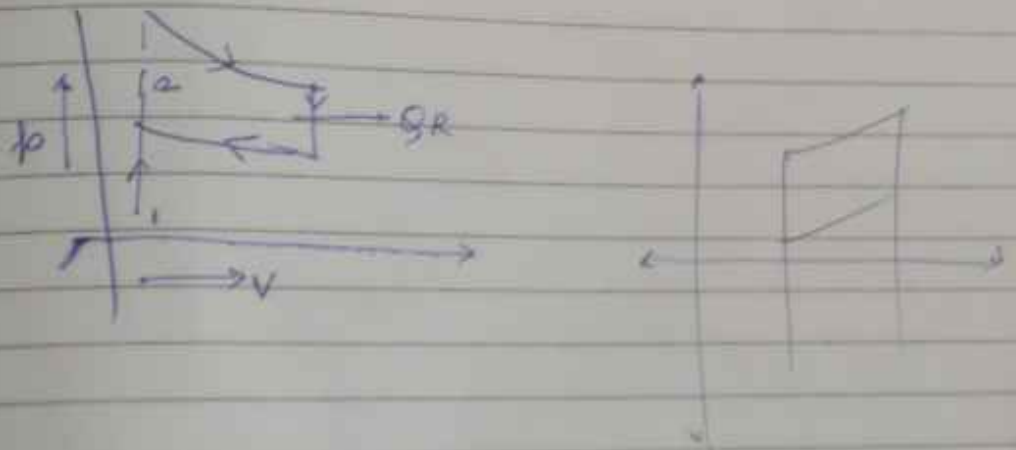
Steam Engine | Steam Turbine

Mean Effective Pressure :- It is defined as the ratio of net work done in one cycle to the piston displacement $= V_{max} - V_{min}$

Otto cycle



It consists of 4 process two adiabatic and 2 const volume. + const pressure.

1 → 2 : It consist of const volume (compression)

$$Q_{1-2} = 0$$

$$Q_1 = Q_{2-3} = mC_v(T_3 - T_2)$$

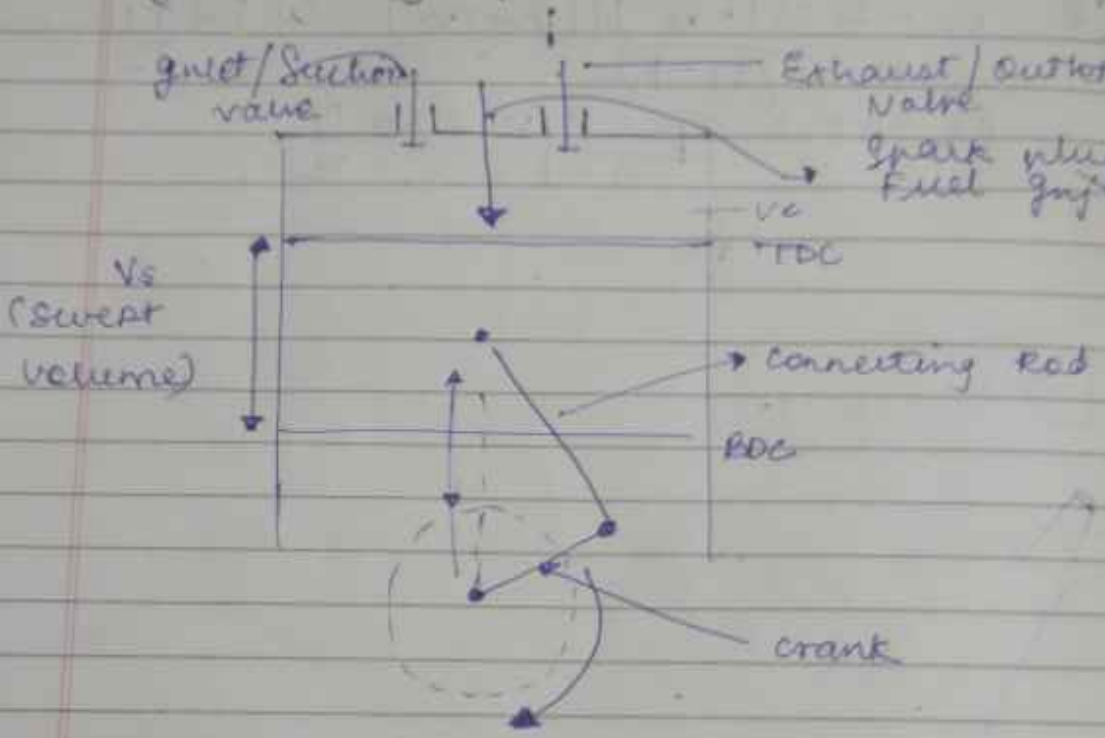
$$Q_{3-4} = 0$$

$$Q_R = mC_v(T_4 - T_1)$$

$$\eta = \frac{mC_v(T_3 - T_2) - mC_v(T_4 - T_1)}{mC_v(T_3 - T_2)}$$

$$\boxed{\eta = 1 - \frac{T_4 - T_1}{T_3 - T_2}}$$

① ICE - Internal Combustion Engine
② ECE - External combustion Engine → Boiler, Steam generator
③ Terminology of ICE



① ~~Bore~~ Bore
② TDC
③ BDC
④ Stroke Volume $V_s = \pi/4 \, d^2 l$
⑤ Cylinder Volume
⑥ Compression Ratio (rc) $= \frac{V_s + V_c}{V_c}$

⑦ Air Standard efficiency $\eta = \frac{Q_s - Q_R}{Q_s} = \frac{W_{net}}{Q_s}$

Prove that for the cha

$$S_2 - S_1 = \frac{(\gamma - n)}{(\gamma_1 - 1)} \left(\frac{p - (v)}{} \right) \quad (v) \ln \frac{T_1}{T_2}$$

$$S_2 - S_1 = \frac{C_p - n C_v}{n - 1} \ln \frac{T_1}{T_2}$$

$T_1 = 427 + 273 = 700\,K$

$T_3 = 7 + 273 = 280\,K.$

$\eta_A = \frac{W_A}{Q_1} = \frac{T_1 - T_2}{T_1}$

$W_A = Q_1 \left(\frac{T_1 - T_2}{T_1}\right)$

$W_B = Q_2 \left(\frac{T_2 - T_3}{T_2}\right)$

$W_A = 2W_B.$

$Q_1 = W_A + Q_2$

$\boxed{W_A = Q_1 - Q_2}$

$\therefore Q_1\left(\frac{T_1 - T_2}{T_1}\right)$

$\therefore W_A = (W_A + Q_2)\left(\frac{T_1 - T_2}{T_1}\right)$ Incomplete.

$\Rightarrow$

Ques^n 3 carnot engine C_1, C_2, C_3 operates btwn 4 heat reservoirs in series which are at temp of 1000 K and 300 K. Calculate temp of intermediate reservoirs if amount of work produced by these engines are in the proportion of 5 : 4 : 3

nd B are
ngine A
eliver 200
the hot source
n with a
°C. If
rice that of
d B.

273

$Q_2 = ?$.

$Q_1 = 200\,KJ$. $T_1 = 400$.

$T_3 = 9°C = 300\,K$.

$W_A = 2 W_B$.

$$\frac{T_1 - T_2}{T_1} = 2\,\frac{T_2 - T_3}{T_2}$$

$$\Rightarrow \frac{400 - T_2}{400} = 2\,\frac{T_2 - 300}{T_2}$$

$$T_2(400 - T_2) = 800\,(T_2 - 300).$$

$$400T_2 - T_2^2 = 800T_2 - 240000$$

$$\Rightarrow \frac{Q_2}{Q_1} = \frac{T_2}{T_1} \qquad \frac{Q_3}{Q_2} = \frac{T_3}{T_2}$$

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

$$Q_1 = \frac{T_2 Q_1}{Q_2} \qquad \frac{T_2 Q_1}{T_1} \qquad Q_3 = \frac{T_3 Q_2}{T_2}.$$

$$Q_2 =$$

$$\Rightarrow 1 - \frac{T_2}{T_1} = 2\left(1 - \frac{T_3}{T_2}\right).$$

$$1 - \frac{Q_2}{Q_1} = 2 \qquad Q_1 = \frac{Q_2 T_1}{T_2}$$

$$Q_2 - Q_1 = 2(Q_3 - Q_2).$$

$$Q_2 - Q_1 = 2Q_3 - 2Q_2.$$

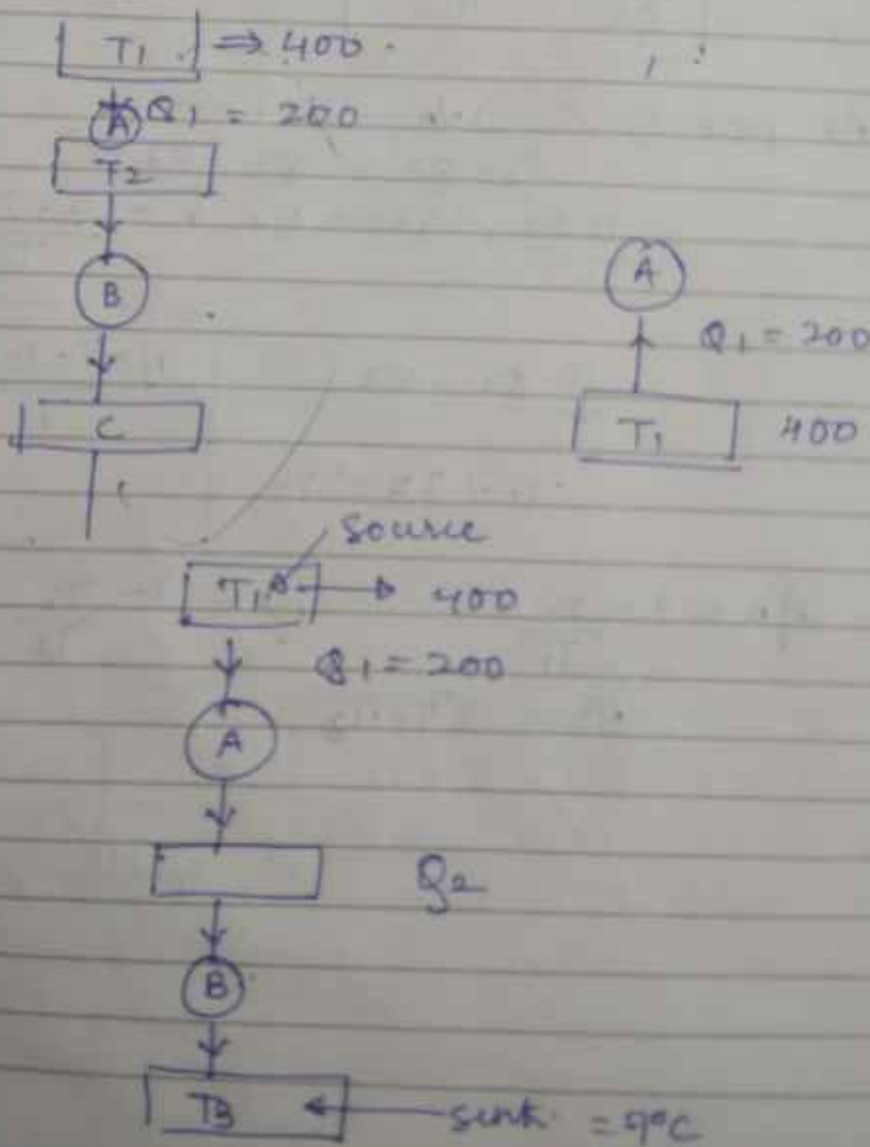
$$3Q_2 - Q_1 = 2Q_3.$$

$$\Rightarrow 3\left(\frac{T_2 Q_1}{T_1}\right) - 3\left(\frac{Q_2 T_1}{T_2}\right) - 3.$$

Ques" 2 reversible heat engines A and B are arranged in series. The heat engine A rejects heat directly to B. A receives 200 KJ at a temp of 400 from the hot source while engine B is in communication with a low temp sink at a temp of 7°C. If the workout of engine A is twice that of engine B. Determine

1) Intermediate temp btwn A, and B
2) Efficiency of each engine and heat rejected to the sink.

→



For equal network

$W_A = Q_1 - Q_2$

$W_B = Q_2 - Q_3$.

$$\frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$$ For 1st power cycle.

$$\Rightarrow 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

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

Similarly

$$\boxed{\frac{Q_3}{Q_2} = \frac{T_3}{T_2}} \qquad \frac{Q_2 T_3}{T_2}$$

As per Ques^n: $W_A = W_B$. $\longrightarrow$

$$Q_1 - Q_2 = Q_2 - Q_3$$

$$\frac{T_1 Q_2}{T_2} - Q_2 = Q_2 + \frac{Q_2 T_3}{T_2}$$

$$\frac{T_1 Q_2}{T_2} - Q_2$$

$$T_1 + T_3 = 2T_2$$

$$\eta = \frac{T_1 - T_2}{T_1} = \frac{Q_1 - Q_2}{Q_1} = \frac{W}{Q_1}$$

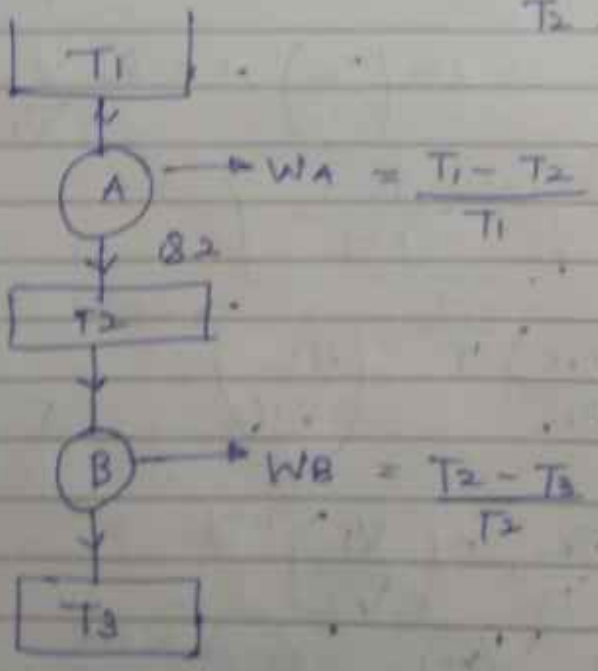
$$\eta_A = 1 - \frac{T_2}{T_1} \qquad \eta_B = 1 - \frac{T_3}{T_2}$$

$$T_2 = \sqrt{T_1 T_3}$$

CV

2 reversible power cycles are arranged in series. The 1st cycle receives energy by heat transfer from a reservoir at a temp t_1 and rejects energy to a reservoir at an intermediate temp 2. The second cycle receives the energy rejected by the 1st cycle from the reservoir at a temp t_2 and rejects energy to a reservoir at temp t_3 lower than t_2. Derive an exp for the intermediate temp t_2 in terms of t_1 and t_3 when

1) The network of two power cycle is equal
2) The thermal efficiency of 2 power cycles are equal.



Integrating btwn ① and ②

$$\int_1^2 ds = Cv \int_1^2 \frac{dT}{T} + R \int_1^2 \frac{dv}{v}$$

$$\boxed{S_2 - S_1 = Cv \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_2}{V_1}\right)}$$ **

↖ general eqn

Prove that ΔS of a gas btwn 2 states 1 and 2 is given by

$$S_2 - S_1 = \frac{\gamma - n}{\gamma - 1} (Cp - Cv) \ln\left(\frac{T_1}{T_2}\right)^{1/(n-1)}$$

→ We know that general eqn of ΔS is given by

$$S_2 - S_1 = Cv \ln\left(\frac{T_2}{T_1}\right) + R \ln \frac{V_2}{V_1}$$

We know $\boxed{Cv = \frac{R}{\gamma - 1}}$

$$\frac{T_H}{T_L} = \left(\frac{P_H}{P_L}\right)^{\frac{n-1}{n}} = \left(\frac{V_L}{V_H}\right)^{n-1}$$

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

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

$$c_2^2 = 2(h_1 - h_2)$$

In case of nozzle

$c_2 >>> c_1$ ∴ We neglect c_1

$$\therefore c_2^2 = 2(h_1 - h_2)$$

for diffeiser

$c_1 >> c_2$ ∴ We neglect c_2

$$c_1^2 = 2(h_2 - h_1)$$

Turbine and compressor.

- Change of Entropy

(1) By FLOT

$$dQ = dU + dW$$

The temp measured by thermo is Dry Bulb ~~thermo~~ temp.

$$dQ = mc_v dT + P dV$$

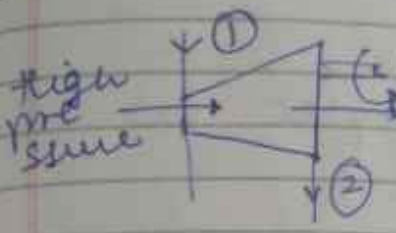
Dividing bts B T. For unit mass

$$\frac{dQ}{T} = mc_v \frac{dT}{T} + \frac{P dv}{T}$$

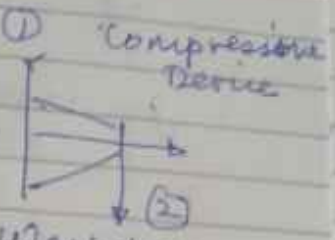
$$S = c_v \frac{dT}{T} + \frac{RT}{V} \cdot \frac{dV}{T} \qquad PV = RT$$

$$\frac{dQ}{T} = c_v \frac{dT}{T} + R \frac{dv}{v}$$

② Turbine & compressor



+ Work done



- Work done

SFEE : $h_1 + \frac{c_1^2}{2} + gz_1 + Q = h_2 + \frac{c_2^2}{2} + gz_2 + W$

For Nozzle . $c_2 >> c_1$ $\boxed{z_1 = z_2}$

$q = 0 = W$.

$c_2^2 = 2(h_2 - h_1)$.

For Compr

$c_1 >> c_2$

$c_1^2 = 2(h_2 - h_1)$.

A nozzle is a device in which velocity ↑ses at the expense of pressure

Nozzles and diffusers are commonly utilized in jet engines, rocket, aircraft, spacecraft engines and even in gardens sprinklers.

Diffuser is a device that ↑ses the pressure since no heat and work transfers across the boundary of the system and the datum remains same

$(\because z_1 = z_2)$

$\therefore h_1 + \frac{c_1^2}{2} = h_2 + \frac{c_2^2}{2}$

mRT_1

We know that $Q = W + dU$

$= \frac{P_1V_1 - P_2V_2}{n-1} + m C_v (T_2 - T_1)$

$dU = \frac{mRT_1 - mRT_2}{n-1} + \frac{m \cdot R}{\gamma - 1}(T_2 - T_1)$

$= mRT_1 \left[\frac{1 - T_2}{(n-1)T_1}\right] + \frac{mR}{\gamma - 1}(T_2 - T_1)$

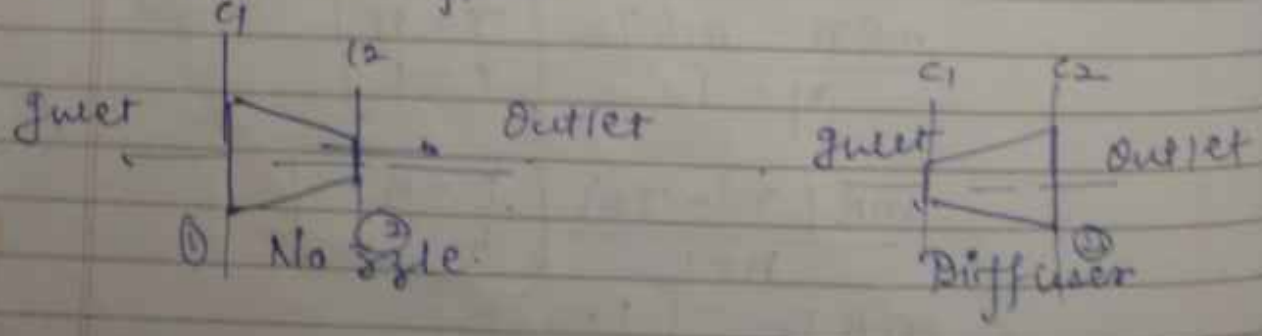
$= mR(T_1 - T_2)\left[\frac{\gamma - n}{(n-1)(\gamma-1)}\right]$

$= \frac{P_1V_1 - P_2V_2}{n-1}\left[\frac{\gamma - n}{\gamma - 1}\right]$

$= W\left[\frac{\gamma - n}{\gamma - 1}\right]$

Application of steady flow Energy eqn :-

① Nozzle & Diffuser.



K.E	$\frac{c_1^2}{2}$	$\frac{c_2^2}{2}$
P.E	gz_1	gz_2
Heat transfer to the system	q	—
Shaft work	—	w
Input pe internal energy	$u_1 + p_1V_1 + \frac{c_1^2}{2} + gz_1 + q$	$u_2 + p_2V_2 + \frac{c_2^2}{2} + gz_2 + w$

Prove that.

$$Q = W\left[\frac{\gamma - n}{\gamma - 1}\right]$$

The work done for a polytropic process.

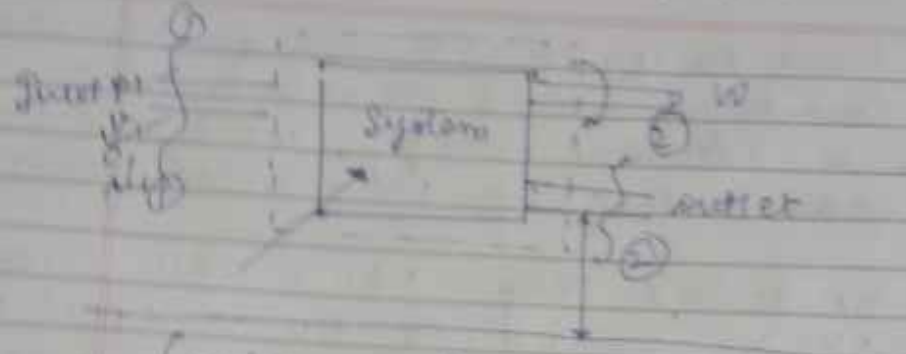
$$W = \frac{p_1V_1 - p_2V_2}{n-1}\left[\frac{\gamma - n}{\gamma - 1}\right]$$

$$\frac{mRT_1 - mRT_2}{n-1}\left[\frac{\gamma - n}{\gamma - 1}\right]$$

$$\frac{mR(T_1 - T_2)}{n-1}\left[\frac{\gamma - n}{\gamma - 1}\right]$$

$$= mRT_1\left[1 - \frac{T_2}{T_1}\right]$$

c_1 → velocity of fluid



Consider a TD system having inlets and outlets having sections (11) and section (22)

At Inlet

p_1 → Intensity of pressure

v_1 →

c_1 → Velocity of fluid

u_1

For Energy Balance

Energy input = Energy output

Table

Specific Energies	Energy Inlet	Energy outlet
① Flow Energy or Flow work	p_1V_1	p_2V_2
② Internal Energy	u_1	u_2

Steady flow Energy equation is a fundamental eqn in thermodynamics which relates the change in internal energy, work and heat for a system undergoing in a steady flow.

It can be derived from FLOT which states that ΔU of a closed system is equal to the heat added to the system − work done

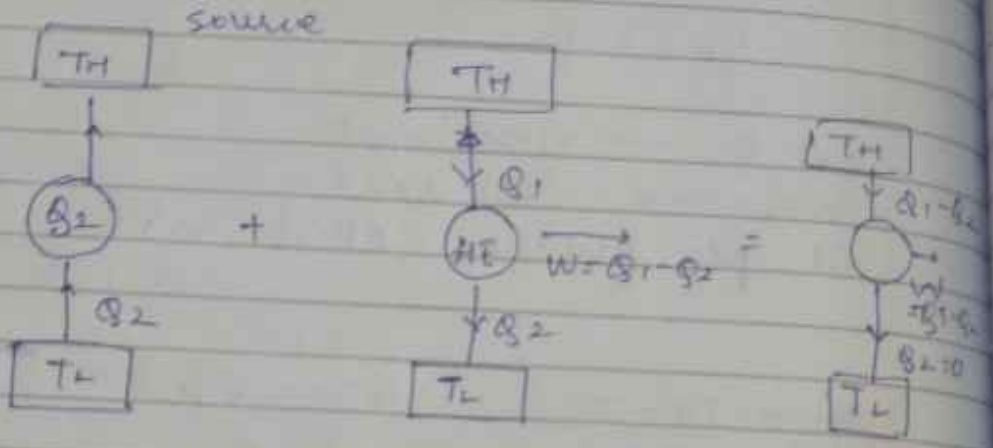
There are various assumptions

1. Heat transfer remains const during the system.
2. Mass flow remains const
3. The system is a steady flow system means that the mass and energy flow rate are kept always.
4. $\dot{m} = \frac{dm}{dt} = \text{const}$
5. State of working substance at any point within the system is
6. There is no change in chemical composition

If none of the above does not satisfy the process then it is called unsteady flow.

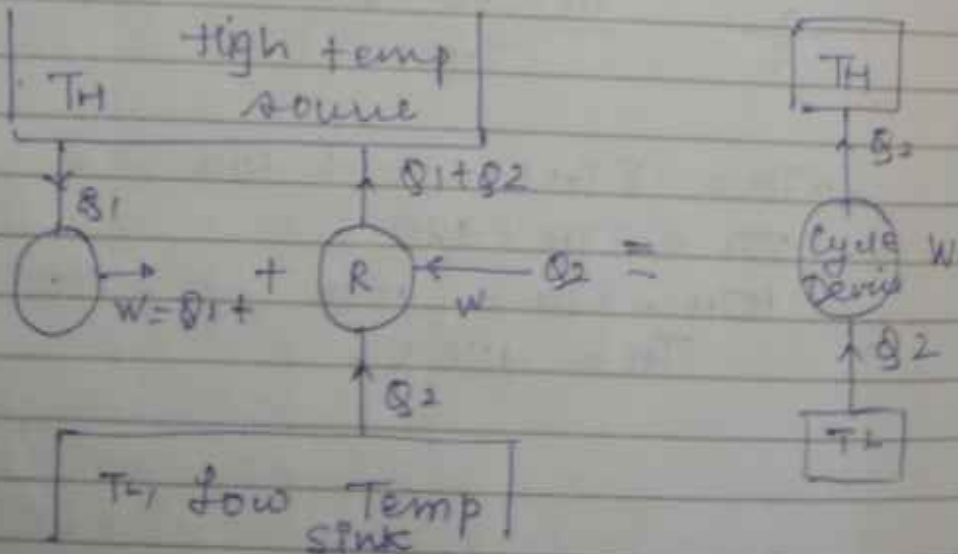
Equivalence of Kelvin & Clausius statement.

(A) Violation of clausius leading to violation of Kelvin.



(2) Steady flow Energy equation (SFEE)

(B) Violation of Kelvin leading to violation of clausius.



$\therefore x = 900\,K$.

$\therefore T_H = 900$

$T_C = 900 - 80$

$= \underline{820\,K}$.

$\eta_2 = 2\eta_1$.

Let $Q_1 \longrightarrow$ Heat input

$W_1 \longrightarrow$ Work done

As per question (APQ) $W_1 = \frac{Q_1}{5}$ $\frac{W_1}{Q_1} = \frac{1}{5} = \eta_1$

$\eta_1 = \frac{T_H - T_L}{T_H}$ $\qquad 4T_H = 5T_L$

Case 2 $T_2' = T_L - 80$ $\qquad \eta_2 = 2\eta_1$

$\eta_2 = \frac{T_H - T_L'}{T_H} = \frac{T_H (T_L - 80)}{T_H}$

$\frac{2}{5} = \frac{T_H - T_L + 80}{T_H}$

$2T_H = 5T_H - 5T_L + 400$

$5T_L = 3T_H + 400$

$4T_H - 3T_H = 400$.

$T_H = 400\,K$.

$\eta_{carno} = \frac{T_L}{T_L - T_H}$

$= \frac{}{}$

$0.7MJ = \frac{0.7 \times 10^7}{3600} = 0.29 \times 10^3$

$\therefore \eta_{actual} < \eta_{ref}$ the inventor's claim is not justified

Q A heat engine working on carnot cycle converts a $\frac{1}{5}^{th}$ of heat input into work. when the temp of sink is reduced by 80°C the efficiency gets doubled $\frac{Q}{5} = W$

$T_c = 80°C = 353\,K$

$T'c = T_c - 80$

$\eta_2 = 2\eta_1$

$\eta_1 = \frac{T_H}{T_H - T_c} \quad \frac{T_H - T_L}{T_L}$

$\frac{1}{5} = \frac{T_H - T_L}{T_H}$

$\frac{1}{5} = \frac{[x - (x - 80)]}{5x}$

A heat engine operates on a carnot cycle with an efficiency of 25%. What COP would a refrigerator operating on the same cycle have? The low temp is 0°C?

$$0.4 = \frac{T_H}{T_H - 273} \qquad \frac{273}{273 - T_H}$$

$$T_H$$

$$273 - T_H = \frac{273}{0.4}$$

$$0.4(273 - T_H) = 273$$

$$109 - 0.4T_H = 273$$

$$10 \qquad = 0.4T_H$$

$$T_H = 364$$

$$= 109.2 - 0.4T_H = 273$$

An inventor claims to have developed a refrigerating machine which operates between $-23^\circ C$ to $27^\circ C$ & consumes (1kW) of power. The machine gives a refrigerating effect of 27MJ/h.

Comment on the claim of inventor

$250\,K = T_L = -23^\circ C \qquad T_H = 27^\circ C = 300\,K$

$Q_c = 27\,MJ. = 27 \times 10^{-6}\,J.$

$$COP = \frac{\quad}{1}$$

$$COP = \frac{1}{\eta}$$

Ques" An inventor claims to have developed a heat engine which operates btwn 27°C & 327°C and produces 10 kW of power. The heat supplied to the engine is 25 kW. Comment on the claim of the the inventor

→ High temp $T_{HL} = 27 + 273 = 300\ K$

Low temp $T_{EH} = 327 + 273 = 600\ K$

$$\eta_{Carnot} = \frac{T_H - T_L}{T_H}$$

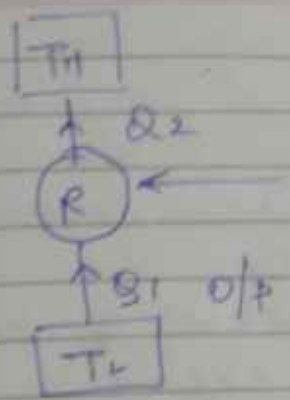
$$= \frac{600 - 300}{600} = 0.5$$

$P = 10\ kW$

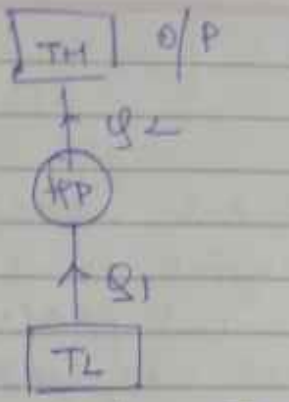
$$\eta_{ACTUAL} = \frac{\text{Power Obtained} = \text{Net work done}}{\text{Heat Supplied}}$$

$$= \frac{10}{25} = 0.4$$

Since the $\eta_{Carnot} > \eta_{actual}$ ∴ the claim of the inventor is justified



$$C.O.P = \frac{T_L}{T_H - T_L}$$



$$COP = \frac{T_H}{T_H - T_L}$$

C.O.P = Coeff of Performance

$$= \frac{\text{Refrigerating Effect / cooling effect}}{\text{Network done}}$$

$$= \frac{R.E}{W_{net}}$$

IInd law of TD.

1) Kelvin Plank constant
2) Clausius Statement

$$1 + COP_{HP} = \frac{T_H}{T_H - T_L}$$

$$\Downarrow$$

$$\boxed{COP_R = \frac{T_L}{T_H - T_L}}$$

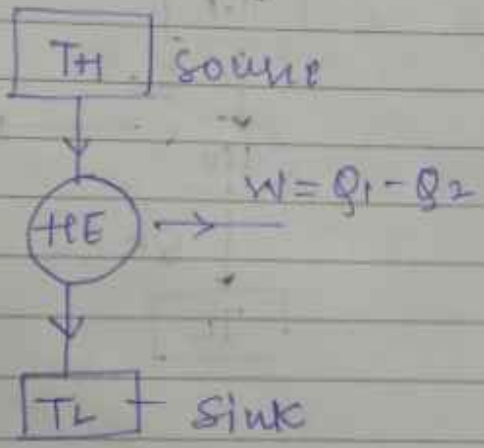
$Q_3 = T_{H1}(S_2 - S_1)$

$Q_R = T_2(S_2 - S_1)$

$$\eta = \frac{Q_3 - Q_R}{Q_3}$$

$$\eta_{const} = \frac{T_{H1} - T_R}{T_3}$$

Difference bwn Heat Engine, Refrigerator & Heat Pump.



$$\eta_{HE} = \frac{T_H - T_L}{T_H} = \frac{Q_s - Q_R}{Q_s}$$

$$= \frac{W_{net}}{Q_s}$$

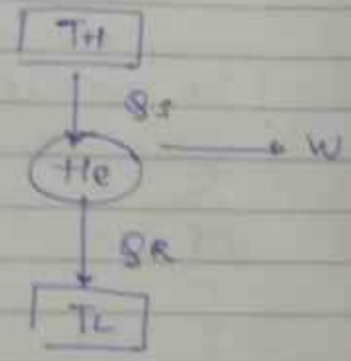
Perpetual Motion Machine : (Hypothetical) (PMM-)
The workdone by system without giving energy.

Limitations of first law :-
1. Direction of Heat flow & workdone was not defined
2. Losses of energy during the heat combustion was not defined

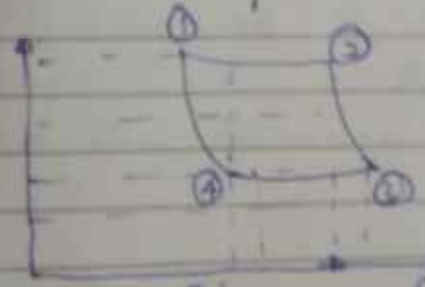
Kelvin Plank state

$$\eta = \frac{Q_S - Q_R}{Q_S}$$

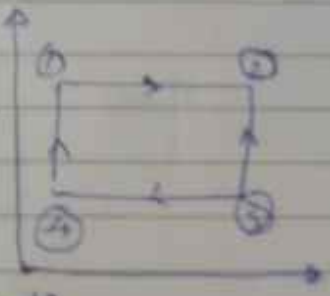
$$\eta = \frac{W_{net}}{Q_S}$$



Carnot cycle



$PV^{\gamma} = C$

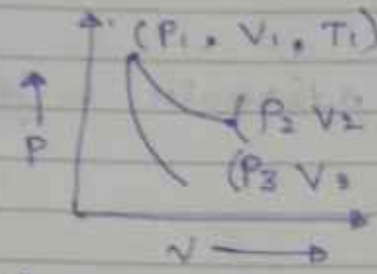


adiabatic → Reversible cycle
→ Entropy is const

1-2 → Heat supplied at const temp (Expansion)
2-3 → Adiabatic expansion
3-4 → Isothermal compression process
4-1 → Adiabatic compression

Divide ① & ②

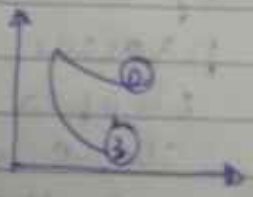
$$\frac{\text{Slope of Adiabatic}}{\text{slope of Isothermal}} = \gamma$$



→ For Isothermal process
$dU = 0$ as T = const
while for adiabatic $dQ = 0$

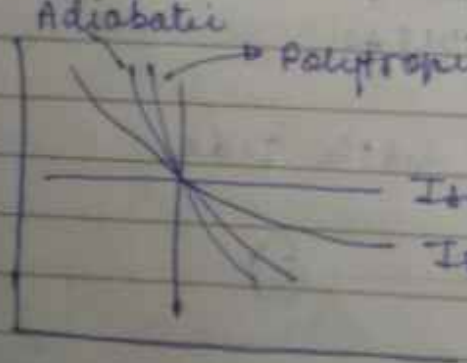
$$dQ = dU + dW$$

$$dU = -dW \longrightarrow -ve = T_2 < T_1$$



Note for Isothermal process
$dU = 0$
$dQ = dW$

$W_{isothermal} > W_{adiabatic}$
(Work of Hyperbola)



$$W = 0.06 \times 10^3 \ln\left(\frac{0.3}{0.06}\right)$$

$$= 60 \ln 5$$
$$= 60 \times 1.609$$
$$= 96.54$$

Slope of PV curve for Adiabatic & Isothermal process

For adiabatic Process.

$$PV^\gamma = C$$

Differentiating

$$dpV^\gamma + P\gamma V^{\gamma-1} dV = 0$$

$$\frac{dp}{dV} = -\frac{P\gamma V^{\gamma-1}}{V^\gamma}$$

$$= -P^2\gamma V^{-1}$$
$$= -P\gamma V^{-1}$$

$$\boxed{\frac{dp}{dV} = -\frac{\gamma P}{V}} \quad \text{— (A)}$$

Slope for Adiabatic process

Since $\gamma > 1$ We can say that the slope of adiabatic process is more slipper than slope of isothermal process

→ For Isothermal process

$$PV = C$$

Differentiating both sides

$$PdV + VdP = 0$$

$$\boxed{\frac{dV}{dP} = -\frac{V}{P}} \quad \text{— (B)}$$

slope for isothermal

Ques: A fluid system a non flow process by $p = \frac{4.5}{V} + 2$

the volume changes from 0.12 to 0.04 m³ and the system rejected 40 K Joule. Determine

dW and dU.

$V_1 = 0.12$ $\quad Q = -40$ K Joule.

$V_2 = 0.04$

$p = \frac{4.5}{V} + 2.$

$U = dQ + dW.$

$U = -40 + \int_{0.04}^{0.04} p\,dV.$

$U = -40 + \int_{0.1}^{0.04} \left(\frac{4.5}{V} + 2\right)$

$U = -40 + 4.5 \int_{0.12}^{0.04} \log V.$

$= -40 + 4.5 \left[\log V\right]_{0.12}^{0.04}$

Q1 For Isothermal

$W = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right) \times 100$

$= 0.3 \times 100 \ln\left(\frac{0.06}{0.3}\right)$

$= 30 \ln\left(\frac{1}{5}\right) = -30 \ln 5$

$= -48.27$

(Q2) For Isothermal

5×10^{-2}.

$$10 = \frac{A}{(0.05)^2} - \frac{B}{0.05}$$

$$\log 10 = A(0.05)^{-2} - B(0.05)^{-1}.$$

$$\log 10 = A[-2 \log 0.05] + B \log 0.05$$

$$\log 1 = A[-1 \log 0.1] + B \log 0.1$$

$$\Rightarrow \quad 1 = A(-2 \log 0.05) + B \log(0.05).$$

$$\rightarrow \quad 0 = A[-1 \log 0.2] + B \log 0.2.$$

1333.

Temp ↑ Temp ↓

Ques"

Given $R = \frac{R_v}{M} = 1.279$ $V_2 = 0.27$

We know $p_1 V_1 = m R T_1$

$$W_{12} = \int_{0.01}^{0.47} 561 V + 200 \frac{V^2}{2} + 100 \frac{V^3}{3}$$

$$W_{1,2} = \int_{0.02}^{0.47} p\, V \left[561 + \frac{V}{2} + \frac{100}{3} \frac{V^2}{2}\right]$$

$$W_{12} = \int_{0.02}^{0.47}$$

$p_2 = 561 + 200 V_2 + 100 V_2^2$

$= 622.29.$

Ques". $p = \frac{A}{V^2} - \frac{B}{V}$ A certain fluid at 10 bar is contained in a cylinder behind a piston. The initial volume is $0.05\ m^3$ Calculate the work done by the fluid when it expands acc to a law $\left[p = \frac{A}{V^2} - \frac{B}{V}\right]$ to a final volume of $0.2\ m^3$ and a final pressure of 1 bar where A, B are constants.

$$\frac{T_2}{T_1} = \left(\frac{10}{3}\right)^{\left(\frac{1.4-1}{1.4}\right)}$$

Compression Temp ↑
Expansion Temp ↓

$$T_2 = 400 \times \left(\frac{10}{3}\right)^{\frac{0.4}{1.4}}$$

$$T_2 = 400 \times \left(\frac{10}{3}\right)^{0.285}$$

$$T_2 = 2.916 \qquad T_2 = 263.$$

$$W = \frac{mR\,[T_2 - T_1]}{\gamma - 1}$$

$$= \frac{2.57 \times 0.116\,[2.916 - 500]}{1.4 - 1}$$

$$pV_1 = mRT_1$$

$$R = \frac{10 \times 0.15 \times 100}{2.57 \times 500}$$

$$\boxed{R = 0.116}$$

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

$$T_2 = 500\left(\frac{0.15}{0.3}\right)^{\frac{1.32-1}{1.32}}$$

$$= 500 \times \left[5\right]^{\frac{0.32}{1.32}}$$

Polytropic Process

$$P_1 V_1^n = P_2 V_2^n$$

Taking log both sides

$$\Rightarrow \log P_1 + n \log V_1 = \log P_2 + n \log V_2$$

$$n \log V_1 - n \log V_2 = \log P_2 - \log P_1$$

$$n \log\left(\frac{V_2}{V_1}\right) = \log \frac{P_1}{P_2}$$

$$n = \frac{\log \frac{P_1}{P_2}}{\log \frac{V_2}{V_1}}$$

$$\left[n = \log\left(\frac{P_1}{P_2} - \frac{V_2}{V_1}\right) \right]$$

Here $n < 1.4$

For polytropic process $\left[W = \frac{P_1 V_1 - P_2 V_2}{n-1} \right]$

Ques" 2.57 kg of a gas for which the $\gamma = 1.35$ occupies a volume of 0.15 m^3 at 10 bar and 500 K. The gas undergoes expansi to 0.6 m^3. Determine the heat rejected are to $PV^{1.32} = C$ (ii) Adiabatic = ?

$\Rightarrow$ $m = 2.57$ $\gamma = 1.35$

$T = 500$ $V_1 = 0.15$ $V_2 = 0.6$

$P = 10$ bar.

$\frac{PV}{T} = \text{const.}$

$dQ = dU + dW$.

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

$W = 2.57 \times 0.288 \{$

$W = \frac{P_1 V_1 - P_2 V_2}{n-1}$

$C_p - C_v = R$

$2.005 - 0.$

$dU = nC_v \Delta T$

$dH = nC_p \Delta T$

$W = \int p\, dV$

$pV^\gamma = C$

$p = \frac{C}{V^\gamma}$

$W = C \int V^{-\gamma}\, dV$

$= C \left[\frac{V^{-\gamma+1}}{-\gamma+1} \right]_1^2$

$= \frac{C}{-\gamma+1} \left[V_2^{-\gamma+1} - V_1^{-\gamma+1} \right]$

$= \frac{C}{-\gamma+1} \; p_2 V_2$

$= \frac{C}{\gamma - 1} \left[p_1 V_1^\gamma V^{-\gamma+1} - p_2 V_2^\gamma V_2^{-\gamma+1} \right]$

$$\boxed{W = \frac{p_2 V_2 - p_1 V_2}{\gamma - 1}}$$

$$\boxed{W = \frac{p_1 V_1 - p_2 V_2}{\gamma - 1} = \frac{nR(T_1 - T_2)}{\gamma - 1}}$$

Adiabatic Process (~~Entha~~ Entropy is const)

$\boxed{\Delta Q = 0}$

$\boxed{pV^\gamma = c}$

$\boxed{H = U + pV}$

Differentiating

$\boxed{dH = dU + v\,dp}$

Carnot cycle not possible b/c fours speed process at same time is not poss.

$$\boxed{p_1 V_1^\gamma = p_2 V_2^\gamma}$$

$$\boxed{\frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^\gamma}$$

$PV = nRT$

$n = 1\,cg$

$R = const$

$\therefore \frac{PV}{T} = const$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{T_2}{T_1} = \frac{P_2 V_2}{P_1 V_1}$$

$$\frac{T_2}{T_1} = \frac{V_1^\gamma}{V_2} \times \frac{V_1}{V_2}$$

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

$$\frac{T_1}{T_2} = \frac{P_2}{P_1}\left(\frac{V_1}{V_2}\right)^\gamma \cdot \frac{V_2}{V_1} \Rightarrow \frac{T_H}{T_L} = \left(\frac{P_H}{P_L}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_L}{V_H}\right)^{\gamma-1}$$

$dU = m C_v \Delta T$

$= 0$

$\Rightarrow$ Isothermal Process

$dU = 0$

$W = p V_1 \ln \frac{V_2}{V_1}$

$= 10 \times 0.15 \ln \left(\frac{0.6}{0.15}\right)$

$= \frac{10 \times 15}{100}$

$= 1.5 \ln \left(\frac{60}{15}\right)^{100/1}$

$= 1.5 \ln 2 \log 2$

Nitrogen a 100°C and 8 bars expands such a way that it can

onstant
emp)

2.57 kg of a gas for which the ratio of $\gamma = 1.35$ occupies a volume of $0.15\ m^3$ at 10 Bar and 500 K. The gas undergoes an expansion to $0.6\ m^3$. Determine the heat absorbed or rejected for the following process.

1) Constant pressure process
2) Hyperbolic
3) Isothermal

$m = 2.57$ kg
$\gamma = 1.35$
$V_1 = 0.15\ m^3$
$P_1 = 10$ Bar
$T_1 = 500$ K.
$V_2 = 0.6\ m^3$

At const pressure.

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$T_2 = \frac{V_2 T_1}{V_1}$

$= \frac{0.6 \times 500}{0.15}$

$= 0.116.$

$P_1 V_1 = mRT_1$, R

$10 \times 0.15 = 2.57 \times R \times 500$

$R = 0.116.$

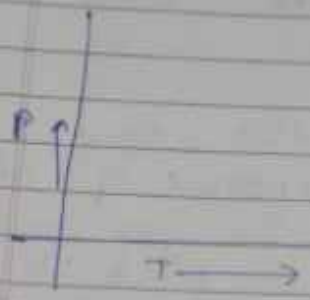
$C_p = \frac{\gamma R}{R - 1}$

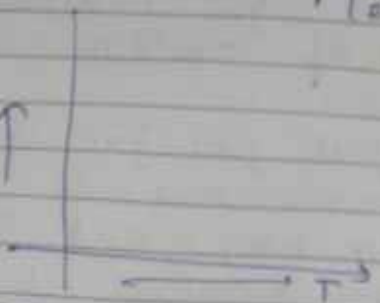
$= \frac{1.35 \times 0.116}{0.116 - 1}$

$= 0.44.$

$C_v = 0.83$

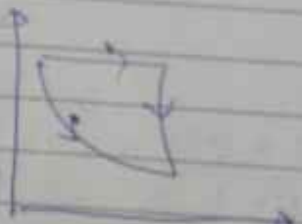
Isothermal Process (Hyperbolic / Constant Temp)

① 



② $p_1V_1 = p_2V_2$

$\boxed{pV = C}$



$W = \int p\,dV$

$= \int \frac{C\,dv}{V}$

$= C \ln \frac{V_2}{V_1}$

$\therefore dQ = -x - 241$

- ve sign indicates that heat is taken out of system

#4 A perfect gas for which the ratio of $\gamma = 1.4$ occupies a volume of $0.06 m^3$ at 10 bar and 500 K. The gas undergoes an expansion of $0.3 m^3$. Find the heat rejected / absorbed by the gas at const p and const 'V'.

$R = 0.25$ kJ/kg

$\gamma = 1.4$

$V_1 = 0.06$

$P_1 = 10$ bar

$T_1 = 500$ K

$V_2 = 0.3$

$$c_p = \frac{R\gamma}{\gamma - 1} = \frac{0.25 \times 1.4}{1.4 - 1} = \frac{\cdot}{0.4}$$

$c_p = 0.875$

At const pressure

A perfect gas for which the ratio of specific heat is 1.4 occupies a volume of 0.3 meter cube at 1 bar 27° celcius. The gas undergoes a compression to 0.06 m³. Determine the heat rejected or absorb by the gas for constant pressure process using gas const as 0.287 kJ/kg K

$\frac{C_p}{C_v} = \gamma = 1.4$

$V_1 = 0.3\ m^3$

$p_1 = 1\ bar$

$T_1 = 27°C + 273 = 300\ K.$

$R = 0.287\ kJ/kg\ K.$

$V_2 = 0.06\ m^3,$

$dQ = ?$

$dQ = dU + dW$

$= mC_V[T_2 - T_1] + p_2V_2 - p_1V_1$

By using PV^n for const pressure proces

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\frac{0.3}{300} = \frac{0.06}{T_2}$

$T_2 = \frac{0.06 \times 300}{0.3}$

$\boxed{T_2 = 60\ K}$

$C_p = \frac{R}{\gamma - 1} = \frac{0.287}{1.4 - 1} \times 1.4$

$= 1.009$

$\frac{PV}{T}$ = const

$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}} \quad P \propto T$$

(1) $dU = mC_V(T_2 - T_1)$

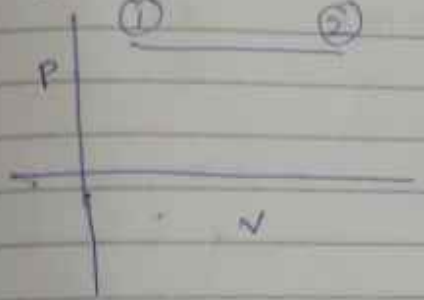
(2) $dW = \int p\,dV = 0$

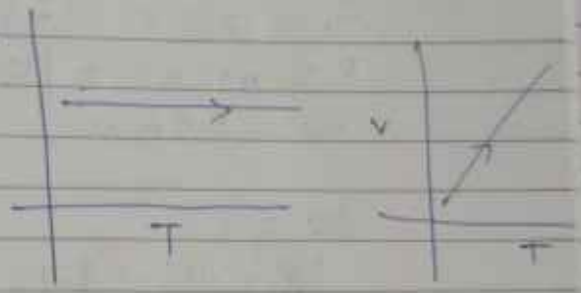
(3) $dQ = dU + dW = 0$

$\boxed{dQ = mC_V\Delta T}$

(4) $\boxed{dH = mC_p\Delta T}$

Isobaric





(2) Isocheric.

By $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$W = \int p\,dV$

$= p\int dv.$

$= p_2V_2 - p_1V_1$

$\boxed{W = mR(T_2 - T_1)}$

$$C_p - \frac{C_p}{\gamma} = R$$

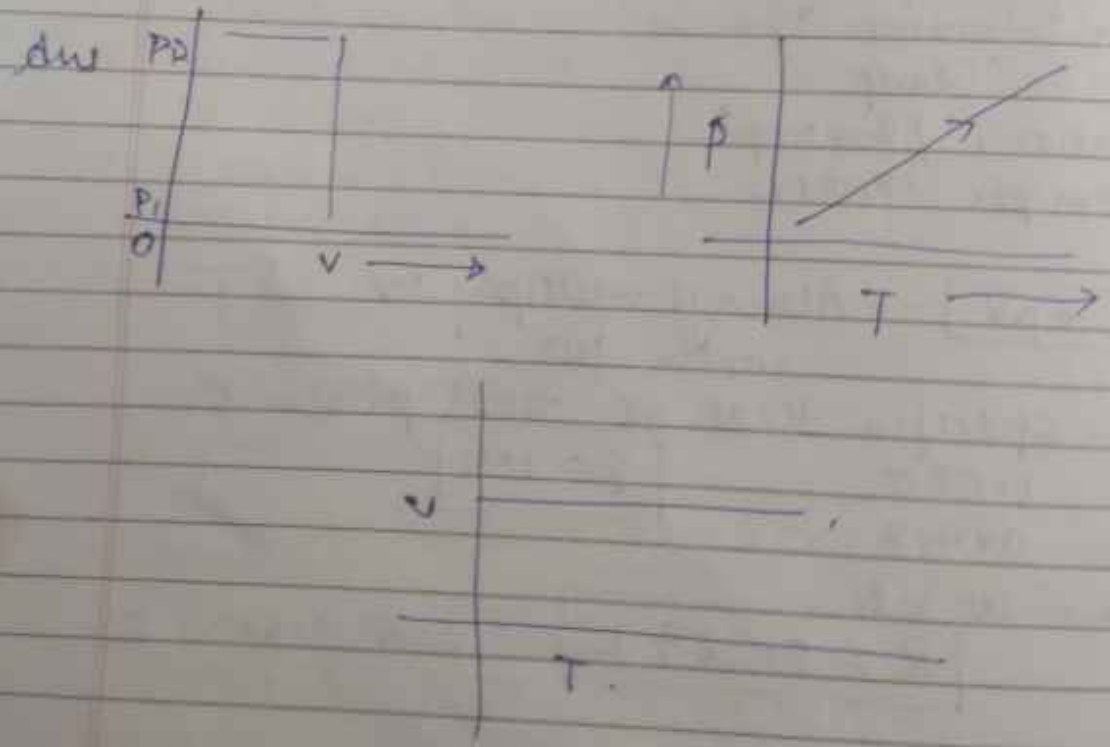
$$C_p\left[1 - \frac{1}{\gamma}\right] = R$$

$$C_p(\gamma - 1) = R$$

$$C_p = \frac{R\gamma}{\gamma - 1}$$

Constant Volume Process

(A) P-V & P-T diagram
(B) Find Relation :
(C) ~~Et~~ dU
(D) dW
dQ = ?
dH = ?



State - Defined as condition of system measured by properties.

Process - Change of state.

~~Path~~

(1) Point function
(2) Path function
3.) Sign convention
(4) Internal Energy
(5) Entropy Enthalpy.
(6) Rel^n b/w Specific Heats
(7) Gas Eq^n
(8) Various Laws.

$C_p - C_v = R$.

$C_p = \gamma C_v$ or $\frac{C_p}{C_v} = \gamma$

$C_p - C_v = R$.

$\frac{C_p}{\gamma} = C_v$

$C_p - \frac{C_p}{\gamma} = R$.

$C_p - \gamma C_v = R$.

Non flow process
const Volume Process
Temp
Adiabatic / Isotropic
Polytropic Process

$H = U + pV$ — Always multiply pv with 100.

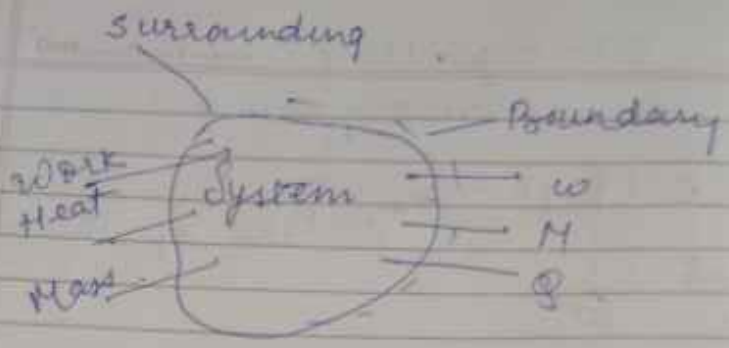
C_p — Specific heat at const pressure

$C_p = 1.005$ $\quad \gamma = 1.4$.

$C_v = 0.718$

$C_p - C_v = R$

$R = 0.287$ KJ $= 0.287 \times 1000$ J.



Closed System:- Only Heat can be transferred not Mass.

there is no difference btwn Gas and Vapours

Properties - Any Measurable or observable quantity is ~~the~~ called properties.

① Intensive
→ Does not depend on mass.
→ Pressure, Temp, Density
↓
Does not depend on mass!

② Extensive
Depend on Mass
Moles. Specific heat

Intrinsic
The quantities that do not req reference for measurement

- Extrinsic.

ET - Engineering Thermodynamics

E | E | E → IInd law of Thermodyna

Zeroth law of TD

1st law of TD

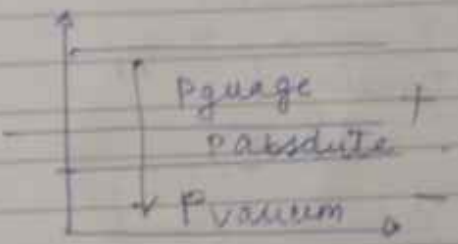
Thermodynamic Properties

- Pressure 1 bar = 10^5 Pa = 10^5 N/m² 1 Pascal = 1 N/m².
- Temp $dQ = T ds$
- Volume

System → Boundary.
Surrounding

Closed system.
Open
Isolated "

Properties
1) State
Process
Path
Cycle.



$ds = \frac{dQ}{T}$

$P_{abs} = P_{atmo} + P_{guage}$

$P_{abs} = P_{atmos} - P_{vacuum}$