Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Engineering Thermodynamics

Lecture – 25
Applications of Second Law of Thermodynamics: Entropy 2

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Let us start this lecture with a, quotation entropy is an unconscious property based on classes inequality.

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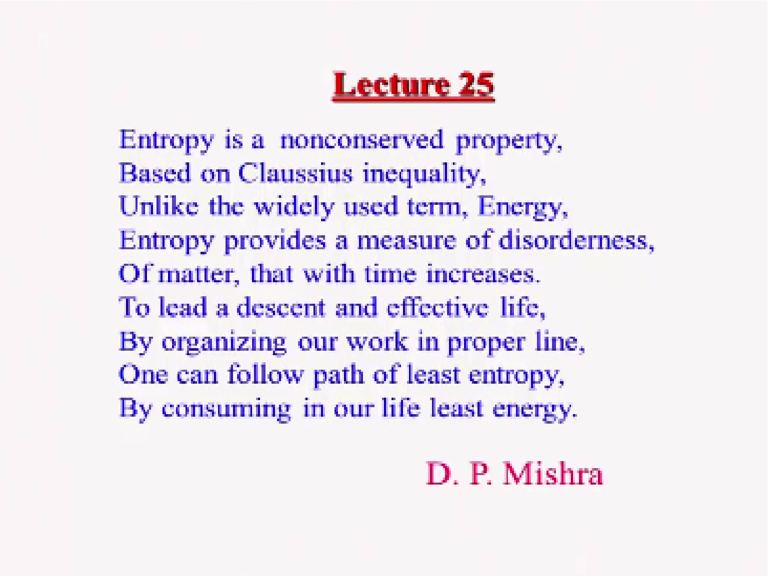

Lecture 25

Entropy is a nonconserved property,
Based on Claussius inequality,
Unlike the widely used term, Energy,
Entropy provides a measure of disorderness,
Of matter, that with time increases.
To lead a descent and effective life,
By organizing our work in proper line,
One can follow path of least entropy,
By consuming in our life least energy.

D. P. Mishra

Unlike the widely used term energy the entropy provides a measure of disorderness of matter that with time increases to lead a decent and effective life by organizing or work in proper line one can find follow the path of least entropy by consuming in our life least energy, so this is what we have learned from the second law of thermodynamics and what we will do now we will just recapitulate certain thing what we have learnt and about entropy.

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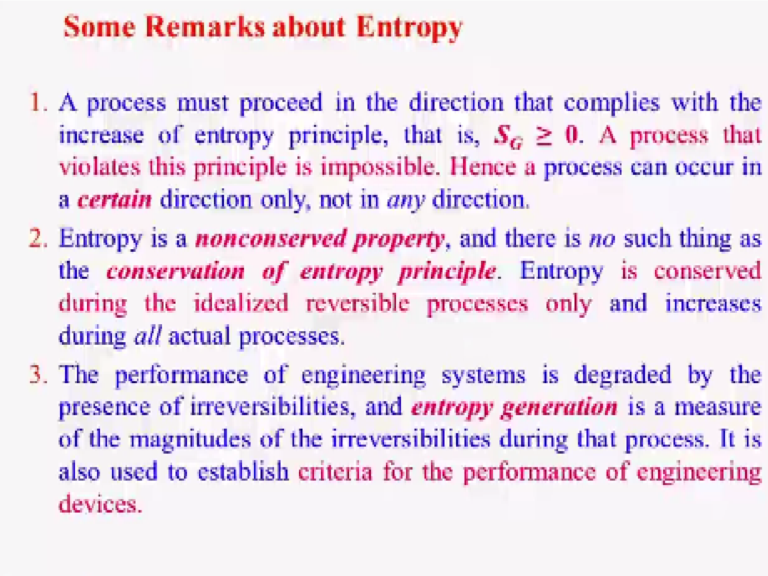

Some Remarks about Entropy

1. A process must proceed in the direction that complies with the increase of entropy principle, that is, $S_G \geq 0$. A process that violates this principle is impossible. Hence a process can occur in a ***certain*** direction only, not in *any* direction.
2. Entropy is a ***nonconserved property***, and there is *no* such thing as the ***conservation of entropy principle***. Entropy is conserved during the idealized reversible processes only and increases during *all* actual processes.
3. The performance of engineering systems is degraded by the presence of irreversibilities, and ***entropy generation*** is a measure of the magnitudes of the irreversibilities during that process. It is also used to establish criteria for the performance of engineering devices.

We have seen that that process can take place in certain direction and which will be satisfied the increase of entropy principle that is $Se \geq 0$ of course by reversible process it will be equal to 0 and if it is violating the principle of entropy increase you know then it would not really take place, so as I told that a process will be taking place in a particular direction not that all the direction whatever one can have and that stipulates the vertical direction of the process and in other words the feasibility of the passes right.

And as I told earlier that the entropy is a non conserve property unlike the energy is a conserved property and we know that according to the increase in entropy principle that it will be goes on increasing and there is no question of such that the conservation of entropy principle will be there like the energy of course whenever the process is reversible I mean which is the ideal case then entropy can be conserved right.

Otherwise it will be goes on increasing for all real processes and we can also judge the performance of the engineering system right and how good or bad it is and what are the identify also the what you call irreversibility right and once we identify the irreversibility then we will try to reduce it, such that entropy generation can be minimized and entropy generation is basically a measure of magnitude of the irreversibility in a vertical process right or in a system and it is basically establishes the criteria for the performance of engineering devices.

As you go along we will see that we will try to find out various criteria how to charge about the, you know it will extend up in irreversibility kind of things we will do that.

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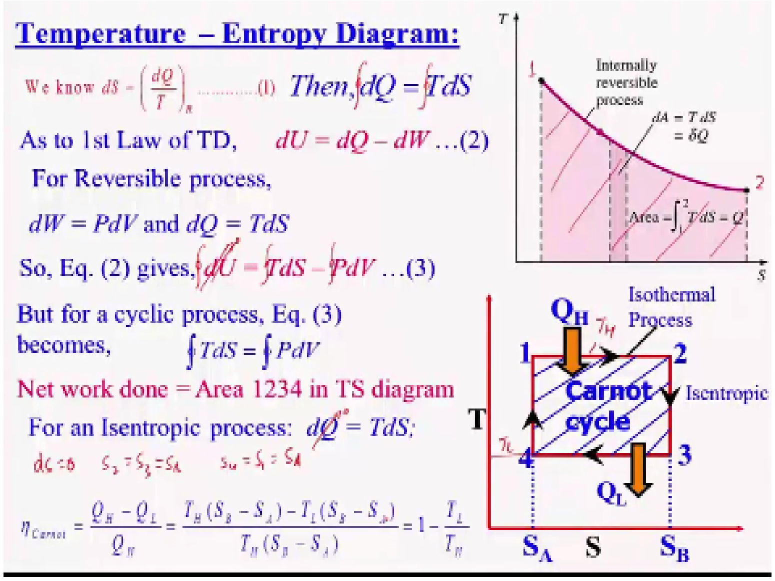

Temperature – Entropy Diagram:

We know $dS = \left(\frac{dQ}{T}\right)_R$ ....(1) Then, $\int dQ = \int TdS$

As to 1st Law of TD, $dU = dQ - dW$ ...(2)

For Reversible process,

$dW = PdV$ and $dQ = TdS$

So, Eq. (2) gives, $\oint \cancel{dU} = \oint TdS - \oint PdV$ ...(3)

But for a cyclic process, Eq. (3) becomes, $\oint TdS = \oint PdV$

Net work done = Area 1234 in TS diagram

For an Isentropic process: $d\cancel{Q}^{0} = TdS;$

$dS = 0 \quad S_2 = S_3 = S_B \quad S_4 = S_1 = S_A$

$$\eta_{Carnot} = \frac{Q_H - Q_L}{Q_H} = \frac{T_H(S_B - S_A) - T_L(S_B - S_A)}{T_H(S_B - S_A)} = 1 - \frac{T_L}{T_H}$$

But before that let us not dwell into some applications of the this entropy what we have learnt in the last lecture, so one way is that we can talk about basically you know a process diagram like let us say we are having a PV diagram we can convert into T_S diagram and so on so forth it will be helpful for to visualizing the process, so we know T_S is basically dQ / T for a reversible process right.

So from this I can write down you know like what will be dQ is basically dD = T and dS of course this is mean for the reversible process right then we can write down this one and if it is for a cyclic process right then we can integrate over here and this thing right and if it is cyclic right we can say that you know for that can be integrated over let us say if it is station 1 you know I can integrate from station 1 to station 2 and this strip is nothing but your TdS is which is equal to dQ and this is of course mean for the internal irreversible process right.

That means basically system will be reversible surrounding may not so that you know that area the total area can give me how much heat because this is temperature versus entropy if I integrate I will get how much heat interaction is taking place during this irreversible process this area will give me and that indicates the integration right and according to the first law of thermodynamics for a control mass system and considering that there is no kinetic energy change and there is no potential energy change we know that dU = dQ - dW right that we know.

So and for a reversible process the work done is nothing but you PdV and dQ is TdS and if I substitute these values here you know if I substitute these values dW here you know in place of dW PdV and in place of dQ TdS so what we will get we will basically get an express that is $dU = TdS - PdV$.

So if you look at the first law of thermodynamics now combined with the second law of thermodynamics right because through that EdQ we have already considered of course this is valid for a reversible process right now if I integrate this thing for a cycle right what will happen what will happen for the cycle I mean whole cycle I am integrating, so we have seen from the first law thermal cycle process the internal energy will be 0 yes or no, so for the cycle whole cycle this term will be 0 because it is going from state 1 to 2.

And then coming back again reversible, so therefore a change into internal energy will be 0 it is a property so therefore it will be 0 right, if that is the case then you know we will get TdS integral is equal to the PdV let means and we know that PdV is work done so that you can very well you know get from this here that means this process you know TdS if you look at that will give me in a cycle the work done the work done is basically this portion that means this hatch portion what I have given this nothing but your TdS right and integral and if you look at it is taking qh amount of heat from the source.

And it is rejecting ql amount so this process you know is basically this portion is the what you call the work done and for isentropic process and as I told that net work done is basically the area 1, 2, 3, 4 in the TS diagram that will give me the work done and for an isentropic process we know that dQ = Td I isentropic process means adiabatic and reversible, so therefore what it would be that will be 0 right that means that dS what you call dS will be equal to 0 because temperature cannot be 0 right.

So therefore that means if I take the isentropic process between the what you call state 2, 1, 3 right that will be isentropic expansion right in a Carnot cycle so that will be what $S_2=S_3$ entropy is remaining constant in this case is equal to SB right similarly for compression process from state 4 to the 1 that is $S_4 = S_1 = S_a$ right and we can are now you know express this Carnot efficiency in terms of you know entropy diagram from this.

We can do for example that is basically we know that connotations Qh - QL / Qh and what is Qh Qh is nothing but Th this is your what we call temperature T_H right this is T_H and this is your T_L right so S_B - S_A right this is S_B write and S_A and the Q_L is nothing but T_L x S_B -S_A and / the P_H S_B-S_A so that what will happen this will cancel it out so you will get the efficiency Carnot efficiency is equal to 1 -T_L by T_H we have already done that it is just to relook at it in you know in terms of entropy.

Which is much easier than if you remember that we had done for the ideal gas right considering and then we have arrived at a similar expression but this is a very simpler way of doing you know expressing Carnot efficiency in terms of the sink temperature and the source temperature, so this is the one aspect how you can apply you know the concept of entropy for constructing the not only the process diagram but also the understanding the process and deriving the expression for the Carnot efficiency and other things as well.

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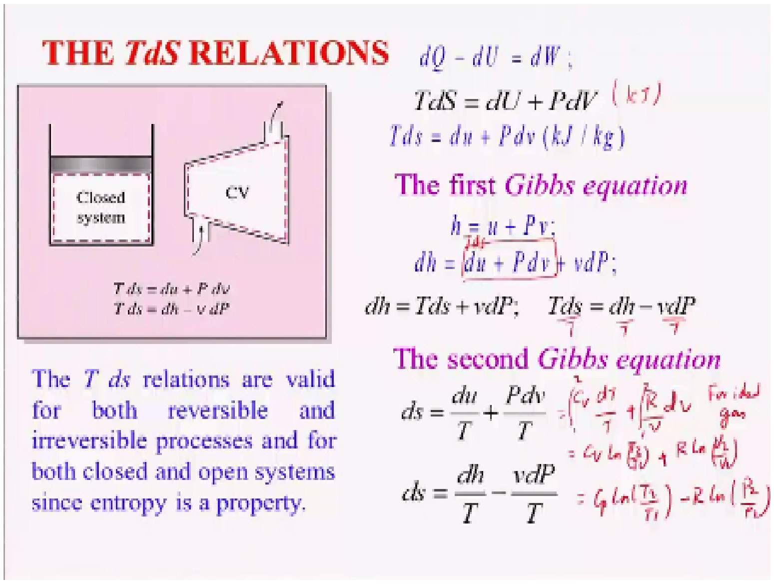

THE *TdS* RELATIONS

$dQ - dU = dW;$

$TdS = dU + PdV$ (kJ)

$Tds = du + Pdv$ (kJ / kg)

The first *Gibbs equation*

$h = u + Pv;$

$dh = \underbrace{\boxed{du + Pdv}}_{}\!\!{}^{Tds} + vdP;$

$dh = Tds + vdP; \quad \frac{Tds}{T} = \frac{dh}{T} - \frac{vdP}{T}$

The second *Gibbs equation*

$$ds = \frac{du}{T} + \frac{Pdv}{T} = \int C_v \frac{dT}{T} + \int \frac{R}{v} dv$$

For ideal gas

$$= C_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{v_2}{v_1}\right)$$

$$ds = \frac{dh}{T} - \frac{vdP}{T} = C_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$$

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

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

The *T ds* relations are valid for both reversible and irreversible processes and for both closed and open systems since entropy is a property.

So let us look at the TdS diagram a relationship so that we have already know that for the control mass the first law of thermodynamics is basically dQ – Du is equal to dW and we have also derived this expression TdS = dU+ PdV and per unit you know if you look at mass wise so that will be TdS this is a specific entropy is equal to Du + PdV and that unit if you look at it is kilo joule per kg and this unit will be kilo Joule basically right and this expression is known as the first gives equation right it is known as the first give equation.

And this is what you call we can also derive you know another gives equation by considering the enthalpy is nothing but U +Pv and then if you differentiate that you will get dh = dU + Pv+ vdP right and what is this dU + Pdv this portion this is nothing but you according to the first gives equation that is nothing but you TdS so this portion is TdS so therefore I can express this equation in terms of the what you call that TdS is nothing but equal to dh -vdP right.

So this is this one is known as the second gives equation which will be very useful for you know finding out entropy change and keep in mind that this we have derived considering the control mass system however it will be both valid for the closed system and also an open system this expression will be valid, so and this will be process will be valid for the both reversible and irreversible process okay although we have assumed the what we call reversible process in deriving this but it can be valid and if you look at like I can divide this equation you know protocol second gives the equation by the T and I will get this T and then I will get this expression that is T TS =dh/ T –vdP and YT and similarly if I will divide this expression first give equation I will get ds = dU T + pdv / T right so for an ideal gas you know I can write down here that is nothing but Cv dt/ t + this if I take ideal gas law what will be that is R by v x dv.

If I will integrate it so what I will get I will get is equal to Cv Ln T2 / T1 + R Ln (v_2/v_1) right is indeed we have already done for an ideal gas this is valid for ideal gas right and otherwise also you can integrate provided you know the CV is a function of temperature you know like of course that is for ideal gas and some other things and in this case we have assumed that CV is constant it is not a function of temperature therefore we have taken out and integrated.

Similarly you can also derive an expression for here like ds= C_P ln (t_2/t_1) right for an ideal gas that is ln (p_2/p_1) okay so that one can derive and then get an expression so therefore from this one can really you know apply this relationship very easily and find out.

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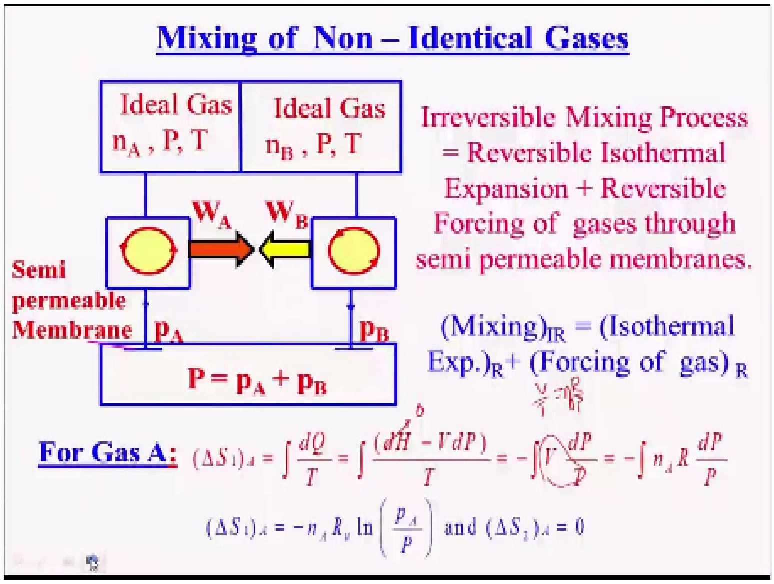

Mixing of Non – Identical Gases

Irreversible Mixing Process = Reversible Isothermal Expansion + Reversible Forcing of gases through semi permeable membranes.

$(\text{Mixing})_{IR} = (\text{Isothermal Exp.})_R + (\text{Forcing of gas})_R$

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

For Gas A: $(\Delta S_1)_A = \int \frac{dQ}{T} = \int \frac{(\cancelto{0}{dH} - VdP)}{T} = -\int \boxed{V}\frac{dP}{P} = -\int n_A R \frac{dP}{P}$

$(\Delta S_1)_A = -n_A R_u \ln\left(\frac{p_A}{P}\right)$ and $(\Delta S_2)_A = 0$

So now we will take another example how we will calculate basically mixing of non-identical gases what will take, we will take ideal gas you know of of-course n moles of gas at pressure P and T is kept in one chamber and there is another chamber and which contains n_B amounts of n_B moles of gas at same pressure and then we will remove this partition right if you remove this partition what will happen the gas will be mixed right yes or no?

And when it we mixed then that will be there will be change in entropy and it is irreversible process now how to calculate that if you know entropy change for an irreversible process because mixing is an irreversible process you cannot really reverse it back so one can actually you know substitute this process in terms of reversible process right one can think of that as if this gas A you know is coming through something reversible isothermal expansion process.

And then of course after that what is happening that it will come to the P that is the partial pressure and then it will be passing through a semi-permeable membrane again that is also reversible by forcing the gas similarly you can think of there is a you know in the similar way that Gas B basically having like reversible isothermal expansion here and then it will be again forcing through a semi-permeable membrane kind of things to that so that both will be mixed and with this chamber right.

Which is at a partial pressure A and B and total pressure will be P so that is a basically imaginary but of course in reality one can do like but not for all the gases for oxygen there is a foil through which you can you know as selectively pause the gases, so but however this process we are considering an imaginary reversible process so that means the mixing of which is irreversible process consists of two reversible process one is isothermal expansion of course isothermal reversible expansion and other is forcing of gas reversible right.

That is the thing what we are considering so now for the gas A if you consider this is gas A right the isothermal expansion process for that will have to find out entropy change for the gas A that is DQ/T and you can express dH- VdP that is we have already done that is divided by T and in this case that it is an isothermal process so this will be 0 so then it is equal to minus VdP/ T and then what you call you can express this for an ideal gas equation in terms of what you call VYT = R/P right.

And then you will put this of course L will be there the number of moles right and then I will find out n_R dP/P and you can integrate this and then find out what is the expression so that will be change in entropy is equal to $-n_A R_u \ln(P_A/P)$ because it is going to the partial pressure of A like from the pressure P and for the forcing of gas through the semi permeable membrane right so that is entropy is change in entropy is 0 that is the second process right that is equal to 0 similar expression will be getting for the gas B, right.

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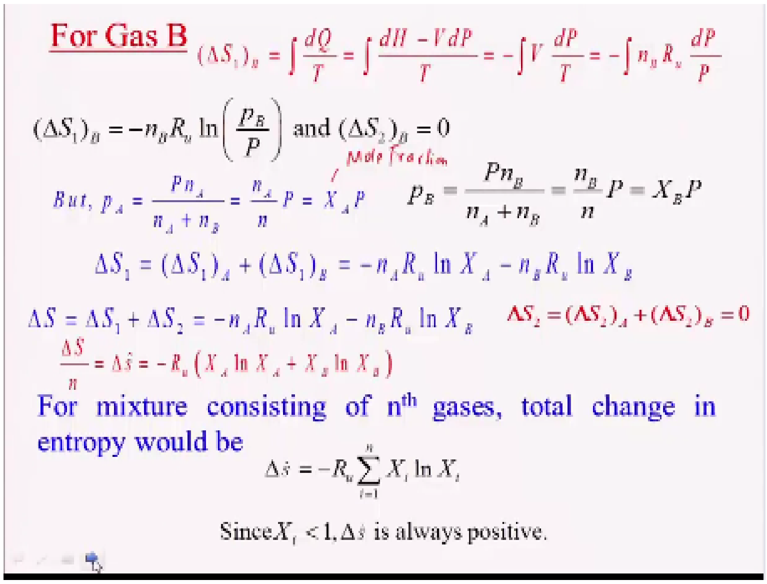

For Gas B $(\Delta S_1)_B = \int \frac{dQ}{T} = \int \frac{dH - VdP}{T} = -\int V \frac{dP}{T} = -\int n_B R_u \frac{dP}{P}$

$(\Delta S_1)_B = -n_B R_u \ln\left(\frac{p_B}{P}\right)$ and $(\Delta S_2)_B = 0$

Mole fraction

$But,\ p_A = \frac{Pn_A}{n_A + n_B} = \frac{n_A}{n} P = X_A P \qquad p_B = \frac{Pn_B}{n_A + n_B} = \frac{n_B}{n} P = X_B P$

$$\Delta S_1 = (\Delta S_1)_A + (\Delta S_1)_B = -n_A R_u \ln X_A - n_B R_u \ln X_B$$

$\Delta S = \Delta S_1 + \Delta S_2 = -n_A R_u \ln X_A - n_B R_u \ln X_B \qquad \Delta S_2 = (\Delta S_2)_A + (\Delta S_2)_B = 0$

$\frac{\Delta S}{n} = \Delta \hat{s} = -R_u \left(X_A \ln X_A + X_B \ln X_B \right)$

For mixture consisting of nth gases, total change in entropy would be

$$\Delta \hat{s} = -R_u \sum_{i=1}^{n} X_i \ln X_i$$

Since $X_i < 1, \Delta \hat{s}$ is always positive.

We will get (Δs) B = -n_B Ru, dQ/T right and of course when you integrate this thing you will get Δs 1B basically n_B R_u $\ln(P_B/P)$ and ΔS2 for the Gas B will be also equal to 0 so of course we know that partial pressure is basically equal to the mole fraction this is mole fraction which is nA/n, N is the total mixture in this case $n = n_A + n_B$ so we can express that in terms of you know a P_A as $X_A P$, X_A is the mole fraction.

And similarly P_V is equal to mole fraction of B into the pressure so if I will add this you know this ΔS for both the gas A and B for the path one then you know it will reach $-n_A R_u \ln X_a - n_B R_u \ln X_B$, so we know that for Δs 2 or the second process forcing the gas reversibly through the semi-permeable membrane that is equal to 0 so therefore the total entropy change during this mixing of the gas will be equal to $n_A R_u \ln X_A - n_B R_u \ln X_B$.

And of course per unit mole you can express in the similar manner right that is equal to $-R_u X_A \ln X_A + X_B \ln X_B$ of course the in the bracket that one so mixture for a of course we have taken two gases right that might be n^{th} gases you know like n^{th} number of gases one can think of so the total entropy change one can say the change in entropy that is what you call small s right and is equal to $R_u X_i \ln X$ some over the number of gases whatever it will be it.

May be two gases it may be five gases it might be 10 gases so you can find out basically entropy change for what you call mixture of gases and during the mixing right and which is an irreversible process we have basically found out reversible way and do that so if you look at that way that X I < 1 so therefore entropy is always you know positive quantities because XI < 1 so it also says that adheres to the principle of entropy increase right.

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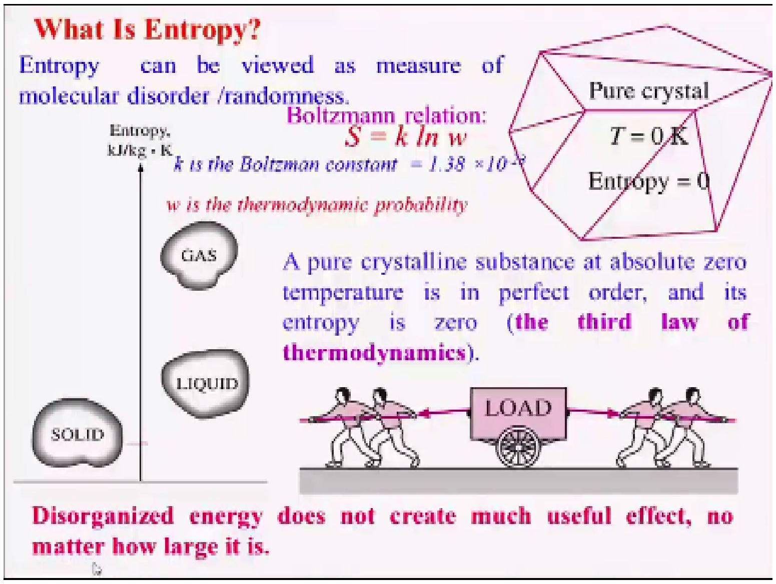

What Is Entropy?

Entropy can be viewed as measure of molecular disorder /randomness.

Boltzmann relation:

$$S = k \ln w$$

k is the Boltzman constant $= 1.38 \times 10^{-[illegible]}$

w is the thermodynamic probability

A pure crystalline substance at absolute zero temperature is in perfect order, and its entropy is zero (**the third law of thermodynamics**).

Disorganized energy does not create much useful effect, no matter how large it is.

So you know we have discussed a lot about entropy but a question might be lurking in your mind what is the physical meaning of entropy, right because we are talking about it you know we are using it we know how to calculate during process and it will also tell us about the quality of energy and it will talk about the feasibility of process lot of applications we are having right what is the physical meaning of that.

So entropy can be viewed as a measure of molecular desire or the randomness because the molecule will be moving along right and if you consider this definition you can see that for a solid let us say what will be the interim for the gaseous what will we intervene in which case the entropy will be higher the very simple definition itself will tell you that the solid case the molecules are in a very close contact and they move vibrate around their own positions.

They would not really change the position therefore the entropy will be what we call very, very small and of course the liquid is basically little movable it goes together but it moves and therefore the liquid entropy is higher and gaseous entropy is the highest among all three stages you know all three states of matter and if you look at I had given earlier an example like earlier days our bond in the family was very strong you know therefore we are having less entropy.

That means you know stress level in life was very, very small because all stress being taken care by other shared by others and later on we are a family degenerated in our country and then we become liquid state entropy increases and today we are in gaseous state right so therefore you know we are facing lot of what you call problem in our life right because we are moving at a faster rate and therefore the efficiency is coming down and then entropy is increasing.

So if you look at from the statistical point of view we can express the entropy and that is the Boltzmann relationship that is equal to $s = K \ln W$, K is your Boltzmann constant and w is the thermodynamic probability that will be representing how randomness and other extent of randomness available in that so if you look at if you consider the matter and of course this will be dependent on the temperature at which if you take a solid you know if it is a higher temperature the entropy will be you know higher you can consider.

And if you take a pure crystal right and you will find that entropy will be 0 only when the temperature is you if the temperature is different then it cannot be 0 it will be some finite value so that basically says the third law of thermodynamics we state that a pure crystalline substance at Absolute Zero temperature is in perfect order and therefore its entropy will be 0 or 0 right so that is nothing but your third law of thermodynamics just to illustrate how you know what you call entropy have a physical meaning.

Let us say there is a you know a what you call let us consider a load something is there in the cart and it is being pulled by few people on left hand side let us say and pull by the right hand side will it really move already vibrate you know move here and there, so then if you look at the basically it will be in the random order and the similar situation in our case also like if we consider you might have gone to our land pool crossing that everybody wants to go.

But as a result nobody could manage to go in a traffic jam and it is resulting into a traffic jam so there might be several examples I can give you like that where you we encounter the entropy I will give an another example suppose before examination you are trying to read study a lot and then when you will go to the exam hall then it will be a blackout suppose you cannot do something then you cannot retry back the your you-know-what you call the information from your memory.

Because it is not being orderly place and I will give another example like suppose for example like in your room you have kept the books right or you or in a library if the books are kept randomly it is very difficult to locate the book that means in that case the entropy of that library now in the rooms the library it will be very higher order so higher the order of the entropy it is very difficult to and you know so therefore one has to be this thing and this organized energy basically does not create much useful effect although we may be you know using it.

So therefore one has to take you know entropy into a you know like what you call consideration and minimize the entropy by organizing ourselves right so that is the thing that is why if you look at when I look at you people and compare when you was in your place that you know we are used to work less you people are all the time busy right.
And working hard let me tell you harder than what I could think but if you look at the net effect is not that effective and you are not on an average scale not all right people in the what you call more effective working hard let me tell you harder than what I could think but if you look at the net effect is not that effective and you are not on an average scale not all right people in the you call more effective. So therefore to be effective in this thing one has to organize oneself and that is the says that you have to minimize the entropy in life.

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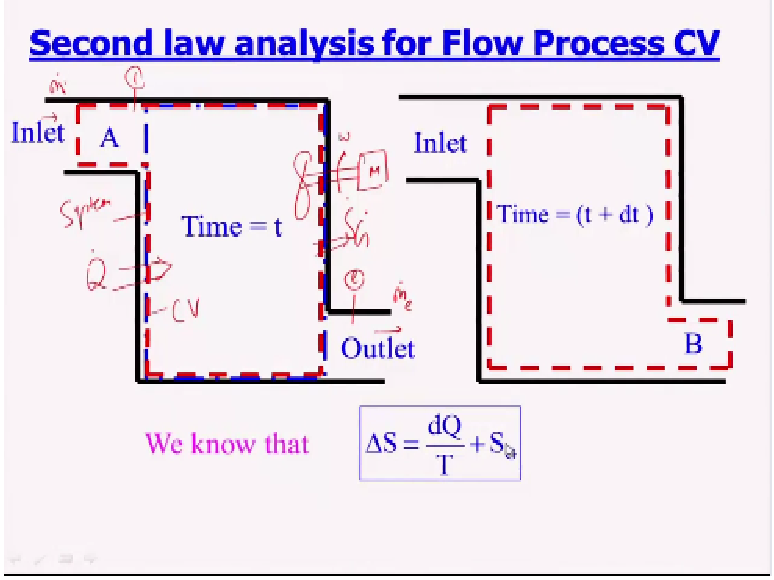

Second law analysis for Flow Process CV

We know that $\boxed{\Delta S = \frac{dQ}{T} + S_g}$

So till now what we have done so till now we are basically looked at how to handle the control mass system or the closed system but however we need to also handle the flow system where you know low mass will be entering and leaving and there will be some interaction kind of things. You know and then how to handle that we will do in a basically similar way that is let us consider a flow system here.

In this case some mass is entering in this case and if I say this is my I inlet and this is my exit right and there is some soft work right they some soft work is going on and there is some heat interaction also let us say some heat is entering here and this thing and then and as a result there will be some entropy change also like the entropy will be change right so the entropy change will be there generation will be there.

Now this is I call it as basically this dashed line I call it as a CV control volume right but we have not derived anything till now the expression for the entropy change you know which we have seen Delta S=DQ / T+SG right entropy generation that we have seen. Now that is applied only for the control mass system but we as this a problem where the flow is entering and it is leaving out right mass is entering and leaving out right if I say this is mass in and this is mass out.

Right exit then how will do that we will do in a similar manner the way we handle first law of thermodynamics that means we will say that this process flow process will be can be converted into series of non flow process. Right we have done like you know video camera convert into various now still images you know. So therefore we can do that we will consider that at time = t let us say certain amount of mass is entering you know this is my system now the system the rate color what I have shown here and this is my system right.

At time t and at the time dt you know the system becomes this is a new system which is having the certain mass is about leave this control balance and in there at time B the certain amount of mass which is shown in this A region that is about to enter into the control button exactly. Then what we will do we will take this one as a system in the left hand side what I have shown and the right hand side whatever SM the system between the time dt + dt is very small. So therefore we will apply this Δs which we have derived for the control mass =the Δ= DQ by t + h is the entropy generation.

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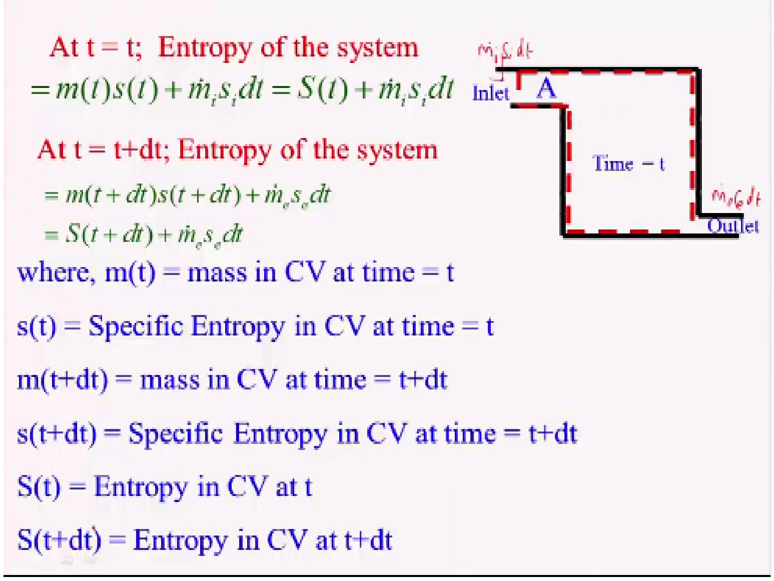

At t = t; Entropy of the system

$$= m(t)s(t) + \dot{m}_i s_i dt = S(t) + \dot{m}_i s_i dt$$

At t = t+dt; Entropy of the system

$$= m(t+dt)s(t+dt) + \dot{m}_e s_e dt$$

$$= S(t+dt) + \dot{m}_e s_e dt$$

where, m(t) = mass in CV at time = t

s(t) = Specific Entropy in CV at time = t

m(t+dt) = mass in CV at time = t+dt

s(t+dt) = Specific Entropy in CV at time = t+dt

S(t) = Entropy in CV at t

S(t+dt) = Entropy in CV at t+dt

So let us do that and other time t the entropy of the system what it would be it will be the entropy whatever is therein this system in this portion right and the entropy is entering if you look at this is basically entering into this is $m._i$ dt that is entering and then total entropy which is at time d and then this amount of entropy you know is entering during time dt. And similarly at time T + DT the entropy change of the system will be basically mt + dt into you know mass at t + dt and entropy at t + dt time.

Right = the amount of what you call entropy is going out in this that is m.e x dt right so and this balance will have to do by using the what we call entropy change for a control mass because we have considered at time t is one control mass system and time t + dt is another control system right.

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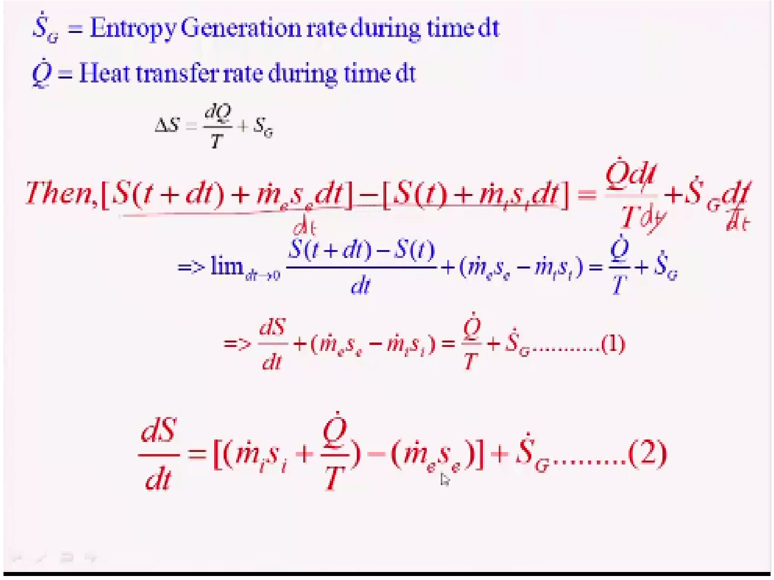

$\dot{S}_G$ = Entropy Generation rate during time dt

$\dot{Q}$ = Heat transfer rate during time dt

$$\Delta S = \frac{dQ}{T} + S_G$$

$$Then, \frac{[S(t+dt)+\dot{m}_e s_e dt]-[S(t)+\dot{m}_i s_i dt]}{dt} = \frac{\dot{Q}\cancel{dt}}{T\cancel{dt}} + \dot{S}_G \frac{\cancel{dt}}{\cancel{dt}}$$

$$\Rightarrow \lim_{dt \to 0} \frac{S(t+dt)-S(t)}{dt} + (\dot{m}_e s_e - \dot{m}_i s_i) = \frac{\dot{Q}}{T} + \dot{S}_G$$

$$\Rightarrow \frac{dS}{dt} + (\dot{m}_e s_e - \dot{m}_i s_i) = \frac{\dot{Q}}{T} + \dot{S}_G \text{..........(1)}$$

$$\frac{dS}{dt} = [(\dot{m}_i s_i + \frac{\dot{Q}}{T}) - (\dot{m}_e s_e)] + \dot{S}_G \text{.........(2)}$$

So we have already know this expression and what we will do we will put that thing like in that that is nothing but your change in entropy here at the exit - the entropy at the inlet a at this because this is at the entropy at the time t + dt and this is entropy at the time t right and you just change in entropy= qxdt /t right and that is nothing but an entire generation rate right during time dt.

And then and Q .is the heat transfer rate during daytime DT therefore Q .xdt/ t it will come over here that is nothing but your DQ / T and this SG is nothing but entropy generation rate during time d dt x dt right. So you will divide this you call by time right i can divide by this time T here R and T here this will cancel it out and then when DT is tending towards zero. So we will get basically an expression like this and that is nothing.

But you d s by DT+ m.i S_C-M_I right is =Q./T + S_G if this is the expression for what you call entropy you know balance in the case of your control volume system or the flow system .So if you look at that we can rewrite I will take this Q.T in that whatever the entropy is entering you know like Inlet and then I can write on m.e AC and DC r + s .

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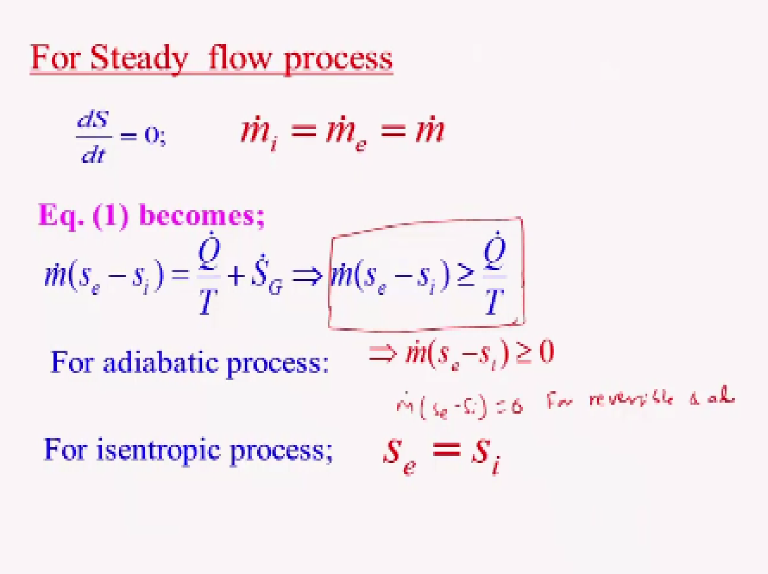

For Steady flow process

$\frac{dS}{dt} = 0;\qquad \dot{m}_i = \dot{m}_e = \dot{m}$

Eq. (1) becomes;

$\dot{m}(s_e - s_i) = \frac{\dot{Q}}{T} + \dot{S}_G \Rightarrow \boxed{\dot{m}(s_e - s_i) \geq \frac{\dot{Q}}{T}}$

For adiabatic process: $\Rightarrow \dot{m}(s_e - s_i) \geq 0$

$\dot{m}(s_e - s_i) = 0$ For reversible & ad

For isentropic process; $s_e = s_i$

And for a steady flow process right what will be happening that entropy change = 0 right enter me change will be = 0 and of course the mass is conserved you know according to because you know steady state process there is no accumulation of mass therefore m . i =m. e =m. Right and once equation becomes basically the equation1 which you would arrived just now is = m.x sc- S_I that is the change in entropy between the exit and the inlet =the heat transfer rate.

That means what it says it says change in entropy is basically will be greater than =Q.T. Right okay and similar expression we have got also for the control mass system but only thing is that here it is the mass flow rate.

That is the thing and this is the also heat transfer rate that is coming that means entropy rate which is considered here and for adiabatic process what it would be Q will be 0right so therefore the change in entropy will be always greater than equal to 0right for an adiabatic process and for I sent a process that =0 right ice interview process that is nothing but your m into SC - s i equal to 0soreversible process reversible and adiabatic that is nothing but I sends. o. s e =s I that is entropy will be remaining same at the exit and the inlet for an isentropic process and if you look at what are the applications of the second law of thermodynamics that is I have already discussed that.

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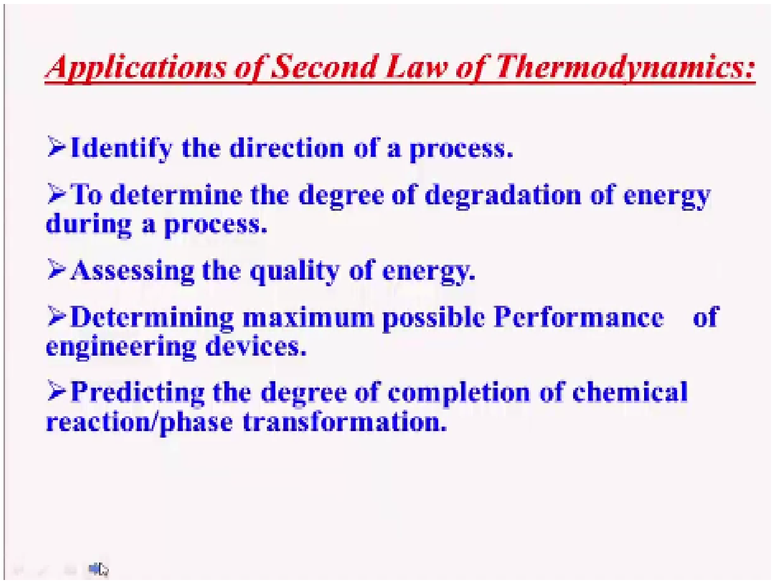

Applications of Second Law of Thermodynamics:

- Identify the direction of a process.
- To determine the degree of degradation of energy during a process.
- Assessing the quality of energy.
- Determining maximum possible Performance of engineering devices.
- Predicting the degree of completion of chemical reaction/phase transformation.

Thing let us summarize that is to identify direction of a process that means whether the process is feasible or not that repeat say and to determine the degradation of energy during the process that means you know what are their reversibility because in this reversible energy will be decorated one example is the friction you know like mixing there are another example where you know energy will be lost you cannot really retry bit rate and assessing the quality of energy what will be the you know like suppose I am having large amount of it but its quality is low.

So that I you know I cannot really use it properly and determine the maximum possible performance of an engineering device because that will give us limit you know like with which we can we should strive for and predicting the degree of completion of chemical reaction and phase transformation that will be using basically of course we would not be discussing but we want to calculate the equilibrium product in a chemical reactions right which we can determine by applying the second law of thermodynamics or the entropy right and let me tell you we had a discussion about the adiabatic temperature right.

We have taken a very simple you know approached by which we know you felt that okay we know the product but actually in the real situation you would not be knowing the product you will have to calculate the equilibrium particular products and by assuming the temperature and then you will have to calculate the idea body temperature and I will go on it is a quite a complex process of determining the adiabatic temperature we which we had done in a very simple manner you know you know that is not the actual case one has to do so therefore is very important to look at that.

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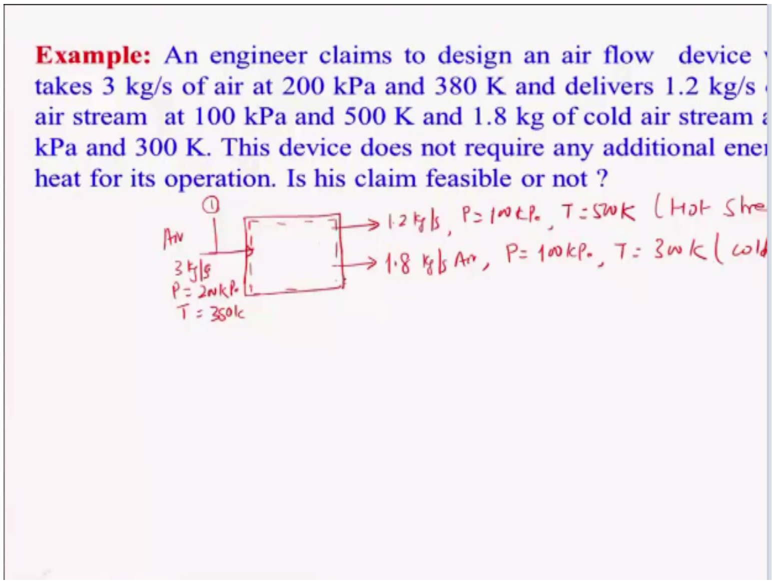

Example: An engineer claims to design an air flow device
takes 3 kg/s of air at 200 kPa and 380 K and delivers 1.2 kg/s
air stream at 100 kPa and 500 K and 1.8 kg of cold air stream
kPa and 300 K. This device does not require any additional ene
heat for its operation. Is his claim feasible or not ?

So these are the applications what one can think of so what I am thinking let us take a an example like that an engineer claims to design and airflow device which takes 3 kg of air at 200 kilo Pascal's and 3 80 Kelvin and delivers1.2 kg per second of hot air steam at100 kilopascal and 500 Kelvin and it also produces 1.8 kg of cold air stream at 100 kilopascal and 300 Kelvin right and this device does not require any additional energy as a heat for it is operation or also there is no you know work being also produced or given to this kind of device right but is his claim is feasible or not that is the thing we need to check so question arises how to go about it might be coming to your mind is it really possible such a device if you look at this is the one what we are having right.

If I look at this is the station 1 and 3kg per second of air is entering right and what is the pressure is something to 100 kilopascal and temperature is something 380 Kelvin and one stream is coming out as basically mass is 1.2 kg per second and pressure is 100 kpa and temperature is 500 KP Kelvin right temperature is500 Kelvin 382, 382 51 and it is giving also another mass is 1.8 kg per second of air of course.

This is air which is entering right here and pressure is again 100 kpa and temperature is something 300 kph so this if you look at this is the hot stream and this is your cold stream right so how to go about it how to go about it how will approach basically it is a simple one what will have to approach allowed to do the three thing this is a what you call flow system so you can consider a control volume as the boundary of this system.

You know that is your control volume and you will have to do a first is allowed to assume what are the assumptions here what are the assumptions that is a steady flow process these are assumptions right steady flow and the change in you know kinetic energy right is equal to zero and change in potential energy is equal to 0 right so for that if want to really find out I am like what you'll have to-do you will have to basically look amass conservation and then energy conservation then you'll have to do entropy that is type second law of thermodynamics right what is that m .1 =m . 2 + m. 3 is it.

It balanced because. 1 how much it is 3 kg per second that then the hot stream is 1.2 kg per second + and the cold stream is 1.8kg per second therefore it is balanced so then it is you know satisfied the conservation of mass is satisfied so therefore that is possible till now wearer possible then what we'll have to do you have to find out the first law of what Google thermodynamics for a control volume that is energy balance right so what it would be then .

Do not 1 h 1 = . 2 h 2 +. 3 s 3 yes or no right so we know from this mass balance that is m . 1= . 2 + m. 3 so can write down that is m. 2 + most 3 h 1 =$_{\mathrm{m\ 2\ s\ 2}}$ + m .3 s 3 right okay so we'll have to check this equation like or i can write down also this way that is m . 2 h 1 -s2 + m . 3 h 1 - s 3 =0 if I satisfy this equation that means it will be true and we are also wean assume another thing this is an ideal gas equation we can assume ideal gas equation right .

So if you look at what I will do I can find out that is basically mass what is the mass the air mass is m . 21.2 and I can assume constant CP right and CP of air what it would be at this temperature in like ambient temperature you can consider that is into1 .0 5kilo joule per kg Kelvin into temperature what is T 1 T 1 is 3 80- $_{s2}$ what is s 2 this is your to stream and this is your three stream right the s2 is 500 Kelvin + m. three what is M de three is1.8 into and at1 is your 3 80 - three under that is three is it zero or not actually it is 0 right if you calculate that is equal to zero right in the similar way by applying the second law of thermodynamics I can write down that ism . 1 s 1 =m. 2 s 2 +m. 3 s 3 then what else is adiabatic process.

There will be the Q. T won’t be there right and there will be also Straight yes or no it will be that is that we do not know right so how will find out I mean what we will do we will have to do in the similar way in place of m. one I can write out m2 + m . 3into s1 =m. 2 s2 + m. 3 s 3 + a dodgy right what we will do we will basically can write downs m. to s1 - s2 + m. 3 s 1- s 3 =as the G right okay.

Now can I evaluate this s 1 s 2 or not I can write down s1 - s2 will be basically CP LMK t2 by t1 - r LM p2 by p1 is or no right so similar way we can find out that so if I know t2 t1 I know p2/ p1 these are known so I can find out that happens to be you know we can find out that that will be something. And if you put this mass also write m. To write and together you will find out0.57 right and I can find out is 1 -$_{s\ 3}$ =- 0.07kilo joule per Kelvin so if you look at this term becomes like =m .t2$_{s1}$ - $_{s2}$ + m. $_{3}$ s 1 - s$_{3}$ =you will find out 0.5 will just add that kilo joule per Kelvin.

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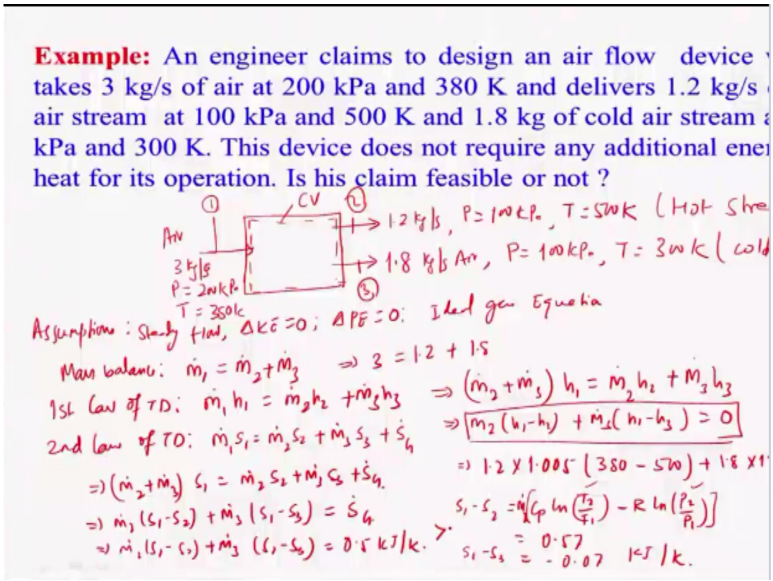

Example: An engineer claims to design an air flow device
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heat for its operation. Is his claim feasible or not ?

1.2 kg/s, P = 100 kPa, T = 500K (Hot Stre

1.8 kg/s Air, P = 100 kPa, T = 300 K (cold

Assumptions : Steady flow, ΔKE = 0; ΔPE = 0; Ideal gas Equation

Mass balance: $\dot{m}_1 = \dot{m}_2 + \dot{m}_3 \Rightarrow 3 = 1.2 + 1.5$

1st Law of TD: $\dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_3 h_3 \Rightarrow (\dot{m}_2 + \dot{m}_3) h_1 = \dot{m}_2 h_2 + \dot{m}_3 h_3$

$\Rightarrow \boxed{\dot{m}_2 (h_1 - h_2) + \dot{m}_3 (h_1 - h_3) = 0}$

$\Rightarrow 1.2 \times 1.005 (380 - 500) + 1.8 \times 1$

2nd Law of TD: $\dot{m}_1 s_1 = \dot{m}_2 s_2 + \dot{m}_3 s_3 + \dot{S}_g$

$\Rightarrow (\dot{m}_2 + \dot{m}_3) s_1 = \dot{m}_2 s_2 + \dot{m}_3 s_3 + \dot{S}_g$

$\Rightarrow \dot{m}_2 (s_1 - s_2) + \dot{m}_3 (s_1 - s_3) = \dot{S}_g$

$\Rightarrow \dot{m}_2 (s_1 - s_2) + \dot{m}_3 (s_1 - s_3) = 0.5$ kJ/k. >

$s_1 - s_2 = -\left[c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)\right]$

$= 0.57$

$s_1 - s_3 = -0.07$ kJ/k.

Which is greater than greater than 0right you will find out this some finite value so if it is greater than 0 then we know that it will be basically what you come that means SG is finite right if it is greater than 0 that means the processes possible right and that is nothing but your article s . G right which is greater than 0 so therefore process is possible right process is feasible so by this way you can find out right how whether the claim is right or wrong we have seen that s . G if it is greater than zero.

Then the process is feasible however if it =0then the process is reversible but incase this a s . g SZ d g is less than zero then the process is not possible at all it is not feasible so we have learn their how to apply basically second law of thermodynamics for a flow process or control volume you know system you can say thank you.

Acknowledgement
Ministry of Human Resource & Development

Prof. Satyaki Roy
Co-ordinator, NPTEL IIT Kanpur

NPTEL Team
Sanjay Pal
Ashish Singh
Badal Pradhan
Tapobrata Das
Ram Chandra
Dilip Tripathi
Manoj Shrivastava

Padam Shukla
Sanjay Mishra
Shubham Rawat
Shikha Gupta
K. K. Mishra
Aradhana Singh
Sweta
Ashutosh Gairola
Dilip Katiyar
Sharwan
Hari Ram
Bhadra Rao
Puneet Kumar Bajpai
Lalty Dutta
Ajay Kanaujia
Shivendra Kumar Tiwari

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