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① External work done by ideal gas in
Isothermal expansion

When gas expand work done against external sourrounding. So by formula of work done

$$W = \int_{V_i}^{V_f} P\,dV \qquad PV = K$$

$$= K \log \frac{V_f}{V_i} \qquad \text{but } P_iV_i = P_fV_f$$

$$P_iV_i = P_fV_f = RT$$

$$W = RT \log V_f/V_i$$

for n moles

$$W = nRT \log_e \frac{V_f}{V_i}$$

$$W = nRT \times 2.303 \log_{10} \frac{V_f}{V_i}$$

② External work done by ideal gas in Adiabatic expansion

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

in adiabatic case $PV^\gamma = \text{Const}$

$$W = \int_{V_i}^{V_f} K V^{-\gamma}\,dV$$

$$= \frac{K}{1-\gamma}\left[V^{1-\gamma}\right]_{V_i}^{V_f}$$

we know that $PV^\gamma = K$

$$P_iV_i^\gamma = P_fV_f^\gamma = K$$

$$= \frac{K}{1-\gamma}\left[V_f^{1-\gamma} - V_i^{1-\gamma}\right]$$

$$= \frac{1}{\gamma-1}\left[\frac{K}{V_i^{\gamma-1}} - \frac{K}{V_f^{\gamma-1}}\right]$$

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$$\frac{dP}{P} + \frac{C_P}{C_V}\frac{dV}{V} = 0$$

We know that $\frac{C_P}{C_V} = \gamma$

$$\frac{dP}{P} + \gamma \frac{dV}{V} = 0$$

integrating

$$\frac{dP}{P} + \gamma \frac{dV}{V} = 0$$

$$\log P + \log V^{\gamma} = \text{Con}$$
$$\log PV^{\gamma} = \text{Const}$$
$$\log PV^{\gamma} = \text{Con}$$
$$\boxed{PV^{\gamma} = \text{Const}}$$

Relation between Temp and Volume

$$P = \frac{RT}{V}$$

$$\frac{RT}{V} V^{\gamma} = \text{Con}$$

$$TV^{\gamma - 1} = \text{Const}$$

Relationship b/w Temp and Pressure

$$P\left(\frac{RT}{P}\right)^{\gamma} = \text{Const}$$

$$TP^{1-\gamma/\gamma} = \text{Const}$$

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$$W = \frac{1}{\gamma-1}\left[\frac{P_1 V_1^{\gamma}}{V_i^{\gamma-1}} - \frac{P_f V_f^{\gamma}}{V_f^{\gamma-1}}\right]$$

$$= \frac{1}{\gamma-1}\left[P_i V_i - P_f V_f\right]$$

$$W = \frac{1}{\gamma-1}\left[P_i V_i - P_f V_f\right]$$ for adiabatic expansion

for n moles

$$W = \frac{n}{\gamma-1}\left[P_i V_i - P_f V_f\right]$$

in term of Temp

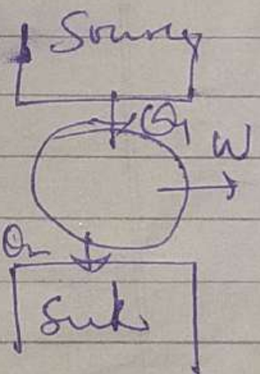
$$P_i V_i = nRT_i \qquad P_f V_f = nRT_f$$

$$W = \frac{nR}{\gamma-1}\left[T_i - T_f\right]$$

<u>Heat Engine</u> — Any device which converts heat continously into mechanical work is called Heat engine

Part of Heat engine

- Source
- Sink
- working substance



$$\eta = \frac{\text{work out put in engy}}{\text{Heat input}} \qquad Q_1 - Q_2 = W$$

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

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Proof of $PV^\gamma = \text{Const}$.

The process in which heat can neither enter or leave the system is called adiabatic process. $Q = \text{Const}$ or $dQ = 0$

$$dW = P\,dV$$

for perfect gas if the volume of gas increases the internal energy depend upon T.

$$dU = 1 \times C_V \times dT$$

from the first law of thermodynamics

$$dQ = dU + dW$$

$$dQ = C_V dT + P dV$$

$dQ = 0$ for adiabatic

$$C_V dT + P dV = 0 \quad \text{——— (1)}$$

for ideal gas equation

$$P dV + V dP = R dT$$

Put these value in eq (1)

$$C_V\left(\frac{P dV + V dP}{R}\right) + P dV = 0$$

$$C_V(P dV + V dP) + R(P dV)$$

We know that Mayer formula.

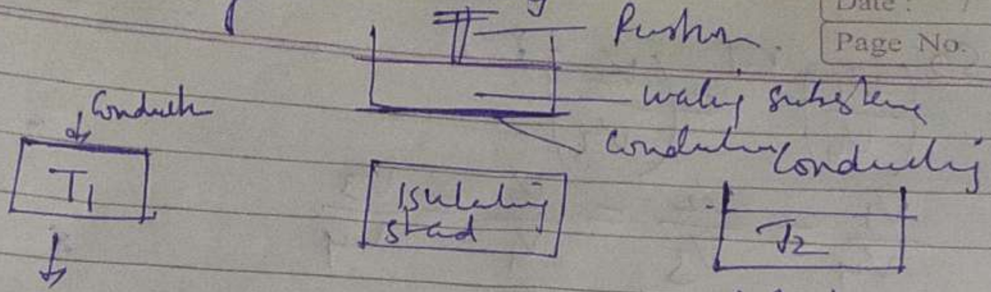
$$C_P - C_V = R$$

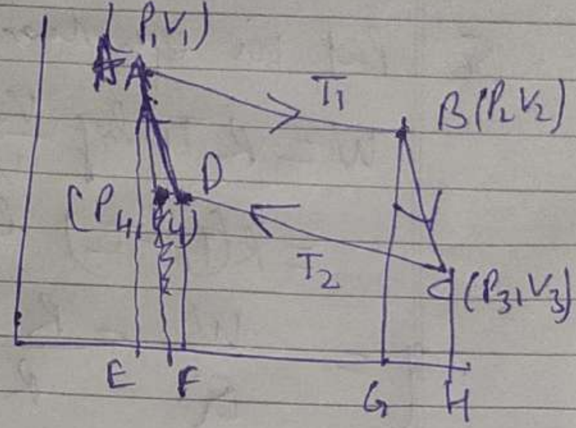
$$C_V(P dV + V dP) + (C_P - C_V) P dV$$

$$C_V V dP + C_P P dV = 0$$

dividing by $C_V PV$

- Reversible and irreversible
- Condition of Reversibility





$$Q_1 = W_1 = RT_1 \log \frac{V_2}{V_1} \quad \text{——— (1)}$$

operation 2, system allowed to expand

$$W_2 = \frac{R(T_1 - T_2)}{\gamma - 1} \quad \text{——— (2)}$$

operation 3

$$Q_2 = W_3 = RT_2 \log \frac{V_4}{V_3} = -RT_2 \log \frac{V_3}{V_4}$$

operation (4)

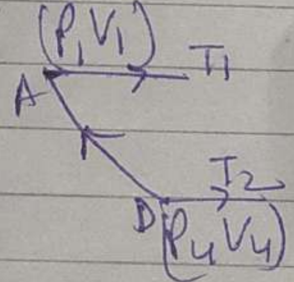
$$Q. W_4 = -\frac{R(T_1 - T_2)}{\gamma - 1}$$

Total work done

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

$$= RT_1 \log \frac{V_2}{V_1} + \frac{R(T_1 - T_2)}{\gamma - 1} - RT_2 \log \frac{V_3}{V_4} - \frac{R(T_1 - T_2)}{\gamma - 1}$$

$$W = RT_1 \log_e \frac{V_2}{V_1} - RT_2 \log_e \frac{V_3}{V_4}$$

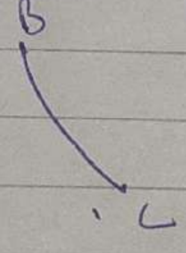


at DA Point

$$T_1 V_1^{\gamma-1} = T_2 V_4^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_4}\right)^{\gamma-1}$$

at BC



$$T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$$

So $\left(\frac{V_1}{V_4}\right)^{\gamma-1} = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$

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

So put in equation

$$W = RT_1 \log \frac{V_2}{V_1} - RT_2 \log \frac{V_2}{V_1}$$

$$= R(T_1 - T_2) \log \frac{V_2}{V_1}$$

$$\eta = \frac{W}{Q} = \frac{R(T_1 - T_2) \log_e \frac{V_2}{V_1}}{RT_1 \log_e \left(\frac{V_2}{V_1}\right)}$$

$$= \frac{T_1 - T_2}{T_1}$$

$$Q = 1 - \frac{T_2}{T_1}$$