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Q. from Ist law of thermodynamics show that the internal energy of ideal gas depends only on temp. (Adiabatic)

Sol $\therefore \quad dQ = dU + dW$

$dQ = 0 \qquad dW = -dU$

$PV^{\gamma} = \text{const} = K$

$P = \frac{K}{V^{\gamma}}$

$P dV = -dU$

$\frac{K}{V^{\gamma}} dV = -dU$

$\int_{U_i}^{U_f} dU = \int \frac{-K dV}{V^{\gamma}}$

$[U]_{U_i}^{U_f} = -K \left[\frac{V^{-\gamma+1}}{-\gamma+1}\right]$

$U_f - U_i = \frac{1}{\gamma-1} \left[K V^{1-\gamma}\right]_i^f$

$= \frac{1}{\gamma-1} \left[(KV^{1-\gamma})_f - (KV^{1-\gamma})_i\right]$

$= \frac{1}{\gamma-1} \left[(PV)_f - (PV)_i\right] = \frac{R}{\gamma-1} [T_f - T_i]$

$\boxed{U_f - U_i = \frac{R}{\gamma-1} [T_f - T_i]}$

for Isothermal.

$\boxed{U_f - U_i = 0}$

$PV^{\gamma} = \text{Const}$

$PV = RT$

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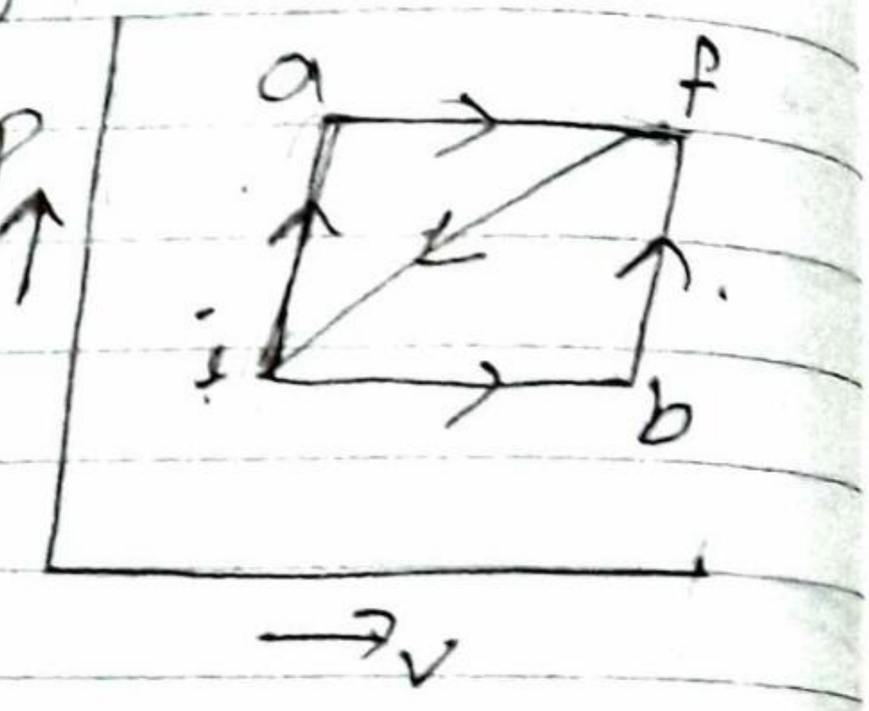
Q. When a system is taken from state i to f along the path iaf as in fig., it is formed that the heat Q is absorbed by system is 50 Cal. & work done by system 20 Cal. along the Path ibf Q = 36 Cal.



(i) what is the work done along the path ibf

(ii) If ω = -13 Cal. for curve return Path fi · what is Q. for this Path

(iii) Ui = 10 cal. what is Uf?

(iv) If Ub = 22 cal. what r Q for the process bf & ib

Sol. (i) $\Delta Q = \Delta U + \Delta W$

$50 = \Delta U + 20$

$\Delta U = 30$ Cal.

(ii) for ibf $\Delta Q_{ibf} = \Delta U_{ibf} + \Delta W_{ibf}$

$36 = 30 + W_{ibf}$

$W_{ibf} = 6$ Cal.

(iii) for fi $\Delta Q_{if} = \Delta U_{if} + \Delta W_{if}$

for return path $\Delta U_{if} = -30$ cal.

$\Delta Q_{if} = -30 - 13 =$ -43 cal

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(iii) $U_i = 10$ cal.

$\Delta U_{if} = U_f - U_i$

$30 = U_f - 10$

$U_f = 40$ (a).

(iv) for bf $U_b = 22$

$Q = \Delta U + W$

$W = Q$

$Q_{bf} = U_f - U_b$

$= 40 - 22 = 18$ cal.

for Path ibf $Q = 36$

bf $Q = 18$

So Path ib $Q_{ib} = 36 - 18 = 18$ cal.

①. for a diatomic ideal gas near room. temp. what fraction of the heat supplied is available for external work. If the gas is expanded

(i) at contt Pressure

(ii) at contt temp.

Sol(i) $\Delta W = P\Delta V = nR\Delta T$ $\quad C_p - C_v = R$

$\Delta Q = C_v \Delta T + nR\Delta T$ $\quad C_v = C_p - R$

$\Delta Q = \Delta T (C_v + nR)$

$\frac{\Delta W}{\Delta Q} = \frac{nR\Delta T}{\Delta T (C_v + nR)} = \frac{nR}{C_v + nR}$

$\frac{\Delta W}{\Delta Q} = \frac{nR}{\left(\frac{5}{2}nR + nR\right)} = \frac{2R}{7R} = \frac{2}{7}$ Ans.

$n = 2$

$C_p - C_v = R$

$\Delta Q = C_p \Delta T$

$\Delta U = C_v \Delta T$

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(ii) $\Delta Q = \Delta U + \Delta W$

$\Delta Q = 0 + \Delta W$

$\frac{\Delta W}{\Delta Q} = 1$ Ans

Q.2 One mole of a mono atomic Perfect gas initially at temp. To expand Volume V_0 to $2V_0$

(i) At contt temp.

(ii) At contt pressure

Calculate the work of expansion & the heat absorb by the gas in each case

Sol. $\int dW = \int P dV$

$W = \int_{V_0}^{2V_0} \frac{RT}{V} dV$

$= RT_0 \left[\log_e V\right]_{V_0}^{2V_0}$

$= RT_0 \left[\log_e 2V_0 - \log_e V_0\right]$

$W = RT_0 \log_e 2$

$\Delta Q = 0 + \Delta W$

$= RT_0 \ln 2$

(ii) $dW = P dV$

$= P[V]_{V_0}^{2V_0}$

$= P[2V_0 - V_0]$

$= PV_0 = \frac{RT}{V_0} \times V_0 = RT_0$

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$dQ = dU + dW$ $\quad dU = C_V \, dT$

$dQ = \frac{3}{2} R T_0 + R T_0$ $\quad U = \frac{3}{2} R T_0$

$dQ = \frac{5}{2} R T_0$

Q.3 Two system with heat capacity is C_1 & C_2 respectively. interact thermally & come to a common Temp T_f. If Initial temp of system was T_1 what was initial tem of system 2

u may assume that total energy of combined system remain.

Sol. $Q_1 = Q_2$

$m_1 s_1 (T_f - T_i) = m_2 s_2 (T_2 - T_f)$

$C_1 (T_f - T_i) = C_2 (T_2 - T_f)$

$C_1 (T_f - T_1) + C_2 T_f = + C_2 T_2$

$C_2 T_2 = C_2 T_f + C_1 (T_f - T_1)$

$$T_2 = \frac{C_2 T_f + C_1 (T_f - T_i)}{C_2}$$

$$T_2 = T_f + \frac{C_1}{C_2} (T_f - T_1)$$ Ans

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10. 1 mole of gas obey Vander'Waal eqn of state. If its molar internal energy is given by $u = cT - \frac{a}{V}$, in which V is molar volume a → one of const in the eqn. of state, T is temp. Calculate the molar heat capacity C_p & C_V

Sol

$$C_V = \left(\frac{du}{dT}\right)_V$$

$$= \frac{d}{dT}\left(cT - \frac{a}{V}\right)$$

$$C_V = c$$

$$C_p - C_V = R$$

$$C_p = C_p + R$$

$$= c + R$$

$$dQ = dU + dW$$

$$\left(\frac{dQ}{dT}\right)_P = \frac{d}{dT}\left(dU + PdV\right)$$

$$C_p = \frac{d}{dV}\left(dU + PdV\right)\left(\frac{dV}{dT}\right)_P$$

$$C_p = \left(\frac{\partial U}{\partial T}\right)_V + \left[P + \left(\frac{\partial U}{\partial V}\right)_T\right]\left(\frac{\partial V}{\partial T}\right)_P \quad \text{---(1)}$$

$$U = cT - \frac{a}{V}$$

$$\frac{\partial U}{\partial V} = 0 + \frac{a}{V^2}$$

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

$$\left[\left(-\frac{2a}{V^3}\right)(V-b) + \left(P + \frac{a}{V^2}\right)\right]\frac{dV}{dT} = R$$

$$\left(\frac{dV}{dT}\right)_P = \frac{R}{\left(\frac{-2a}{V^3}\right)(V-b) + \left(P+\frac{a}{V^2}\right)V}$$

$$= \frac{R}{\left(P - \frac{a}{V^2} + \frac{2ab}{V^3}\right)}$$

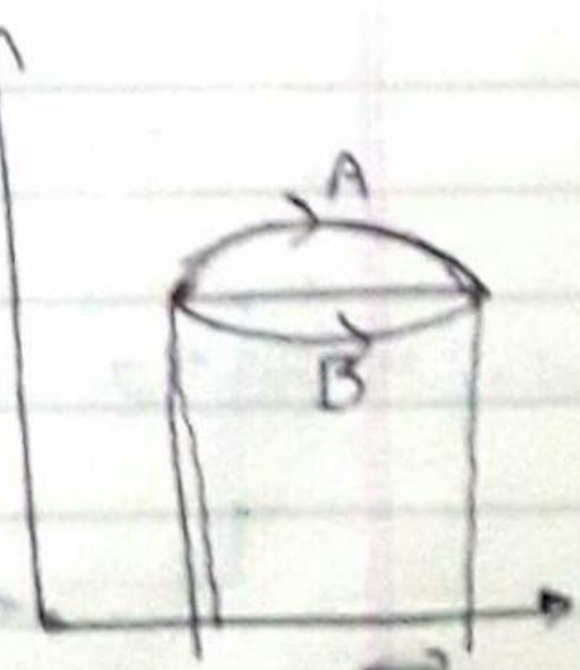
from eqn (1)

$$C_p = C_v + \left[P + \frac{a}{V^2}\right] \times \frac{R}{\left[P - \frac{a}{V^2} + \frac{2ab}{V^3}\right]}$$

or $$C_p = C_v + \frac{R}{1 + (V-b)\left(\frac{-2a}{V^3}\right) \Big/ \left(P + \frac{a}{V^2}\right)}$$

$$C_p = C_v + \frac{R}{1 - \frac{2a(V-b)^2}{RTV^3}}$$

Q. fig. shows two process A & B on a system. let ΔQ_1 & ΔQ_2 be the heat given to system in process A & P. then.



(i) $\Delta Q_1 > \Delta Q_2$

ii $\Delta Q_1 = \Delta Q_2$

(iii) $\Delta Q_1 < \Delta Q_2$

(iv) $\Delta Q_1 \leq \Delta Q_2$

Sol $\Delta Q = \Delta U + \Delta W$

$\Delta W_A = +ve$ $\Delta W_B = -ve$ $\therefore \Delta Q_1 > \Delta Q_2$ Ans

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Reversible Process

A reversible Process is one which can be reverse in such a way that all change in taken place in direct process are exactly repeated in inverse order & opposite sence. and no change in surrounding & any one of the bodies taken part in the process and in the surroundings.

Condition of Reversibility :-

(i) Process must be quasi static

(ii) Process must be non disipative force. e.g (friction, viscosity, electrical resistance, magnetic hysteresis)

(*)

Classify the reversible & irreversible Process.

(i) Isothermal expansion of gas.
Infinite decimaly slow expansion of gas in absence of any friction force. Irreversible

(ii) Adibatic compression of Gas
Irreversible

(iii) Diffusion of Gasses :-
Same Gas → Reversible
Different Gas → Irreversible

- Transfer of heat from hold to

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Cold body → Irreversible
Electric heating of wire - Irrever
Joule's expansion of a perfect
Gas - Reversible
Very slow extension & compression
of spring → Reversible
Disipation of mechanical energy to
heat through friction → Irrevisible
Complete conversion of heat in to
work → Irreversible
Complete conversion of work in to
heat → Reversible (not possible)

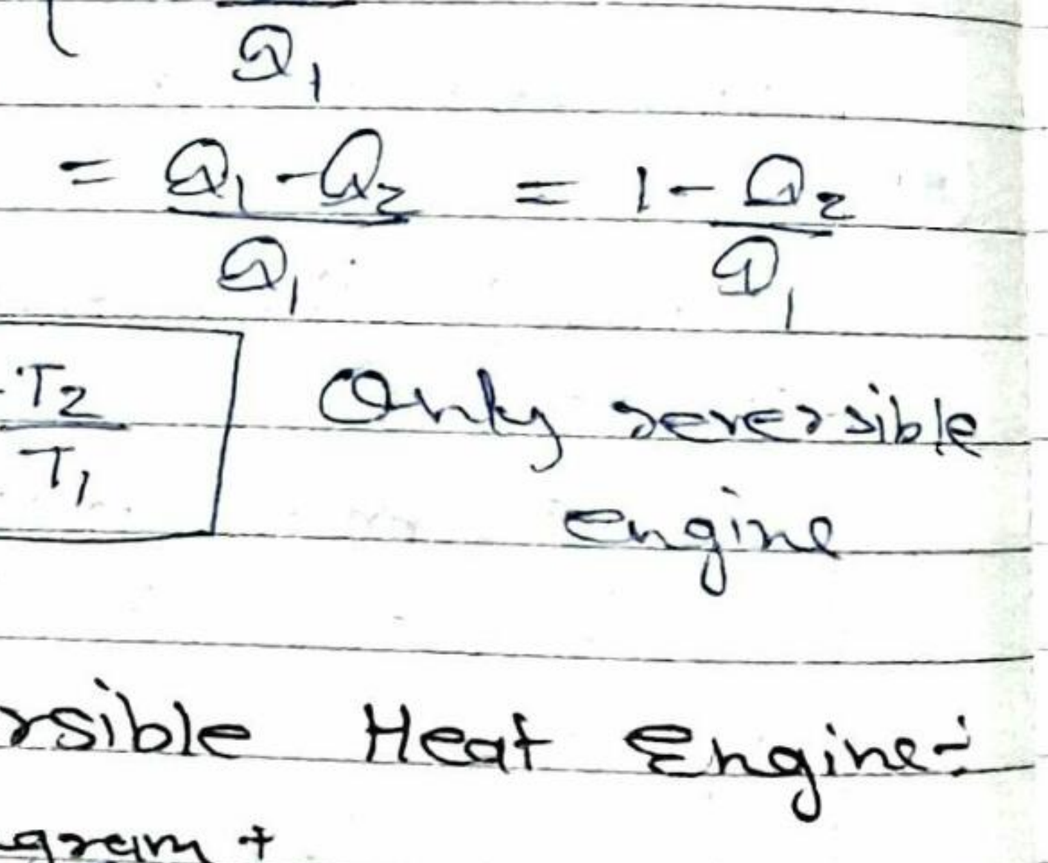
Heat Engine → (Read yourself)

$$\eta = \frac{W}{Q_1}$$

$$= \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

$$\boxed{\eta = 1 - \frac{T_2}{T_1}}$$ Only reversible engine

Carnot Reversible Heat Engine:
indicator diagram →



Efficiency →
for AB →

$$P_1V_1^{\gamma} = P_2V_2^{\gamma} \quad -(a)$$

$$W_1 = \frac{R}{1-\gamma}(T_2 - T_1) \quad -(1)$$

for BC → $P_2V_2 = P_3V_3$ —(b)

$Q_2 = W_2 = RT_1 \ln \frac{V_3}{V_2}$ — (2)

$W = \frac{R}{1-\gamma}(T_1 - T_2)$

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For C → D $P_3V_3^{\gamma} = P_4V_4^{\gamma}$ — (5)

$W_3 = \frac{R}{1-\gamma}(T_1 - T_2)$ — (3)

For D → A $P_4V_4 = P_1V_1$ — (1)

$Q_2 = W_4 = RT_2 \ln \frac{V_4}{V_1}$ — (4)

during Adiabatic A → B

& C → D Process Net

work done → zero

$\frac{(2)}{(4)} \quad \frac{Q_1}{Q_2} = \frac{T_1}{T_2} \frac{\ln V_3/V_2}{\ln V_4/V_1}$ — (5)

(a) × (b) × (c) × (d)

$P_1V_1^{\gamma} \times P_2V_2 \times P_3V_3^{\gamma} \times P_4V_4$

$= P_2V_2^{\gamma} \times P_3V_3 \times P_4V_4^{\gamma} \times P_1V_1$

$V_1^{\gamma-1} V_3^{\gamma-1} = V_2^{\gamma-1} V_4^{\gamma-1}$

$\frac{V_1}{V_2} = \frac{V_4}{V_3}$

or $\frac{V_3}{V_2} = \frac{V_4}{V_1}$

Put in eqn (5)

$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

So Efficiency

$\eta = 1 - \frac{Q_1}{Q_2}$

$\boxed{\eta = 1 - \frac{T_1}{T_2}}$

For CD

$T_1 V_3^{\gamma-1} = T_2 V_4^{\gamma-1}$

Similarly.

For AB

$T_2 V_1^{\gamma-1} = T_1 V_2^{\gamma-1}$

$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$

Adiabatic Ratio

$\rho = \frac{V_2}{V_1}$

$\frac{T_2}{T_1} = (\rho)^{\gamma-1}$

$\boxed{\eta = 1 - \left(\frac{1}{\rho}\right)^{\gamma-1}}$