Reversible Process : Entropy change.

Let us have a look of Carnot's cycle in terms of Entropy.

We know Work = $P\Delta V$

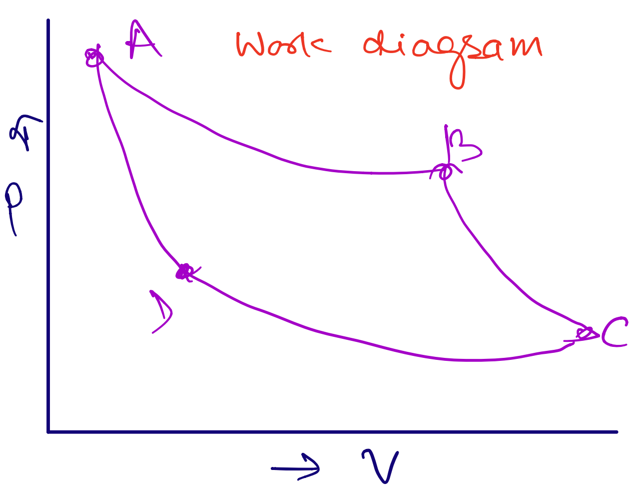
Energy = $T\Delta S$

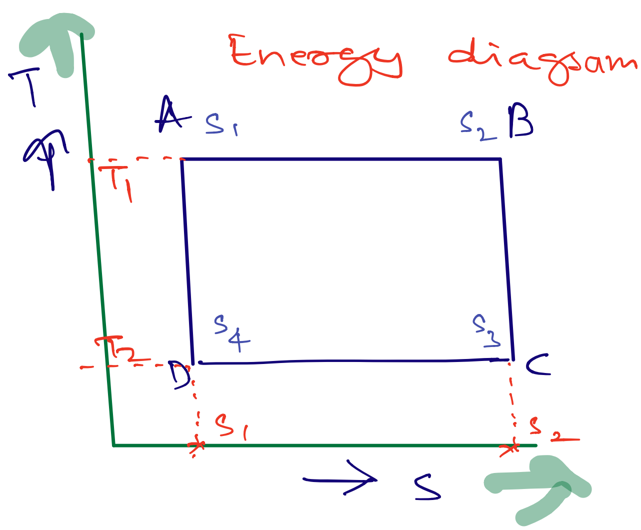
The carnot's cycle represented in

P Vs V diagram = Work Diagram

and as T Vs S diagram = Energy Diagram

Let us try to convert "Work diagram" in "Energy Diagram"





Let us know calculate the entropy change in all four steps thants means in the Process

$A \to B$ = isothermal Process at T_1

$B \to C$ = Adiabatic Process

$C \to D$ = isothermal Process at T_2

$D \to A$ = Adiabatic Process

$$\Delta S_{AB} = \int_A^B \frac{dQ}{T} = \frac{1}{T_1}\int_A^B dQ = Q_1/T_1$$

Let $\Delta Q_{AB} = Q_1$

$$\Delta S_{BC} = \Delta S_{DA} = 0 = \text{adiabatic Process}$$

so $dQ = 0$

$$\Delta S_{CD} = \int_C^D \frac{dQ}{T} = -\frac{Q_2}{T_2}$$

Let $\delta Q_{CD} = Q_2$

So If we plot these values of entropy change on ENERGY DIAGRAM

$\Delta S_{AB} = S_2 - S_1$

$\Delta S_{BC} = \Delta S_{DA} = 0$

$\Delta S_{CD} = S_3 - S_4$

Since it is a cyclic Process and the cycle has to reach at the initial point then

$$\boxed{\underline{S_2 - S_1} = \underline{S_3 - S_4}}$$ so $\Delta S = 0$

Efficiency from ENERGY DIAGRAM

$Q_1 = T \Delta S$ $\quad\quad\quad$ $Q_2 = T_2 \Delta S$

so energy converted into work

$= Q - Q_2$

so $\eta = \dfrac{Q_1 - Q_2}{Q_1} = \boxed{1 - \dfrac{T_2}{T_1} = \eta}$

Reversible Heat Transfer :

If a reversible heat transfer is not an isothermal process.

Let the temperature changes from T_1 to T_2.

then $\Delta S = \displaystyle\int_{T_1}^{T_2} \frac{dQ}{T} \Big|_{rev}$

In such process we can have

$$dQ = m\,c\,dT$$

So we get $\Delta S = \int_{T_1}^{T_2} \frac{m\,c\,dT}{T}$

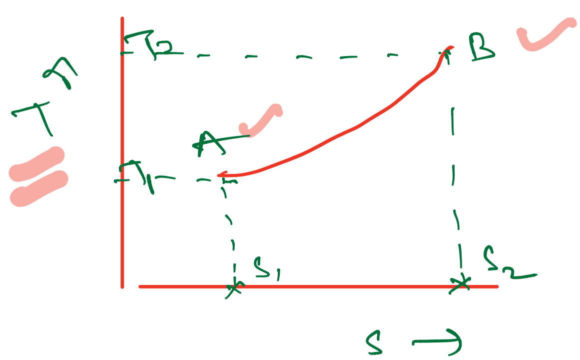
If we assume that heat capacity of the system remains constant in the studied temperature range then

$$S_B - S_A = \Delta S = mc \int_{T_1}^{T_2} dT/T = \boxed{mc \ln T_2/T_1}$$

Such Process can be indicated in TS diagram by AB line as given below

$dQ \neq 0$

$dT \neq 0$



Principle of Increase of Entropy :

When we say increase of entropy we are talking about the total entropy i.e. entropy of Universe which includes entropy of system and entropy of surroundings.

Let us consider a process where ΔQ energy from surrounding [at T_{su}] flows into a system [at T_{sy}] resulting in a work ΔW done by the system.

From Clausius inequality

$$\Delta S_{sy} \geq \Delta Q / T_{sy}$$ for the system.

and for surrounding $\Delta S_{su} \geq -\Delta Q / T_{su}$

Hence the net entropy change of universe

$$\Delta S_U = \Delta S_{sy} + \Delta S_{su}$$

$$\geq \left[\frac{\Delta Q}{T_{sy}} - \frac{\Delta Q}{T_{su}} \right]$$

Since $T_{su} > T_{sy}$ so the R.H.S is positive

that means $\boxed{\Delta S_U \geq 0}$

In opposite process where $T_{sy} > T_{su}$ and energy flows from system to surrounding then

$$\Delta S_U = \Delta S_{\cancel{us}} + \Delta S_{sy}$$

$$\geq \frac{\Delta Q}{T_{su}} - \frac{\Delta Q}{T_{sy}}$$

Since $T_{sy} > T_{su}$ so R.H.S. is +ve

$$\boxed{\Delta S_U \geq 0}$$