text{compressional}}$

$$= -\left[\left(\text{Area of Rectangle}\right) - \left(\text{Area of Semiellipse}\right)\right]$$

$$= -\left[\left(\frac{3P_0V_0}{2} - \frac{\pi P_0 V_0}{8}\right)\right]$$

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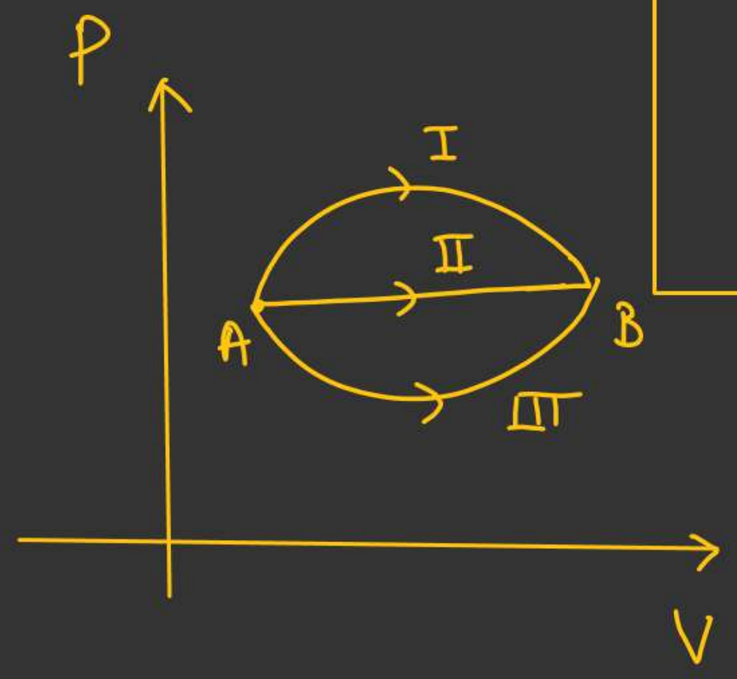
THERMODYNAMICS



$$\Delta U_{I} = \Delta U_{II} = \Delta U_{III}$$

$$\Delta W_{I} > \Delta W_{II} > \Delta W_{III}$$

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THERMODYNAMICS

BREAK

6.30 → 6.40

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First Law of Thermodynamics

(Based on Conservation of Energy)

$$\boxed{dQ = dU + dW}$$

$$\boxed{\Delta Q = \Delta U + \Delta W}$$

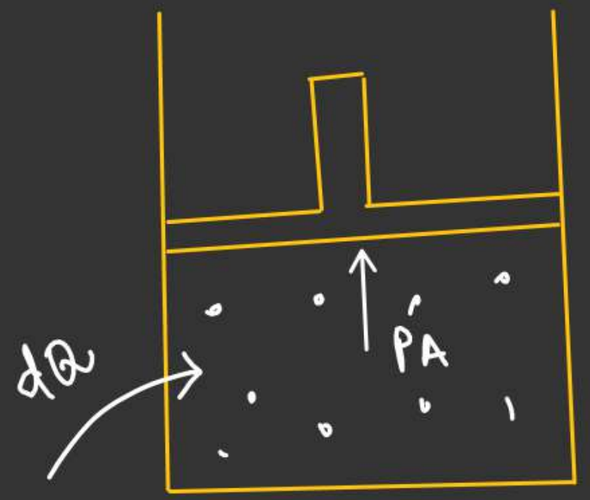
Sign-Convention

$dQ \rightarrow +ve$ (heat given to the System)

$dQ \rightarrow (-ve)$ (heat released)

$dW \rightarrow +ve$ (work done by the gas)

$dW \rightarrow -ve$ (Work done on the gas)



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THERMODYNAMICS

Process

- → Isobaric $(P = C)$
- → Isochoric $(V = C)$
- → Isothermal $(T = C)$
- → Adiabatic $(\Delta Q = 0)$
- → Polytropic

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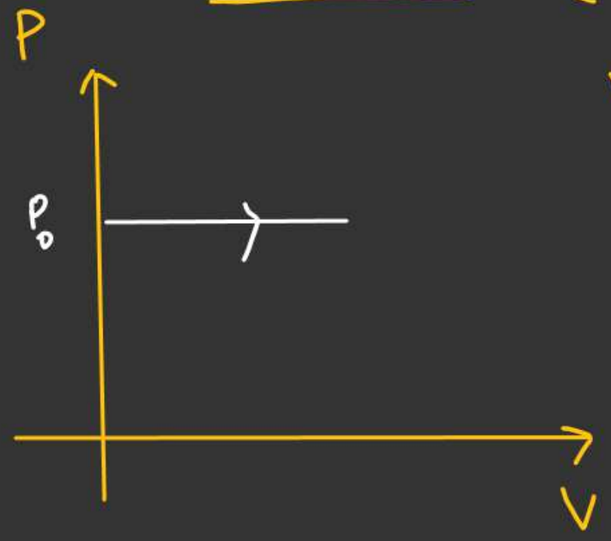
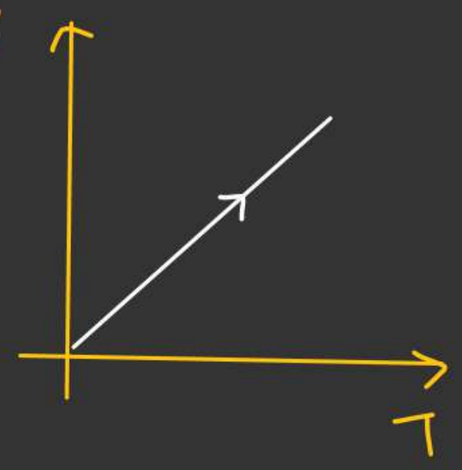
THERMODYNAMICS

Isobaric ($P = C$)



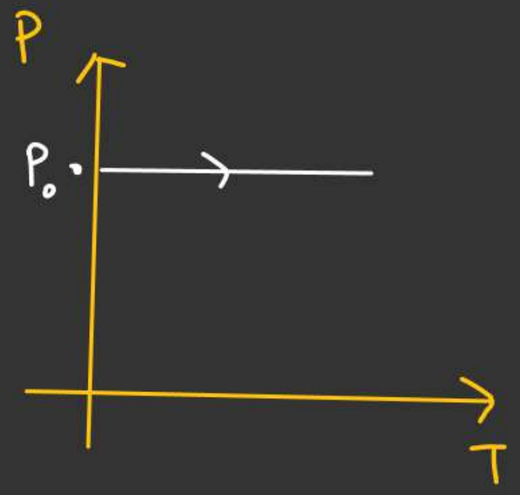


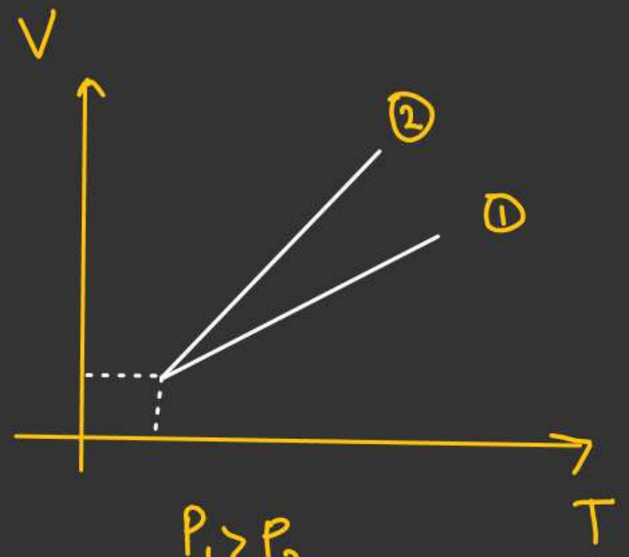
$$PV = nRT$$

$$V = \left(\frac{nR}{P}\right) T$$

$\Downarrow$

Slope





$P_1 > P_2$

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⇒ <u>Molar heat Capacity</u> → (Heat given to raise the temp of 1 mole of gas by 1°C)

$$C = \frac{1}{n}\left(\frac{dQ}{dt}\right)$$

n = Mole

$C \rightarrow C_p$ for Constant pressure.

$$\left(C_p = \frac{1}{n} \frac{(dQ)_{at\ P=C}}{dt} \right)$$

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Work done in isobaric process

$P, V_i, T_i \rightarrow P, V_f, T_f \quad (P = C)$

$$\int_0^W dW = \int_{V_i}^{V_f} P\,dV$$

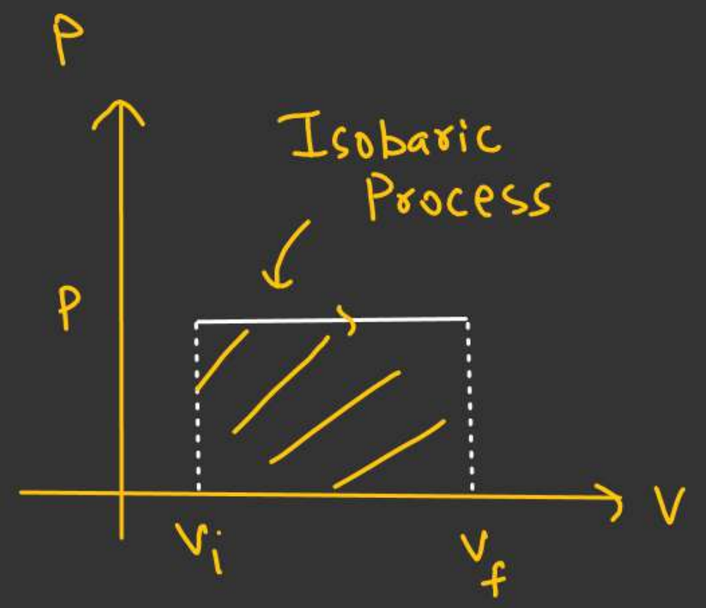
$$W = P\int_{V_i}^{V_f} dV$$

$$\boxed{W = P(V_f - V_i)}$$

$PV_f = nRT_f$

$PV_i = nRT_i$

$$\boxed{W = nR(T_f - T_i)}$$



$W_{isobaric}$ = Area of Rectangle

$= P(V_f - V_i)$ ✓

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Frist law in isobaric process

$$(dQ) = dU + dW$$

$$nC_p dT = nC_v dT + PdV$$

$$nC_p dT = nC_v dT + nRdT$$

$$C_p = \frac{1}{n}\frac{dQ}{dT}$$

$$dQ = nC_p dT$$

$$PdV = nRdT$$

$$\boxed{C_p = C_v + R}$$

Note

dU For any process $= nC_v dT$

$C_v \rightarrow$ Molar heat Capacity at Constant volume

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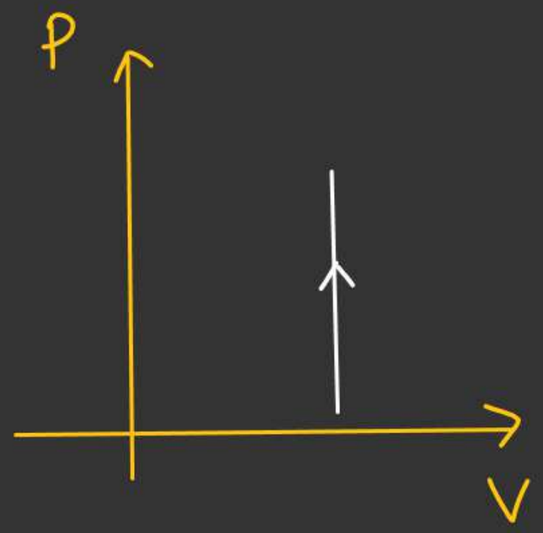
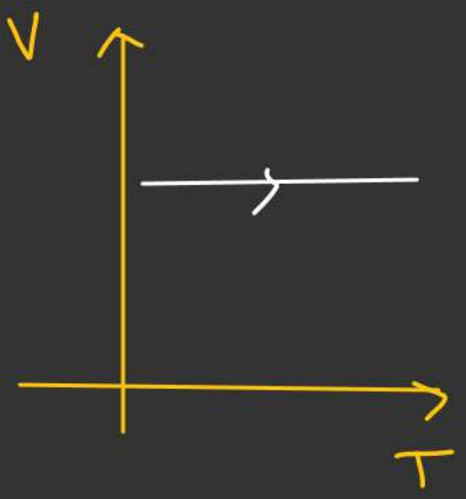
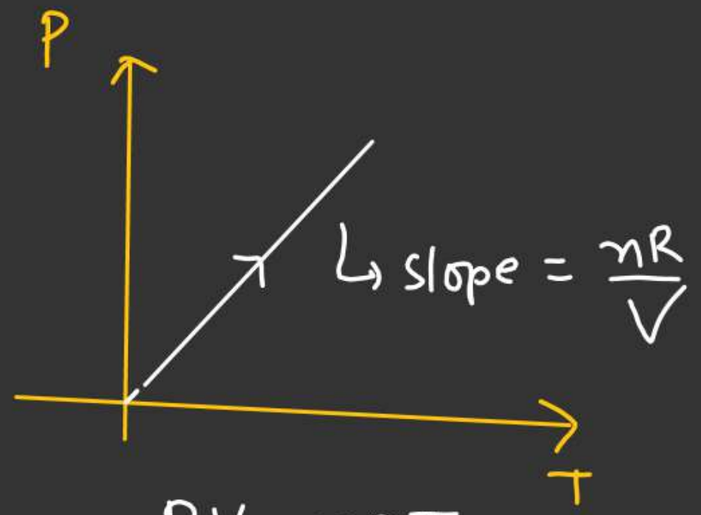
ISOCHORIC PROCESS (V=C)







$$PV = nRT$$

$$P = \left(\frac{nR}{V}\right) T$$

$\Downarrow$

Constant

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Molar heat Capacity at Constant volume

$$C_V = \frac{1}{n}\frac{(dQ)_{\text{at constant volume}}}{dT}$$

Work done $= 0$

$V = \text{Constant}$

$\Delta V = 0$

First Law

$$dQ = dU + \cancel{dW} \rightarrow 0$$

$$\boxed{dQ = dU}$$

$$\boxed{nC_V dT = dU}$$

(Valid for all process)

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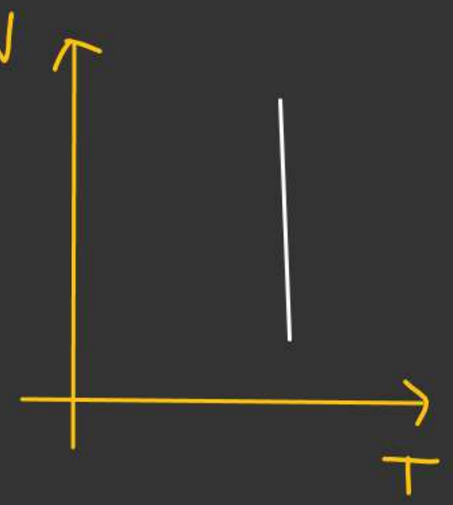
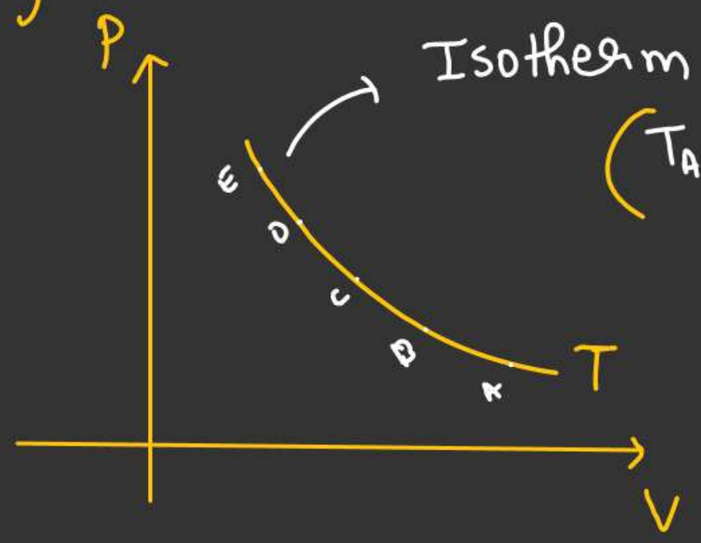
Isothermal process $(T = C)$





Isotherm

$(T_A = T_B = T_C = T_D = T_E = T)$

$PV = nRT \rightarrow$ Constant

$\left(P = \frac{C}{V}\right)$

$xy = C \rightarrow$ Rectangular hyperbola

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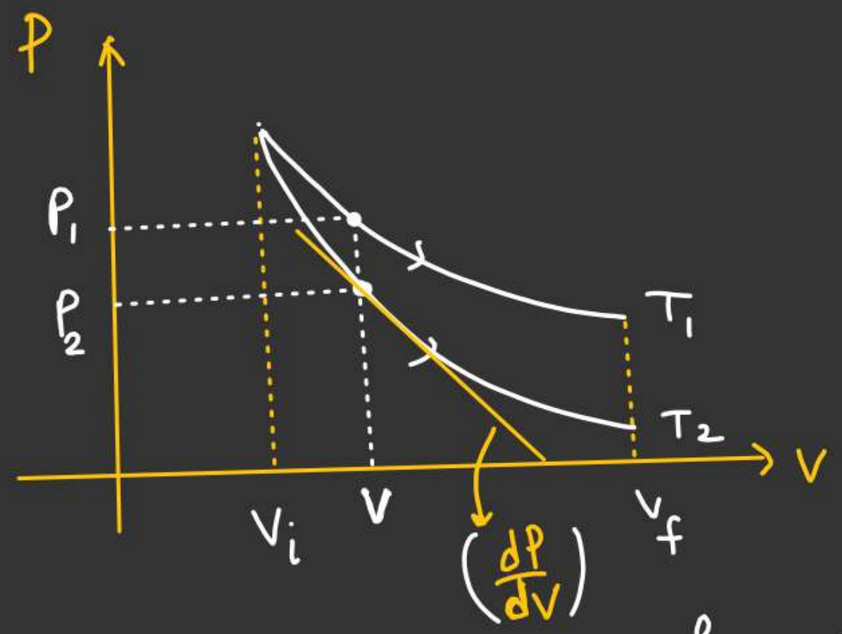
Higher isotherm are at higher temp. ✓



$P_1V = nRT_1$

$P_2V = nRT_2$

$\frac{P_1}{P_2} = \frac{T_1}{T_2}$

$P_1 > P_2$

$\Rightarrow T_1 > T_2$

(*) Slope of isotherm

$PV = nRT$

Differentiating both side w.r.t Volume

$$\frac{d}{dV}(PV) = \frac{d}{dV}(\underset{\text{constant}}{nRT})$$

$$P\frac{d(V)}{dV} + V\frac{dP}{dV} = 0$$

$$P = -V\frac{dP}{dV}$$

$$\frac{dP}{dV} = \left(-\frac{P}{V}\right)$$

$\Downarrow$

Slope of isotherm.

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B is Isothermal process

$$B = -\frac{dP}{\left(\frac{dV}{V}\right)}$$

$$\boxed{B_{isothermal} = P}$$

$$B = \left(-\frac{dP}{dV}\right) \times V$$

$$\Downarrow$$

$$B = \frac{P}{\cancel{V}} \times \cancel{V}$$

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Molar heat Capacity in isothermal process

$$C = \frac{1}{n}\left(\frac{dQ}{dT}\right)$$

for isothermal $dT \to 0$

$C_{\text{isothermal}} \to \infty$ → A very large reservior have ∞ heat Capacity.

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Work-done in isothermal process

$$PV = nRT$$

$$P = \left(\frac{nRT}{V}\right)$$

$$W = \int_{V_i}^{V_f} P \cdot dV = nRT \int_{V_i}^{V_f} \frac{dV}{V}$$

$$\boxed{\begin{aligned} W &= nRT \ln\left(\frac{V_f}{V_i}\right) \\ W &= nRT \ln\left(\frac{P_i}{P_f}\right) \end{aligned}}$$

$$P_i V_i T \longrightarrow P_f, V_f, T$$

$$P_i V_i = nRT$$

$$P_f V_f = nRT$$

$$P_i V_i = P_f V_f$$

$$\frac{P_i}{P_f} = \frac{V_f}{V_i}$$

Nishant Jindal

$$\Delta U_{isothermal} = 0$$

For any process

$$\underset{\downarrow \atop 0}{\Delta U} = nC_v \underset{\downarrow \atop 0}{\Delta T}$$

First Law in isothermal process

$$dQ = \cancel{dU}^{\,0} + dW$$

$$\boxed{dQ = dW}$$