Entropy :- It is the measurment of Degree of disorderness or randomness associated with the molecules.

Entropy Principle:- According to this principle the entropy change of universe can never have negative value.

entropy of universe tends to max.

$$(ds)_{universe} \geq 0$$

$$\left[(ds)_{system} + (ds)_{surrounding}\right] \geq 0$$

$(ds)_{univ.} > 0 \longrightarrow$ irreversible process

$(ds)_{univ.} = 0 \longrightarrow$ Reversible process

$(ds)_{univ.} < 0 \longrightarrow$ Impossible

Entropy change of the system:-

Entropy change of the system is the summation of entropy change due to internal irreversibility and entropy change due to external interaction.

$$ds = (ds)_{IIR} + (ds)_{EI}$$

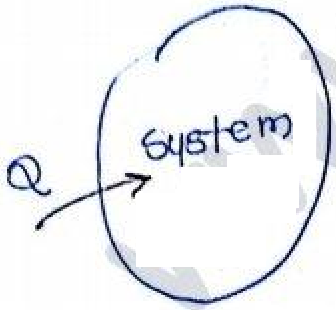
$$ds = (ds)_{IIR} + \frac{dQ}{T}$$

Case A:- If the system is reversible then the value of entropy Generation is equal to zero. $(ds)_{IrR} = 0$

Therefore the entropy change of system is given by

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

Case 1:- If heat is supplied to the system then the entropy change of the system is positive

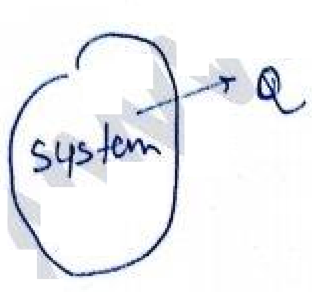


$$dQ > 0$$

$$\frac{dQ}{T} > 0$$

$$\therefore ds > 0$$

Case 2 If heat is rejected from the System then the entropy change of system is negative

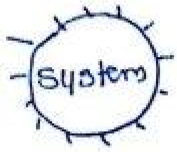


$$dQ < 0$$

$$\frac{dQ}{T} < 0$$

Imp $\boxed{ds < 0}$

Case-3 If the system is adiabatic then the entropy change of the system is having zero value.



$$dQ = 0$$

$$\frac{dQ}{T} = 0$$

$$\therefore \boxed{ds = 0}$$

Imp Note :- ① If the system is reversible and adiabatic then it has to ~~iso~~ isentropic.

② Entropy change of the system may be positive, negative or zero value but the entropy change of the universe is always positive.

Case B :- If the system is Irreversible then entropy change of the system is given by

$$ds = (ds)_{IIR} + (ds)_{EI}$$

$$\boxed{ds = S_{gen} + \frac{dQ}{T}}$$

Case 1 :- If the system is adiabatic then

$$dQ = 0$$

$$\boxed{ds = S_{gen}}$$

Note :- The value of entropy Generation is always positive $\boxed{S_{gen} > 0}$ Always

Case 2 :- Increase in internal irreversibility is compansated by decrease in external intraction then the value of entropy change is equal to zero.

$$ds = \uparrow S_{gen} + \downarrow \frac{dQ}{T}$$

T-ds equation :-

$$dQ = du + Pdv$$

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

$$dQ = Tds$$

$$\boxed{Tds = du + Pdv} \quad \text{---} (1)$$

$$H = U + PV$$

$$dH = dU + PdV + Vdp$$

$$dQ = dU + PdV$$

$$dH = dQ + Vdp \qquad \therefore dQ = Tds$$

$$dH = Tds + Vdp$$

$$\boxed{Tds = dH - Vdp} \quad -(2)$$

~~Integral form~~

The equation (1) & (2) are applicable for both process Reversible & irreversible.

Integral form of Tds eqn:-

$$Tds = du + PdV$$

$$ds = \frac{du}{T} + \frac{P}{T}dV$$

$$PV = RT$$

$$\frac{P}{T} = \frac{R}{V}$$

$$du = C_v\, dT$$

$$\int_{S_I}^{S_F} ds = C_v \int_{T_I}^{T_F} \frac{dT}{T} + \frac{R}{\cancel{V}} \int_{V_I}^{V_F} \frac{dV}{V}$$

$$\boxed{S_F - S_I = C_v \ln\left(\frac{T_F}{T_F}\right) + R \ln\left(\frac{V_F}{V_I}\right)}$$

$$T\,ds = dh - v\,dP$$

$$ds = \frac{dh}{T} - \frac{v}{T}\,dP$$

$$Pv = RT$$

$$\frac{v}{T} = \frac{R}{P}$$

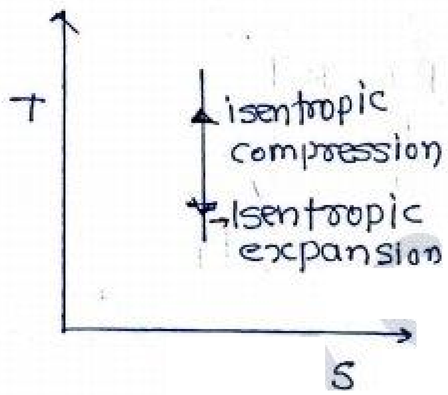
$$h = C_P\,dT$$

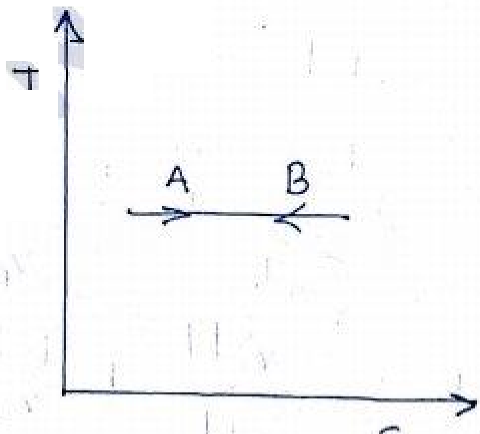
$$\int_{S_I}^{S_F} ds = C_P\int_{T_I}^{T_F}\frac{dT}{T} - R\int_{P_I}^{P_F}\frac{dP}{P}$$

$$\boxed{S_F - S_I = C_P \ln\left(\frac{T_F}{T_I}\right) - R\ln\left(\frac{P_F}{P_I}\right)}$$

* Entropy point function so it is applicable for both reversible and irreversible process.

Representation of Constant Pressure and Constant Volume line on T-S Curve:—





A - Isothermal heat addition

B - isothermal heat addition

Constant Volume Process

$$Tds = du + Pdv$$

$$v = c$$

$$dv = 0$$

$$Tds = du$$

$$Tds = C_v\,dT$$

$$\boxed{\frac{dT}{ds} = \frac{T}{C_v}}$$

Constant Pressure Process

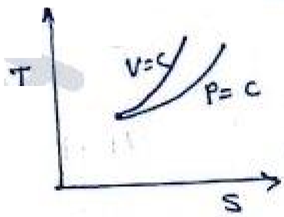
$$Tds = dh - \cancel{v}dp$$

$$P = c,\ dP = 0$$

$$Tds = dh = C_p\,dT$$

$$Tds = C_p\,dT$$

$$\boxed{\frac{dT}{ds} = \frac{T}{C_p}}$$



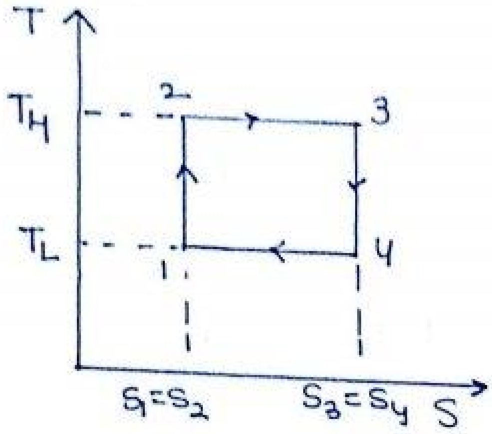
$$\because\quad C_p > C_v$$

$$\frac{1}{C_p} < \frac{1}{C_v} \Rightarrow \frac{T}{C_p} < \frac{T}{C_v} \Rightarrow \boxed{\left(\frac{dT}{ds}\right)_p < \left(\frac{dT}{ds}\right)_v}$$

Note:- The slope of constant pressure line on T-s curve is always less than the slope of constant volume line.

* i.e. less steeper.

Carnot Cycle:-



$$\eta = \frac{\text{output}}{\text{Input}}$$

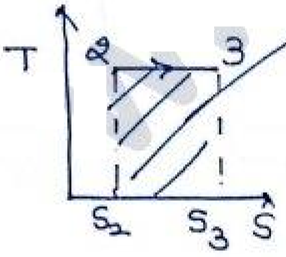
$$\eta = \frac{W_{net}}{Q_s}$$

$$\eta = \frac{Q_{net}}{Q_s} \quad -(1)$$

$$Q_{net} = \cancelto{0}{Q_{1-2}} + Q_{2-3} + \cancelto{0}{Q_{3-4}} + Q_{4-1}$$

$$Q_{Net} = Q_{2-3} + Q_{4-1} \quad -(2)$$

For process 2-3



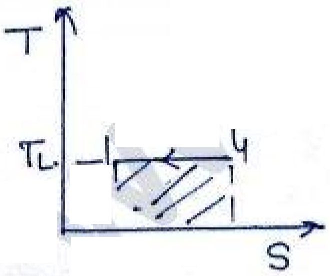
$$ds = S_{gen} + \frac{dQ}{T} \qquad \because S_{gen} = 0 \text{ (Reversible)}$$

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

$$dQ = T\,ds$$

$$Q_{2-3} = T_H(S_F - S_I) = T_H(S_3 - S_2) \quad -(3)$$

For process 4-1



$$dQ = T\,ds = T(S_F - S_I)$$

$$Q_{4-1} = T_L(S_1 - S_4)$$

$$Q_{4-1} = T_1(S_2 - S_3)$$

$$Q_{4-1} = -T_1(S_3 - S_2) \quad -(4)$$

use eq^n ③ & ④ in eq^n ②

$$Q_{net} = T_H(S_3 - S_2) - T_L(S_8 - S_2)$$

$$Q_{net} = \underbrace{(T_H - T_L)}_{+ve}\underbrace{(S_3 - S_8)}_{+ve}$$

$$Q_{net} = W_{net} = (T_H - T_L)(S_3 - S_2) \quad -⑤$$

From equation ⑤ we can say that our system under consideration is a work producing device.

From eq^n ①

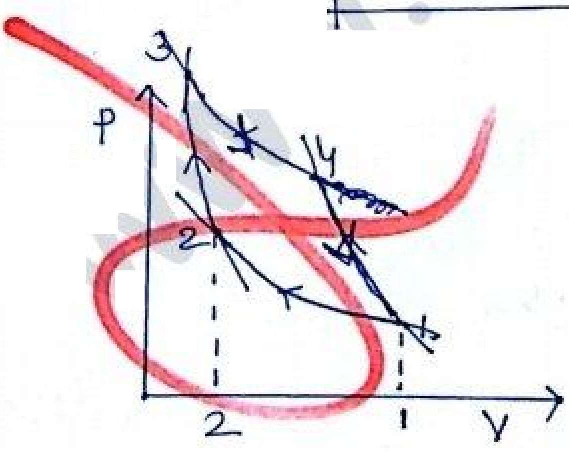
$$\eta = \frac{Q_{net}}{Q_S} = \frac{(T_H - T_L)(S_3 - S_2)}{T_H(S_3 - S_2)}$$

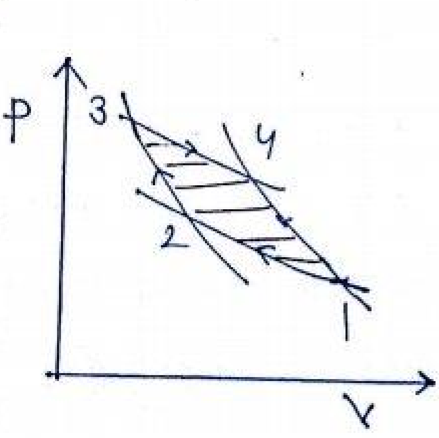
$$\eta = \frac{T_H - T_L}{T_H}$$

$$\boxed{\eta = 1 - \frac{T_L}{T_H}}$$

isothermal - Slow

adiabatic - Fast





Drawback's of Carnot Cycle:-

① All ~~p~~ the processes are '<u>Reversible</u>'. which is impossible to achieve practically

② To achieve isothermal process, it should be infinitelly slow whereas to realise adiabatic condition process has to be externally fast

③ The area under P-V Curve is having very narrow region. More over the swept volume is large.

Note:- ① The reversible engine is more efficient then irreversible engine.

② The maximum possible efficiency of a reversible engine is given by Carnot.

③ The expression of carnot efficiency is

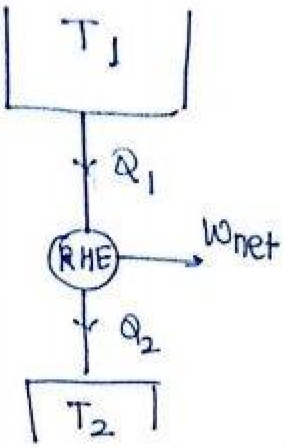
$$\boxed{\eta_c = 1 - \frac{T_L}{T_H}}$$

④ Carnot efficiency is a function of <u>temp only</u>.

⑤ If there are n number of reversible engine Operating between same ~~the~~ temp. Limit with different working fluid then the value of max. possible efficiency or ideal efficiency or carnot efficiency is having same value.

(6) Carnot efficiency is independent of working fluid.

(7)



$$\eta_C = 1 - \frac{T_2}{T_1} = 50\%$$

$$\eta_A = \cancel{Q}\,\frac{W}{Q_1} = 40\%$$

The η of above engine is 40%.

$\eta_A = 40\% \rightarrow$ Actual.

$\eta_c = 50\% \rightarrow$ Ideal.

The above engine is

(a) Irrev./ Possible $\longrightarrow \oint \frac{dQ}{T} < 0$, $(ds)_{univ} > 0$, $\eta_{carnot} > \eta_{actual}$

(b) Rev./ Ideal $\rightarrow \oint \frac{dQ}{T} = 0$, $(ds)_{univ} = 0$, $\eta_{carnot} = \eta_{actual}$

(c) Impossible $\rightarrow \oint \frac{dQ}{T} > 0$, $(ds)_{univ} < 0$, $\eta_{carnot} < \eta_{actual}$

Question:- $ds = C_p \frac{dV}{V} + C_v \frac{dP}{P}$, $PV^{\gamma} = C$

Prove the following for an ideal gas:
using this result show that ($\cancel{PV^{\gamma}=C}$) for an ideal Gas undergoing an isentropic change of state with costant specific heat $PV^{\gamma} = C$

$$Tds = du + Pdv \quad -①$$

$$Tds = dH - Vdp \quad -②$$

from ①

$$ds = \frac{C_v\, dT}{T} + \frac{P}{T} dv$$

from ②

$$ds = \frac{C_p\, dT}{T} - \frac{V}{\cancel{T}} dp$$

$$\frac{dT}{T} = \frac{ds - \frac{P}{T} dv}{C_v}$$

$PV = RT$

$\frac{P}{T} = \frac{R}{V}$

$$ds = \frac{C_p}{C_v}\left(ds - \frac{P}{T} dv\right) - \frac{V}{\cancel{T}} dp$$

$$ds = \frac{C_p}{C_v} ds - \frac{C_p}{C_v} \frac{R}{V} dv - \frac{V}{\cancel{T}} dp$$

$$ds\left(1 - \frac{C_p}{C_v}\right) = -\frac{C_p}{C_v} \frac{R}{V} dv - \frac{V\, dp}{\cancel{T}}$$

$$ds\left(\frac{C_p - C_v}{C_v}\right) = \frac{C_p R \frac{dv}{V} + C_v V \frac{dp}{\cancel{T}}}{C_p}$$

$$ds = \frac{C_p R \frac{dv}{V} + C_v V \frac{dp}{\cancel{T}}}{C_p - C_v}$$

$C_p - C_v = R$

$$ds = \frac{C_p R}{C_p - C_v} \frac{dv}{V} + \frac{C_v}{C_p - C_v} V \frac{dp}{\cancel{T}} \qquad \frac{V}{\cancel{R}} = \frac{R}{P}$$

$$ds = C_p \frac{dv}{V} + C_v \frac{dp}{P}$$

or

$$Tds = du + pdV$$

$$ds = C_v \frac{dT}{T} + \frac{P}{T} dv \qquad \frac{P}{T} = \frac{R}{V}$$

$$ds = C_v \frac{dT}{T} + (C_p - C_v) \frac{dv}{V}$$

$$ds = C_p \frac{dv}{V} + C_v \left(\frac{dT}{T} - \frac{dv}{V} \right)$$

$$PV = mRT$$

$$\frac{Pdv + vdp}{PV} = \frac{mRdT}{PV} \rightarrow \frac{dT}{T} - \frac{dv}{V} = \frac{dp}{P}$$

$$\boxed{ds = C_p \frac{dv}{V} + C_v \frac{dp}{P}}$$

isentropic $ds = 0$

$$C_p \frac{dv}{V} + C_v \frac{dp}{P} = 0$$

$$\frac{C_p}{C_v} \frac{dv}{V} + \frac{dp}{P} = 0$$

$$\gamma \int \frac{dv}{V} + \int \frac{dp}{P} = \int 0$$

$$\gamma \ln v + \ln P = \ln C$$

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

Q1102 The specific heat of the gas are given by $C_p = a + kT$, $C_v = b + kT$, where a, b, K are constant and T is the temp in kelvin Then drive $T^b e^{kT} V^{a-b}$ = Const. for reversible adiabatic process executive

$C_p = \cancel{\text{const}}$

Ans by the gas.

$$C_p = a + kT, \quad C_v = b + kT$$

$$Tds = du + PdV$$

$$ds = C_v \frac{dT}{T} + \frac{P}{T} dv \qquad \frac{P}{T} = \frac{R}{V}$$

$$pv^{\gamma} = \text{const}$$

$$\cancel{PdV} \; P.\gamma V^{\gamma-1} dv + V^{\gamma} dp = 0$$

$$P.\gamma. \frac{dv}{V} + \frac{dp}{p} = 0$$

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

$$ds = (b + kT) \frac{dT}{T} + (C_p - C_v) \frac{dV}{V}$$

$$ds = 0$$

$$(b + kT)\frac{dT}{T} + (a-b)\frac{dV}{V} = 0$$

$$b\int\frac{dT}{T} + k\int dT + (a-b)\int\frac{dV}{V} = 0$$

$$T^{b} e^{kT} V^{a-b} = \text{Const}$$

Question An ideal gas is heated from temp T_1 to T_2 at constant volume the gas is then expanded back to it's initial temp according to the law $PV^n = C$. If the entropy change in the two process are equal the drive the expression for poly-tropic index in terms of adiabatic index.

$$T\,ds = du + p\,dv, \quad T\,ds = dh - V\,dp$$

1→2

$$(ds)_1 = C_v \frac{dT}{T}$$

$$(ds)_1 = C_v \ln\left(\frac{T_2}{T_1}\right)$$

$$ds = \frac{dh}{T} - \frac{V\,dP}{T}$$

$$(ds)_2 = C_p\frac{dT}{T} - \frac{R\,dP}{P}$$

$$PV^n = \text{Cons}$$

$$V = \left(\frac{C}{P}\right)^{1/n}$$

$$PV = RT$$

$$V/T = \frac{R}{P}$$

$$\cancel{(ds)_2 = C_p \frac{dT}{T} - (C_p - C_v)\frac{dP}{P}}$$

$$(ds)_o = C_p \frac{dT}{T} - C_p \frac{dP}{P} + C_v \frac{dP}{P}$$

$\underline{2\text{-}3}$ $\quad T_3 = T_1$

$$T\,ds = du + P\,dV$$

$$ds = \frac{du}{T} + \frac{P}{T}\,dV$$

$$S_{2\text{-}3} = C_v \ln \frac{T_1}{T_2} + R \ln \frac{V_3}{V_2}$$

$\underline{\text{So}}$

$$C_v \ln\left(\frac{T_2}{T_1}\right) = C_v \ln\left(\frac{T_1}{T_2}\right) + R \ln\left(\frac{T_2}{T_1}\right)^{1/n-1}$$

$$2\,\frac{R}{\gamma-1} \ln\left(\frac{T_2}{T_1}\right) = R \ln\left(\frac{T_2}{T_1}\right)^{1/n-1}$$

$$\frac{2}{\gamma-1} = \frac{1}{n-1}$$

$$2n - 2 = \gamma - 1$$

$$2n = \gamma + 1$$

$$\boxed{n = \frac{\gamma+1}{2}}$$

IES

Question A gas follows the equation $P(V-b) = RT$ (clausius equation) where b is constant. Internal energy of the gas is given by '$U = C_v T + \text{Const}$' Then show that $P(V-b)^{\gamma} = \text{Const}$. for a reversible adiabatic process executed by this gas.

Sol^n

$$P(V-b) = RT \quad , U = C_v T + \text{Const}$$

$$ds = 0$$

$$Tds = du + Pdv$$

$$\frac{du}{T} = -\frac{P\,dv}{T}$$

$$\frac{d(C_v T + \text{Const})}{T} = -\frac{P\,dv}{T}$$

$$\frac{d(C_v T + C_1)}{T} = -\frac{R\,dv}{V-b}$$

$$C_v \int \frac{dT}{T} = -R \int \frac{dv}{V-b}$$

$$C_v \ln\left(\frac{T_2}{T_1}\right) = -R \ln(V-b)\Big|_{V_1}^{V_2}$$

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

$$\ln\left(\frac{T_2}{T_1}\right) = \ln\left(\frac{v_1-b}{v_2-b}\right)^{\gamma-1}$$

$$\frac{1}{T} \propto (v-b)^{\gamma-1}$$

$p(v-b) = RT$

$$p(v-b)^{\gamma} = \text{Const}$$

$$C_v\frac{dT}{T} + R\frac{dv}{v-b} = 0$$

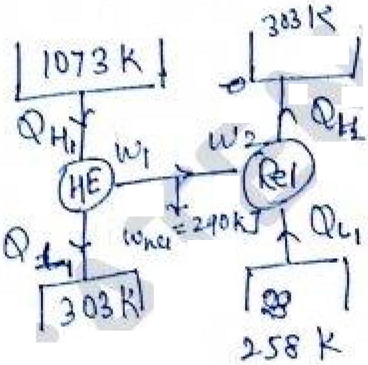
$$\int\frac{dT}{T} + (\gamma-1)\int\frac{dv}{v-b} = 0$$

$$T(v-b)^{\gamma-1} = C$$

$$p(v-b)^{\gamma} = C$$

★★
~~Imp Very Imp~~
~~Question~~
~~6 times IES~~
3 time IAS

Chap 4
Q.15



$w_1 - w_2 = 290$ kJ

$w_2 = 1073$ kJ

800
273
1073

$Q_{L_1} + Q_{H_1} = ?$

1073 ~~536~~ + 6154

→ 7764 Ans

$Q_{H_1} = 1900$ kJ

$Q_{H_1} - Q_{L_1} = \cancel{290\text{ kJ}}\ w_1$

~~Q_{L_1} 1610 kJ~~

$1 - \frac{303}{1073} = 1 - \frac{Q_{L_1}}{1900}$

$Q_{L_1} = 536$ kJ so $w_1 = 1363$ kJ

COP of Ref

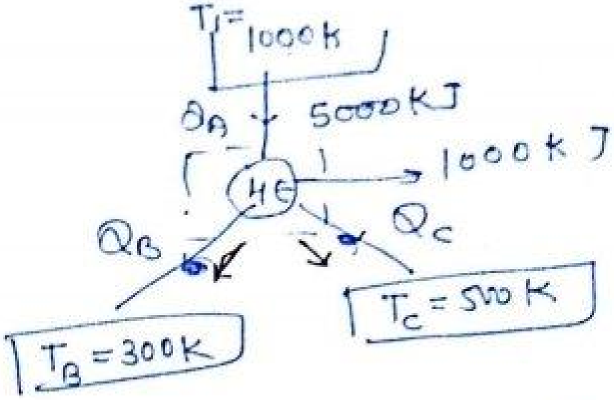
$\frac{258}{303-258} = \frac{Q_{L2}}{\cancel{290}\,1073}$

$Q_{L_2} = \cancel{\text{kJ}}$ 6154 kJ

~~$Q_{H_2} = Q_L + W$~~

~~$Q_{H_2} = 1452.67$ kJ~~

(16)



Assume direction of Q_B & Q_C are away from engine

$$\frac{Q_A}{1000} - \frac{Q_B}{300} - \frac{Q_C}{500} = 0$$

$$\frac{Q_B}{300} + \frac{Q_C}{500} = 5 \quad -(1)$$

$$Q_A - Q_B - Q_C = 1000$$

$$Q_B + Q_C = 4000 \text{ kJ} \quad -(2)$$

(1) & (2)

$$\frac{Q_B}{300} + \frac{4000 - Q_B}{500} = 5$$

$$\frac{Q_B}{3} + \frac{4000 - Q_B}{5} = 500$$

$$\frac{Q_B}{3} - \frac{Q_B}{5} + 800 = 500$$

$$\frac{2Q_B}{15} = -300$$

Towards engine $Q_B = -2250$ kJ

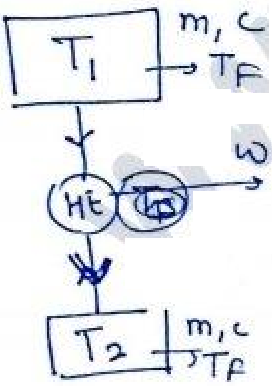
Away engine $Q_C = 6250$ kJ

15 marks

Quest

6 IES
3 IAS

Two identical bodies of equal mass 'm' and specific heat 'c' initial at temp T_1 & T_2 both in kelvin, are used as a reservior for a heat engine operating in a reversible cycle. The bodies may be treacted as operating at constant pressure. If the engine interact with the reservi ors until they attain the same final temp then drive the expression for final temp and max. work obtain



$$W_{net} = Q_1 - Q_2$$

$$W_{net} = mc(T_1 - T_F) - mc(T_F - T_2)$$

$$W_{net} = mc(T_1 + T_2 - 2T_F) \quad (1)$$

$$(ds)_{net} = 0$$

$$(ds)_1 + (ds)_2 = 0$$

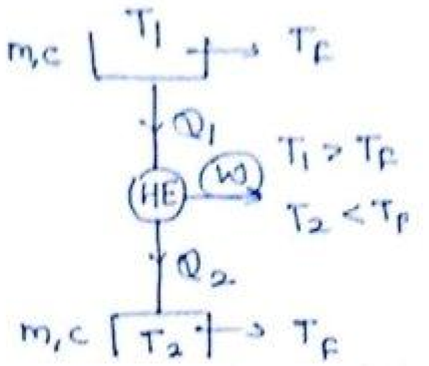
$$ds = m\frac{dH}{T} - \cancel{\frac{V\,dP}{T}}^{\,0}$$

$$ds = mC_p \frac{dT}{T}$$

$$ds = mc\frac{dT}{T} \Rightarrow S_2 - S_1 = mc\ln\left(\frac{T_F}{T_1}\right)$$

$$mc\ln\left(\frac{T_F}{T_1}\right) + mc\ln\left(\frac{T_F}{T_2}\right) = \ln 1 = 0$$

$$\frac{T_F}{T_1} \times \frac{T_F}{T_2} = 1 \Rightarrow T_F = \sqrt{T_1 T_2}$$



let us assume $T_1 > T_2$ and T_F is the final temp attain by both body

$$Q_1 = W_{max} + Q_2 \qquad \text{Reversible}$$

$$W_{max} = Q_1 - Q_2 \qquad \underbrace{Q = mc(T_H - T_L)}_{\text{Always}}$$

$$W_{max} = mc[T_I - T_F] - mc[T_F - T_2]$$

$$W_{max} = mc[T_1 + T_2 - 2T_F] \quad -①$$

Rev $\oint \frac{dQ}{T} = 0$, $(ds) = 0$

$$(ds)_I + (ds)_{II} = 0 \quad -②$$

$$Tds = dh - vdp$$

$$P = c$$

$$Tds = dh$$

$$\int ds = mc\int_{T_I}^{T_F} \frac{dT}{T} = mc \ln\left(\frac{T_F}{T_I}\right)$$

So usein ②

$$mc \ln\left(\frac{T_F}{T_1}\right) + mc \ln\left(\frac{T_F}{T_2}\right) = 0 = \ln 1$$

$$\frac{T_F}{T_1} \times \frac{T_F}{T_2} = 1 \quad \Rightarrow \quad \boxed{T_F = \sqrt{T_1 T_2}}$$

So $W_{max} = mc[T_1 + T_2 - 2\sqrt{T_1 T_2}]$

$$W_{max} = mc[\sqrt{T_1} - \sqrt{T_2}]^2$$

Imp

$$\boxed{\begin{aligned} W_{max} &= mc\left[\sqrt{T_H} - \sqrt{T_L}\right]^2 \\ T_F &= \sqrt{T_H T_L} \end{aligned}}$$

Question:- A fluid of mass 'm' at temp 'T_1' is mixed with an equal amount of same fluid at a temp T_2 The specific heat of the fluid if 'c' Then. drive the express for total entropy change due to the mixing process.

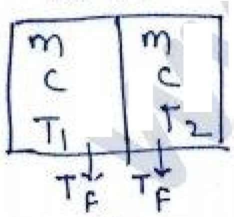
Soln let us assume the system is well insulated i.e. There is no heat interaction between system and surronding. i.e. The entropy change of surrounding is 0.

let us assume $T_1 > T_2$ and T_F is the final temp. atain by both bodies

Apply

(Heat loss by 1 body) - (Heat gain by 2nd body)

$T_1 > T_2$



$T_1 > T_F$
$T_2 < T_F$

$$mc(T_1 - T_F) = mc(T_F - T_2)$$

$$\boxed{T_F = \frac{T_1 + T_2}{2}}$$ (Q) A.M

$$(ds) = (ds)_{I} + (ds)_{II}$$

$$= mc \ln \frac{T_F}{T_1} + mc \ln \frac{T_F}{T_2}$$

$$(ds) = mc \ln \frac{T_F^2}{T_1 T_2} = 2 mc \ln\left(\frac{T_F}{\sqrt{T_1 T_2}}\right)$$

so $$\boxed{\Delta S = 2mc\ln\left(\frac{\frac{T_1+T_2}{2}}{\sqrt{T_1 T_2}}\right) = 2mc\ln\left(\frac{A.M.}{G.M.}\right)}$$

Note:- The A.M. is always Greater then G.M. so by using above expression we can say that mixing of fluid is a Case of irreversible process

$$(ds)_{univ} = (ds)_{sys} + (ds)_{surr}$$

$$dQ = 0$$

$$(ds)_{surr} = 0$$

$$(ds)_{univ} = (ds)_{system}$$

$$AM > GM \Rightarrow \frac{AM}{GM} > 1$$

$$(ds)_{univ} > \underline{0}$$

$$(\sqrt{T_1} - \sqrt{T_2})^2 > 0$$

$$T_1 + T_2 - 2\sqrt{T_1 T_2} > 0$$

$$\frac{T_1 + T_2}{2} > \sqrt{T_1 T_2}$$

Question Air is flowing steadily in a insulating duct. The pressure and temp measure of air at 2 station are given below in the form of table
Stablish the direction of two of air in duct.

	S1	S2
Pr.	130 KPa	100 KPa
temp.	50°C	13°C

Soln

Chang in entopy from ① → ② should be > 0

$$ds = \frac{C_p dT}{T} - \frac{v\,dP}{T} \qquad PV = RT$$

$$\frac{V}{T} = \frac{R}{P}$$

$$ds = C_p \frac{dT}{T} - R\frac{dP}{P}$$

Assume 1-2

$$S_2 - S_1 = C_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$$

$$S_2 - S_1 = 1.005 \ln\left(\frac{286}{323}\right) - 0.287 \ln\left(\frac{100}{130}\right)$$

$$S_2 - S_1 = -0.1222 + 0.0752$$

$$\Delta S_{1-2} = -0.0468$$

ue

so $S_2 - S_1 < 0$ flow $\underline{2 \rightarrow 1}$

$S_2 - S_1 < 0$

Assuming the direction of flow of air from station ① to station ②

$$S_2 - S_1 = -0.0486 \ \frac{kJ}{kg\,k}$$

$\therefore$ $dQ = 0$

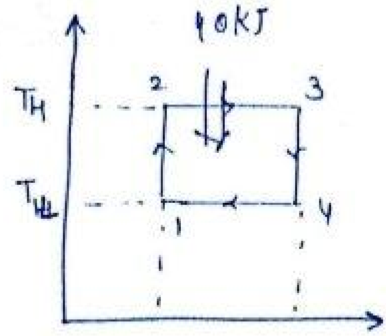
$(ds)_{sur} = 0$ $\Big\}$ $(du)_{univ} = (ds)_{sys}$

so $(ds)_{sys} > 0$

so flow $2 \rightarrow 1$

Ques 0.5 kg of air (ideal gas) executes a Carnot Cycle having a efficiency of 50 %. Heat transfer to air during isothermal expansion is 40 kJ. At begining of isothermal expansion pressure is 7 bar & Volume is $0.12\,m^3$. Determimen max. & min temp of gas in (k) Volume at end of isothermal expansion in m^3 & also determine WT & HT for each of 4 process $C_v = 0.721$ kJ/kgK

$C_p = 1.008$ kJ/kgK



$m = 0.5\ kg$

$\eta = 0.50 = 1 - \frac{T_L}{T_H} \Rightarrow \frac{T_L}{T_H} = 0.5$

$P_2 = 7\ bar,\ V_2 = 0.12 m^3$

$V_3 = ?$

$40 = C \ln \frac{V_3}{V_2}$

$40 = 700 \times 0.12 \ln \frac{V_3}{0.12}$

$V_3 = 0.1935\ m^3$

$P_2 V_2 = m R T_2$

$T_2 = T_H = \frac{7 \times 10^5 \times 0.12}{0.5 \times 287}$

$T_H = 585.36\ K$

$T_L = 292.68\ K$

Process	Q(KJ)	W(KJ)
(1-2):- $ds = 0$	0	-105.45 KJ
(2-3): $T = C$	40 KJ	40 KJ
(3-4): $ds = 0$	0	$+105.45$
(4-1) $dT = 0$	-20 KJ	-20 KJ

4-1

$\eta = \frac{Q_S - Q_R}{Q_S} = 0.5 \Rightarrow \frac{40 - Q_R}{40} = \frac{1}{2}$

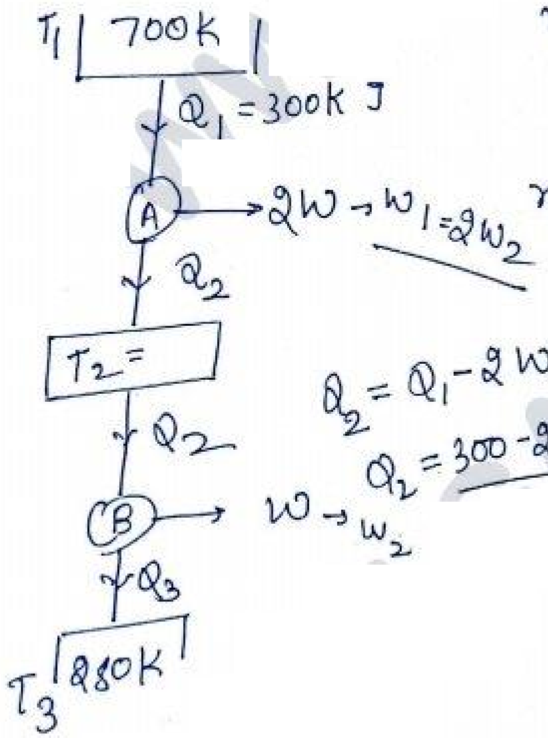
$Q_R = 20 KJ$ (Rejected)

2-1 $W_{1-2} = \frac{P_1 V_1 - V_2 P_2}{r-1} = \frac{mR(T_L - T_H)}{r-1}$

$W_{1-2} = \frac{0.5 \times 0.287 (292.68 - 586.36)}{0.4} = -105.45 KJ \doteq W_{3-4}$

Question Two reversible heat engine A and B are arranged in series. Heat engine A rejects to the heat engine B directly. Engine A receives 300 KJ of heat at 427°C from a high temp. source while engine B rejects heat to a cold sink at 7°C if work produce by engine A is twice of engine B then determine

(i) Intermediate temp between A & B
(ii) Efficiency of each engine
(iii) Heat rejected by engine A
(iv) Heat rejected to the sink.



$$\eta_1 = 1 - \frac{T_2}{700} = \frac{2W}{300} \quad \text{—(1)}$$

$$\eta_2 = 1 - \frac{280}{T_2} = \frac{2W}{Q_2}$$

$Q_2 = Q_1 - 2W$

$Q_2 = 300 - 2W$

$$\frac{T_2 - 280}{T_2} = \frac{2W}{300 - 2W} \quad \text{—(2)}$$

$$\frac{700 - T_2}{700} = \frac{2W}{300} \quad \text{—(3)}$$

$$T_2 = \left(\frac{300 - 2W}{300}\right) \times 700$$

$\underline{300 - 2W}$

$$1 - \frac{280 \times 300}{(300 - 2W)700} = \frac{2W}{300 - 2W} = \frac{(300-2W)700 - (280 \times 300)}{(300 - 2W)\,700}$$

$$1400W = 210000 - 1400W - 84000$$

$$W = 45\ kJ$$

$$Q_2 = 300 - 90 = 210\ kJ$$

$$\eta_1 = \frac{90}{300} = 0.3$$

$\eta_2 =$

$$Q_1 = W_1 + Q_2 \qquad \eta_1 = 1 - \frac{T_2}{T_1} = \frac{W_1}{Q_2}$$

$$300 = W_1 + Q_2 \quad (1) \qquad 1 - \frac{T_2}{700} = \frac{W_1}{300} \quad (2)$$

$$Q_2 = W_2 + Q_3 \qquad W_1 = 2W_2$$

$$\eta_B = 1 - \frac{T_3}{T_2} = \frac{W_2}{Q_3} \qquad Q_1 - Q_2 = 2(Q_2 - Q_3)$$

$$Q_2 = \frac{Q_1 + 2Q_3}{3}$$

$$\eta_B = 1 - \frac{280}{420} \qquad T_2 = \frac{T_1 + 2T_3}{3}$$

$$\eta_B = 0.33 \qquad T_2 = \frac{700 + 2 \times 280}{3}$$

$$\eta_A = 1 - \frac{280}{700} \qquad T_2 = 420\ K$$

$$\eta_B = 0.4$$

$$W_2 = 60\ kJ \qquad Q_2 = \underline{180\ kJ}$$

$$W_1 = 120\ kJ$$

or $$\frac{Q_1}{T_1} - \frac{Q_2}{T_2} + \frac{Q_2}{T_2} - \frac{Q_3}{T_3} = 0$$

$$\frac{300}{700} = \frac{Q_3}{280} \Rightarrow Q_3 = \underline{120\ kJ}$$

Note: – Question :- There are two reversible heat engine which are operating in series and heat rejected by engine A is directly into B then determine the expression of intermidiate temp if Both engine (i) are equally efficient (GM)

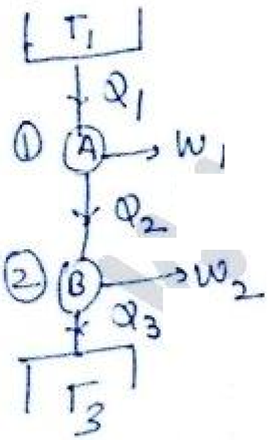
(ii) produce equal amount of work (AM)

(i) if $\underline{\eta_1 = \eta_2}$ $$1 - \frac{T_2}{T_1} = 1 - \frac{T_3}{T_2}$$

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

(ii) if $\underline{W_1 = W_2}$ $\Rightarrow$ $$Q_1 - Q_2 = Q_2 - Q_3$$

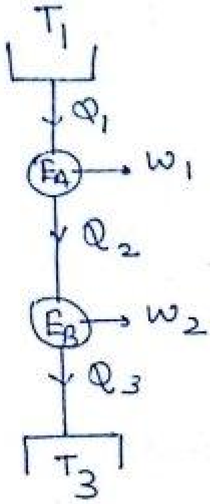
$$Q_2 = \frac{Q_1 + Q_3}{2}$$



$$\boxed{T_2 = \frac{T_1 + T_3}{2}}$$

Question Drive the expression of Combined efficiency

$$\boxed{\eta_{cc} = \eta_1 + \eta_2 - \eta_1 \eta_2}$$



$$\eta_1 = \frac{W_1}{Q_1} \Rightarrow W_1 = \eta_1 Q_1 \quad -(1)$$

$$\eta_2 = \frac{W_2}{Q_2} \Rightarrow W_2 = \eta_2 Q_2 \quad -(2)$$

$$\eta_{cc} = \frac{W_1 + W_2}{Q_1} = \frac{\eta_1 Q_1 + \eta_2 Q_2}{Q_1}$$

$$\eta_{cc} = \eta_1 + \eta_2 \left(\frac{Q_2}{Q_1}\right) \quad -(3)$$

$$\Rightarrow Q_1 = Q_2 + W_1 \qquad \because W_1 = \eta_2 Q_2$$

$$Q_2 = Q_1 - \eta_1 Q_1 \quad -(4)$$

use eqn (3) in (4)

$$\eta_{cc} = \eta_1 + \eta_2 \left(\frac{Q_1 - \eta_1 Q_1}{Q_1}\right)$$

$$\boxed{\eta_{cc} = \eta_1 + \eta_2 - \eta_1 \eta_2}$$

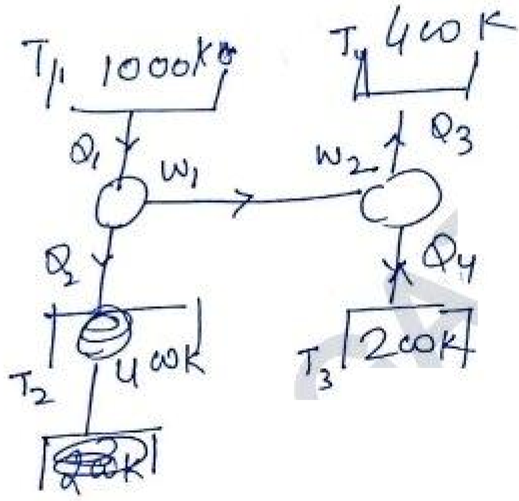
Chap-4

① a

$$\oint \frac{dQ}{T} = \frac{100}{1000} + \frac{50}{500} - \frac{60}{300}$$

$$\oint \frac{dQ}{T} = \frac{1}{10} + \frac{1}{10} - \frac{1}{5} = 0$$

②



$$W_1 - W_2 = 300 \text{ KJ}$$

$$Q_1 = 2000 \text{ KJ}$$

$$1 - \frac{400}{1000} = 1 - \frac{Q_2}{2000}$$

$$\frac{400}{1000} = \frac{Q_2}{2000}$$

$$Q_2 = 800 \text{ KJ}$$

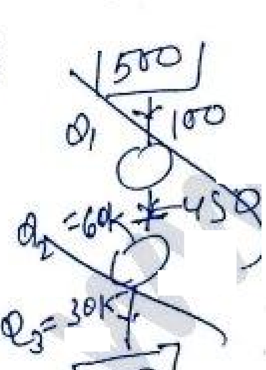
$$W_1 = Q_1 - Q_2$$

$$W_1 = 2000 - 800$$

$$W_1 = 1200 \text{ KJ}$$

$$W_2 = 1200 - 300 \Rightarrow W_2 = 900 \text{ KJ}$$

③



$$\eta_1 = 1 - \frac{450}{550} \qquad \eta_2 = 1 - \frac{380}{450}$$

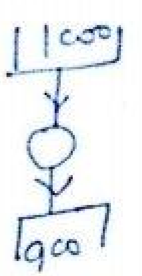
$$\eta_1 = \frac{100}{500} \qquad \eta_2 = \frac{100}{450} = 0.22$$

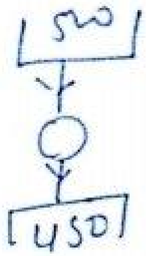
$$\eta_1 = \frac{1}{5} = 0.2 \qquad \eta_2 =$$

$$\eta_1 = \frac{40}{100} = 0.4 \qquad \eta_2 = \frac{30}{60} = \frac{1}{2} = 0.5$$

122

Q.4





$\cancel{Q_{R_1} \propto 900}$

$\cancel{Q_{R_2} \propto 450}$

$\cancel{\frac{Q_{R_1}}{Q_{R_2}} = \frac{900}{450}}$

$$\eta_1 = \frac{100}{1000} \qquad \eta_2 = \frac{50}{500}$$

$$\eta_1 = \eta_2 \qquad \underline{Q_{R_1} = Q_{R_2}} \qquad \cancel{Q_{R_1} > Q_{R_2}}$$

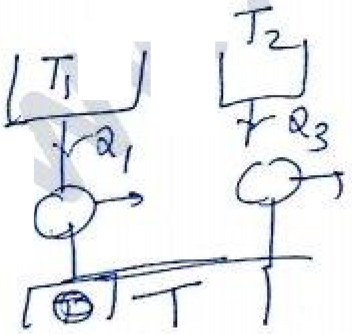
Q.5

A – 2
B – 1
C – 4

Q.6

b

Q.7



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

T_L = const

$T \uparrow$

$T_1 > T_2$

$\eta_1 > \eta_2$

$\underline{W_1 > W_2}$

(8)

$$\eta = 1 - \frac{300}{900} = 66.67$$

$$\eta = \frac{50}{\frac{3}{3600} \times 7500}$$

impossible

$\cancel{= 80\%}$

(11) a $\int \frac{dQ}{T} < 0$, $\int \delta Q > 0$ engine

(12) $\eta_c = 1 - \frac{300}{600}$ $\eta = 45\%$

$\eta_c = 50\%$ $\eta_1 = 1 - 0.45 = 55\%$

(C)

(13) q

(14) rev $\frac{W}{Q_S} = 1 - \frac{293}{879} = \frac{2}{3}$

$\frac{W}{Q_S} = \frac{2}{3} = 0.67\ KJ$

CHA 5

(1) (a) $\oint \frac{dQ}{T} < 0$

(B) $dQ = 0$

$\Delta S_B = 0$

$S_A =$ tue

(3) b $\cancel{S_2 - S_1} = ds = C_p \frac{dT}{T} - R \cdot \frac{dp}{p}$

$C_v = \frac{5R}{2}$

$C_p - C_v = R$

$C_p = \frac{7}{2} R$

$S_2 - S_1 = 10 \left(C_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right) \right)$

$= 10 \left(\frac{7}{2} R \ln\left(\frac{500}{300}\right) - R \ln\left(\frac{200}{100}\right) \right)$

$S_2 - S_1 = 10 \times 314.19\ J = 10 \times 0.314\ KJ/_{K}$

$= 3.14\ KJ/_K$

(4) $\rho = \text{const}$ $\quad Tds = du + PdV$, $du = 0$

$\Delta S = 0$

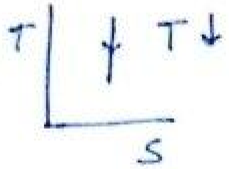
$\Delta T = T_2 - T_1 = 0$

(5) d $\quad Tds = du + PdV$

(8) b

$$\Delta S = 2mc \ln\left(\frac{\frac{T_1+T_2}{2}}{\sqrt{T_1 T_2}}\right)$$

(6) d



(9) $W = mc\left(T_H + T_L - 2\sqrt{T_H T_L}\right)$

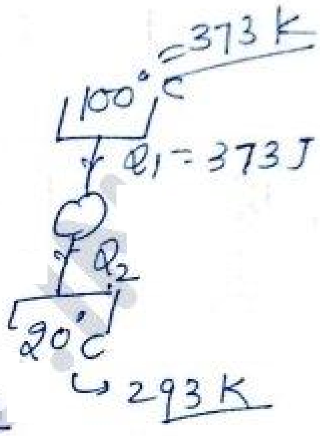
(10) d $\quad \oint \frac{dQ}{T} < 0$

(11) d $\quad \oint \frac{dQ}{T} < 0$

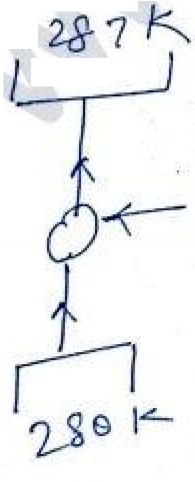
(12) $\oint \frac{dQ}{T}$

$\Delta S = \frac{-373}{373} = -1$

rejection



(7)



$ds = S_{gen} + \cancel{\frac{dQ}{T}} = 0$

$ds = S_{gen}$

$S_{gen} =$

(14) a

$$\Delta S = mc\frac{dT}{T}$$

$$= (a + bT^2)\frac{dT}{T}$$

$$= a\ln\left(\frac{T_2}{T_1}\right) + \frac{b(T_2^2 - T_1^2)}{2}$$

(15) a

$$T\,ds = dH - \cancel{V\,dP}^{\,0}$$

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

(16) d

system

+ve, -ve

(17) a

$$\left(\frac{dT}{ds}\right)_P = \frac{T_0}{C_P} \qquad C_P = \frac{\gamma R}{\gamma - 1}$$

$$= \frac{T_0}{\frac{\gamma R}{(\gamma-1)}} \quad \frac{(\gamma-1)T_0}{\gamma R}$$

(19) b

$$ds = \cancel{\frac{dT}{T}}^{\,0} + \frac{P\,dV}{T} \qquad PV = RT$$

$$ds = R\frac{dV}{V}$$

$$= R\int \frac{dV}{V} = R\ln(2)$$

(20) d

$$\oint dQ = \oint dw = Q \qquad 100 + 40 - Q_R = 140 - 90 = 50\,kJ \quad A$$

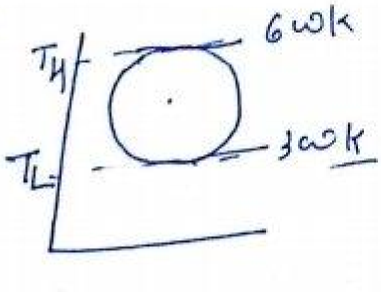
rev $\oint \frac{dQ}{T} = 0 \Rightarrow \frac{100}{500} + \frac{40}{400} = \frac{Q}{300}$

$$\frac{1}{5} + \frac{1}{10} = \frac{Q_R}{300}$$

$$Q_R = \cancel{90}\,kJ \quad 90\ R$$

(21)

$$\eta = 1 - \frac{300}{600}$$



$$\eta = 50\%$$

(18) $m = 1\,kg \quad c = 1\,kJ/kgK$

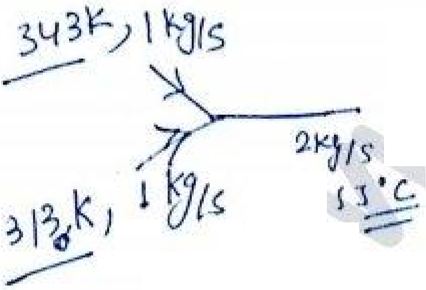
Rejection $\quad T_1 = 273+600$

$T_1 = 873\,K \quad T_2 = 303\,K$

$= -1 \times 1 \times \ln\left(\frac{308}{873}\right)$

$= -1.058\ kJ/kg.$

(13) $(ds) = (ds)_{gen} + \frac{dQ}{T}$



mixing $\quad T_f = 2mc \ln\left(\frac{T_1 + T_2}{2\sqrt{T_1 T_2}}\right)$

$= 2 \times 1 \times 4.2 \ln\left(\frac{328}{327.65}\right) \times 10^3$

$= 8.79\ W/K$

Q.22 $\quad \Delta S > 0$

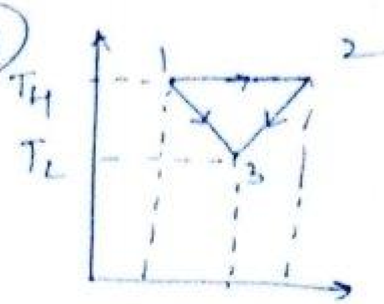
(23) d

$\left(\frac{dT}{ds}\right)_v = \frac{T}{C_v}$

$\left(\frac{dT}{ds}\right)_p = \frac{T}{C_p}$

$\frac{T}{C_v} > \frac{T}{C_p}$

(24)



$W_{net} = \frac{1}{2}(S_2 - S_1)(T_H - T_L)$

$Q_s = (T_H - \cancel{T_L})(S_2 - S_1)$

$\eta = \frac{\frac{1}{2}(S_2 - S_1)(T_H - T_L)}{T_H(S_2 - S_1)} = \frac{0.5(T_H - T_L)}{T_H}$

(25)

C

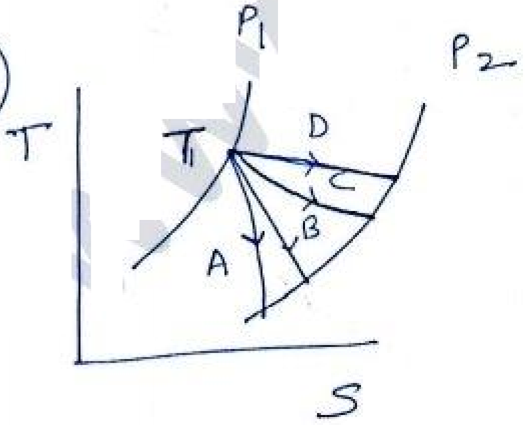
$Tds = du + PdV$

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

$Tds = du - Vdp$

$\left(\frac{dT}{ds}\right)_P = \frac{T}{C_P}$

(26)



$P_1 > P_2$

$T_1 > T_2$

ΔS -ve in A

Rigid $dV = 0$

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

$= C_V \ln \frac{T_2}{T_1}$

$= -C_V \ln\left(\frac{T_1}{T_2}\right)$

(28) b

(27)

b

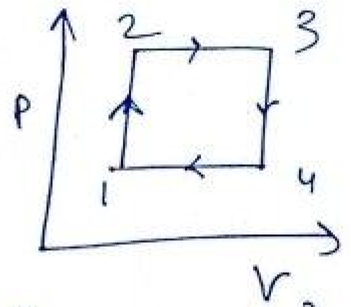
OA → $V = C$ $\gamma = \infty$ $\frac{T}{C_V}$ — (2)

OB → $P = C$ → $\gamma = 0$ $\frac{T}{C_P}$ — (3)

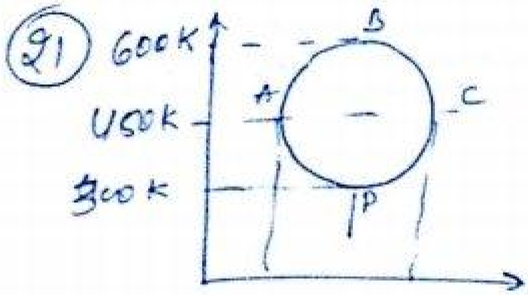
OC → $PV = C$ — (4)

OB → $PV^{\gamma} = C$ — (5)

(29)

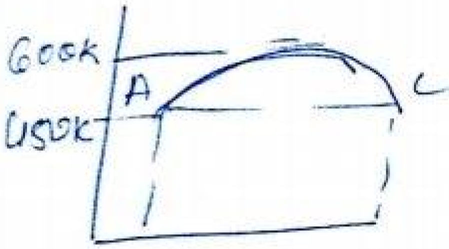


(21)



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

$$Q_{net} = \frac{\pi}{4}(300)^2$$



$$Q_s = \frac{\pi}{2}(150)^2 + 450(S_C - S_A)$$

$$= \frac{\pi}{2}(150)^2 + 450 \times 300$$

$$Q_s = 171034$$

$$\eta = \frac{\frac{\pi}{4}(300)^2}{171034} = 0.415 \text{ Ans}$$

$$= 41.5\%$$

Q.7

100kW

3°C → 276K

14°C → 287K

7°C → 280K

Latent No temp change

$$ds = mc \ln\frac{T_2}{T_1} + \frac{dQ}{T}$$

$$ds = mc \ln\left(\frac{280}{287}\right) + \frac{100}{276} = 9.56 \times 10^{-3} \frac{kW}{K}$$

$$= 9.56 \frac{W}{K}$$

$$dQ = mc\Delta T$$

$$100 = mc(287 - 280) \Rightarrow mc = \frac{100}{7} \frac{kW}{K}$$