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NPTEL ONLINE CERTIFICATION COURSE

Course
on
Laws of Thermodynamics

by

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Lecture 15: Definition of Entropy and
Entropy Change in
Closed Systems

Good afternoon I welcome you all this lecture section of the course loss of thermo dynamics now today we will come very important topic that is the concept of the entropy in the perceptive of classical thermodynamic,so its definition by the heat transfer in the reversible process okay .

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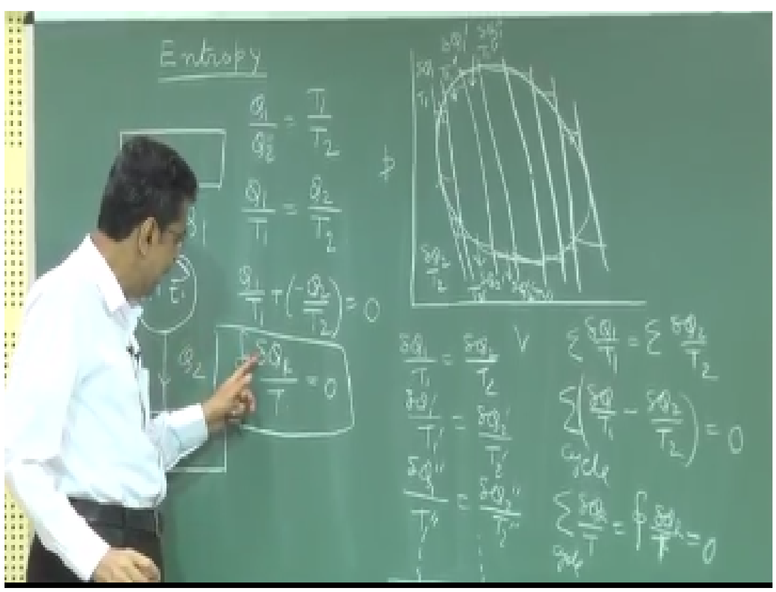

If you do this now entropy is concept in the perspective of the classing the thermodynamics so its definition of the heat transfer in the reversible process how it is done now we have already learned if there it is a heat engine reversible heat engine operating between the source T 1 reversible heat engine operating between the source E 1 and the sink T 2 this T 1 and the T2 absolute thermo dynamic scale temperature taking the heat cube Q1 rejected to the heat Q 2, we know that the Q 1 /T 1 or other the Q 1 /Q2 first tied in this can be written as Q 1 /T 1 = to Q 2 this can be written as the Q / T 1 +(-Q2 /T2)=to 0.

What is this with the respect to the heat engine that is the cyclic integral integration in the cyclic process of δ QR /t cyclic integral it is the cyclic integral δ Q are the simple formula concept comes Q 1 /T 1 q! is the heat that it Q 2 is the heat rejected it is the – and the algebraic sum of the Q / t in the cyclic process for the reversible heat is engine is 0 this is the great concept this you can also prove in the general reversible cyclic engine in the operating on the reversible cycle.

Which does not take the engine in the constant temperature the source is not also in the constant temperature because if the system goes on the constant temperature I have already told that the surrounding at the body from body from the ware it will take the reservoir of the source that the T also varies in this temperature that also I have discussed earlier similarly for the T 2 in this case we can derive the same equation it is the very simple caser we derived it concept. So the concept derived let us consider in the thermo dynamic plane P V A close loop like that which is in the general represent is cycle.

Now in this case we can derive the cycle thermo dynamics in this cycle in to finite small number of the infinite small element and other infinite number of the communist cycle of cycle like this. If this we have the number of the reversible adiabatic if we divide this like this all the reversible adiabatic and by reversible isothermal process as you know the comminute cycle in the reversible isothermal cycle processes and reversible adiabatic process.

Similarly here low temperature region you can divide like that means we can divide this cycle in to the number of the elemental communize cycle so that though the temperature varies in the any elemental cycle for this the temperature is T 1and the T added is δ for this elemental cycle the heat added is δ Q and the – and the temperature T 1 -. Or this elemental cyclic the heat added the elemental and the heat added the δ is the double   and the temperature id the T 1 double.

So now for this all elemental portion of this process we will cause that means when we divide it the cycle in to the elemental and the comminute cycle then we can consider the in the constant values and the heat is added like that in this case the heat rejection also the δ Q 2 and the temperature T 2 for this elemental cycle the δ Q 2‘at the temperature and the T 2‘for this elemental cycle the element Q double ‘in the T 2.

So on it is the very simple just the extension of this and each elemental cycle we can write δ Q 1 / t1 T is δ T 1 this is the δ Q 2 / T 2 simply this is similarly the δ 2 and the T 1‘ and the δ Q 2‘ / T 2‘ and the δ Q 1 double‘ and ‘ and for all this δ Q and the double ‘ and so on ‘ so that if we add this a we get Σ δ Q 1 / T 1 is Σ δ Q 2 / T 2.

So there for by adding we get the Σ δ Q 1 / T 1 = to Σ and the δ Q / t 2 which means the Σ the δ Q 1 / t1 – δ Q 2 / T 2 over a cycle = to 0 and – Q 2 because of the heat rejection you take like within the that is algebraic sum of the δ Q 2 / t over the cyclic which can be retain as the cyclic integral δ Q / t here all the heat transfer is not reversible writing the suppose the reversible actually final expression I Wright the reversible so the δ Q / t is 0.

So therefore from this simple logical proof we get that for the reversible heat engine the reversible thermodynamic cycle δ Q R / t =. Now in this case I will okay I can rub this one. And very important concept is that this δ Q r for a cycle δ Q T. now if the cycle reversible totally reversible now reversible is in the two types internally reversible and externally reversible now what about the temperature is it the temperature is the source are the thermal reservoir are the temperature of the heat engine.

Now the question the heat transfer is not the reversible may be the temperature different now in the heat transfer for the reversible process and then the temperature difference will be their not their source temperature of the temperature system this is the same similarly it is the C temperature or the temperature of the working system during the heat reject it does not matter and the name but this not may not be the case how the question comes the tell the heat transfer as the reversible heat engine.

The heat transfer process is not reversible it is not take under the finite and the temperature difference in this context there are two thing which is very important to you look you know one is internal reversibility discussed earlier also internal reversibility and external reversibility now internal reversibility and the many process due to the internal dis appointment and the mechanical history and the fluid viscosity and all this things it is the distance but the external reversibility the concept as the reversibility due to the heat transfer for the finite difference that menus if you consider the surrounding and the system as the temperature difference so therefore the hearty engine may be internal reversible that means there is not internally due to all this friction and the fluid viscosity and all their thing .

It may take heat under the finite temperature where it will be externally reversible that means the cycle as to totally reversibly test to the both internally reversible and externally reversible is that birth the internally and externally will be 0 that means there is no within the system there is no internally reversibility and there will be no heat transfer takes place across it infinite the small temperature okay this is the case for a simple single process also for example take you for this it is a important concept also.

That is the mass of the gas expands gas and the expands and there piston cylinder arrangements in the piston goes out because of the pressure and also it takes the heat from the surrounding temperature T h for example hot body the gas temperature is that at the any time the gas temperature and the piston and the process is always less than the T H the finite amount of the heat goes to the gas you understand therefore you see this heat transfer T H and system boundary heath transfer and the system temperature.

It will passes through the and in the equilibrium state then should be the infinite because the heat which is transfer now consider the process that this process is infinite is slow free from the internally reversible no friction nothing but the heat is transfer from the high temperature source to the gas in the finite temperature difference this process is has externally reversible internally reversible.

But if the heat transfer takes place from the temperature which is the which is the hollow is the at the same temperature of the infinite small difference with the gas temperature if the gas temperature varies the accordingly is the out side temperature so that is always will be there infinite small temperature then it is externally difference and that the same time is free from internally and the free from the reversible it is totally reversible now with this similar concept when the cycle operate we internally reversible but externally reversible that means the cycle which is internally reversible.

internally reversible but externally reversible that means it takes the heat from source or sink which as the different temperature than the temperature of the working temperature which receives the regencies in the turn cycle is known as the that means which as the internally reversible very useful concept in the reversible side and for the heat engine appropriate in the end of the reversible cycle then the cyclic integral δ Q r / T is again the 0 where the reversible means the end of the reversible process and this is the temperature of the working system during the reversible process.

Not these are the values and the but the cycle is totally reversible not in the reversible and this temperature of the system and the temperature of the source of the same okay so now with this we will proceed further therefore you consider in to the reversible cycle and but the cycle is totally reversible in this temperature and this source or the same in the same so now with this therefore you consider in the reversible and we will see and we call as the reversible process and the bother much about the externally reversible.

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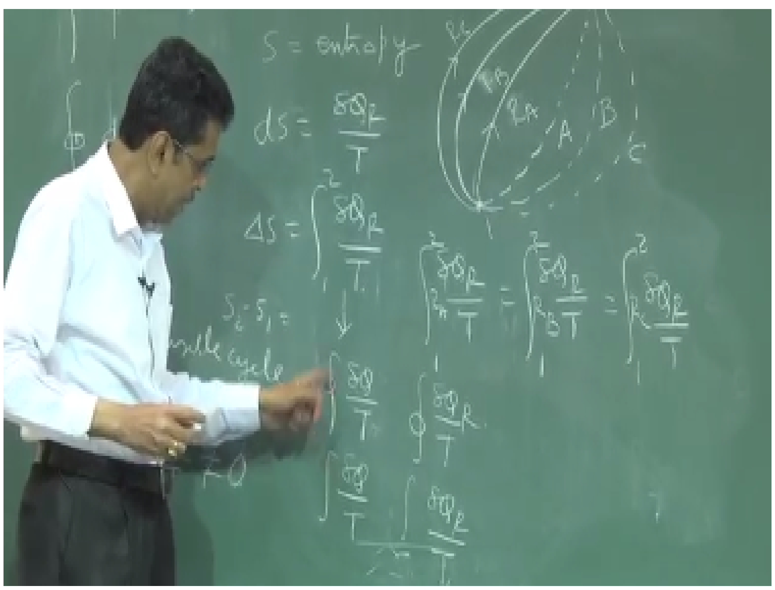

So that δ Q /T cyclic integral is 0- now this keeps the beautiful idea that when the someone the cycle is 0 then if you define now δ Q R / T as the we can define exact differential of the point function is y if you express this substitute this then δ Q R is the D S has to be 0 so when ever we substitute the D s let us consider the very parameter is if the differential change then we substitute this is the cyclic integral is 0. The cyclic and the integral of the nay paremeteristhe 0 this is the point function and become the property of the system the way we disused and that when se replace by the D of the A and the exact function is D of F the cyclic point is the o between nth je and the cyclic or the point function is the o that were define in the integral energy came of okay similarly.

In that case now the we found that Q – in the cyclic process is W so if yousubstitue this as the of the parameter is the 0 it means state function that they two are the path full in the diffrencesis the function and the first law similarly those the Q is the point function and the Q is the T that becomes the point function and therefore by the definition that entropy is this D S is the or the finite change in the entropy is r / t okay now see this will be the birth so the entropy and the designation comes like this three change and the differential change and the finite change and the δ Q R /t process in the confecting in the two state son the two 2-1c is this quantatity and the δ Q R /t is the integral 1 to 2 and this is the point is the little function of the entropy and that is be4cause it satisfies the relation integral in that comes 0 .

And it is like the δ Q R /T enjoys the characteristic it can be expressed in the terms of the differential of the point function which is the property entropy that means the δ Q are the two by the T from the one state point to the other state point is independent of the path because it is the property and it is the function of the independent the path that is most pital thing that means if we have two state point on the one and the two and if they are connected the point number of the reversible process.

Let us consider 1 or 2 are all reversible process okay in the one it is the reversible process and R is the this is the R B this is R C from the state one to the two if the value of this we will send which means that the integral δ Q R / T 2 1 are the two of the ray of this path = δ Q R / T 1 R B 2 = δ Q R / 1 R C 2 that means which are the path we follow if we connect in the two pints in this the integral point is function is the obviously and this is define like that is the S 2 – S 1.

So the S 2 – is fixed and the entropy is fixed in the state point so this is the point function and this one is fixed so whatever we will go the change in the just like work done in the conservative force field so the whatever path we take the change of the entropy is given by thisintergal and this integral is T respect and the p of the path that means if we connect the two points is and the reversible process and the value of the δ Q R /t and the reversible path in the change of therapy of this process.

And the now the big question come what happens in the process and the reversible one for the reversible process now for the reversible cycle which is internally reversible why there it is externally reversible not it is does not matter I the cycles internally reversible and you can consider the reversible internally reversible also internally reversible it is the reversible cycle here and the system temperature so that is why I am bother to it is the internally reversible insister reversible cycle δ cyclic integral δ Q / R is not equal to 0 because the cyclic integral is not the 0 provide the cycle is reversible.

So in case of the reversible cycle weather the temperature is the source of the same temperature or the temperature is not the working system in the cyclic integral never in the 0 now the questions come what is the value of cyclic integral δ Q / T in the reversible process as compared to the cyclic integral δ Q/T in the reversible process or the integral δ Q /T in the single process with the compared to the revisable process now these question comes in The picture now what comes one thing the since is not equal to 0 this is true that the integral δ Q / t is a path function not a point function now the two question come first question.

what is the value of the δ Q / t and in the reversible process if we have the reversible processed us consider are eversible process one is and the 2 and it is done in the dot area the first question is that if you have the system in the reversible process and the process and the one to two and if I evaluate in the and the integral δ Q / T one and the two is the δ S is now the definition and the t is the reversible process that mean I have to connect in the reversible which means you can tell the or the value that the entropy[y change in the reversible process connecting in the integral of the δ Q / 2 and the t is the value if the states could have the connecting by an reversible process then what could be the value of the δ Q / p in that the reversible process in the entropy change in the δ Q / pis the process .

So therefore the next question comes what is the value of the δ Q / p for the reversible process compared to the it revisable path the δ Q / pin a reversible path and similarly in the cyclic path what is the value as compared to this and it is 0 and now I write that this thing you can better understand this is the process and if we had the number of reversible path δ Q / p of the each path

A B C and not equal that means it is not equal in theintergal of the δ Q / p 1 D 2 and the note equal to δ Q / t and C Q are not equal.

And the path function and the but the entropy change will be δ by any reversible with the connecting any the two state is S1 is giving by the δ Q R 1 are the any two reversible process because they are same that means δ Q arte by any reversible process is same because they are the point function they define the entropy change while reversible process is δ Q/ P is not the entropy change it is simply Q / t integral over the process and these are different in the different reversible process now again I am telling questions come out is compare with their counter per these question was answer by clauses and these know as clauses in equality .

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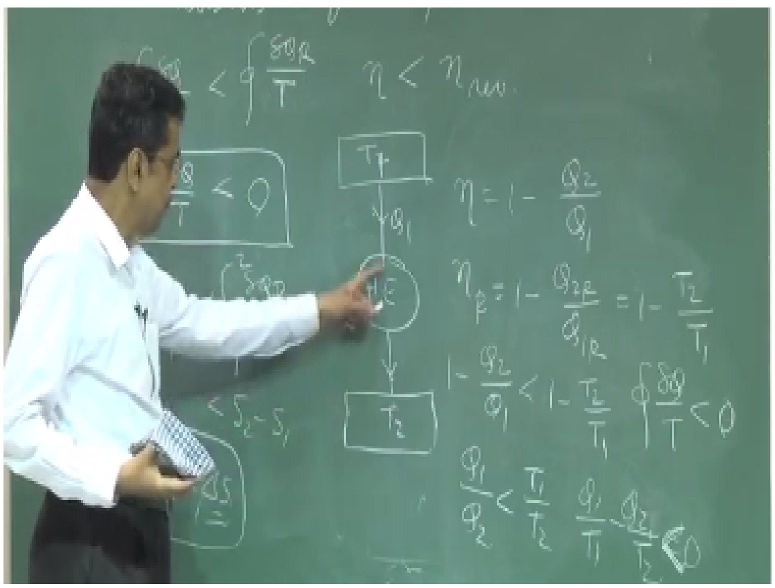

Now this was answered buy the clauses and it is known as in equality and it is very simple prove its concept I tell you the reason the cyclic integral and the T for the reversible process is less that the δ Q / t do r the reversible process and the reversible it is the constant temperature of the work. Since this is o so the cyclic integral and the δ q / T and less than three. This is clauses inequality in the trams of the and the cycling and hence it follows the δ Q r Q /t in may process for example 1 to 2 is less than 1 to 2 in the reversible process.

That means this is less than the differentiate in the 2- or we can tell δ Q / T find that is the less in the terms tart is therefore this is the in this format cyclic integral δ Q / T is less than its counterpart in the reversible cyclic it is less than the 0 it is similar integral to δ Q / T giving the process is the less that the counterpart integral δ Q R/ t.

If over the process it is the nothing but inches this T is give you the concept of the δ classis answer done by them it is very simple to prove in lies in the since in the river engine is less than that over the reversible process that is simple like that that means the reversible engine it is the consider the a is reversible engine T 2 take the Q 1 in the reversible heat engine and in the same temperature T 2.

Consider the engine is totally reversible then Q1 / T 1 = to Q 2 / T 2 or simply you can write this is better this is Q 1 / Q2 and the reversible engine you cannot write this sorry we cannot write this in the reversible engine on the efficiency and the δ is 1 – by the definition of the first law and that is by the conservation of the δ and the you know the δ in the by the definition can we give the first law of the conservation of the energy in the δ and the thermal efficiency is1- Q2 – Q1 and the Q 2 – Q 1 is what is divided1.

By the now if we have the reversible heat engine in the same source T 1 same source And the same temperature the n the efficiency is defined as the, and in that and the 2 R and the Q r are is the heat rejection and then the heat received by the heat engine that become in the 1 – T 2 – T 1 this is for the reversible engine so it is less and the reversible that means 1- Q 2 / Q 1 is less than 1 - Q2 – Q 1 that means the Q 2 / Q 1 is greater than the Q 2 / Q 1 and again we can write and the Q 1 / Q2 is less than T 1 / T 2 which give Q 1 / T 1 – Q 2 – t2 = 0 .

So you see the proof that simple the concept is that he reverse engine is less the n the reversible process T 1v T 2 is the source thing in the source temperature in the efficiency is define like that from the conservation of the energy you know it .

Earlier discussed we have earlier reversible engine it is dissolved also like that you at the Q 1 and the Q 2 and it is rejected for the reversible for the reversible in the it can replace like thi9s Q 1 / T1 but since δ is less than the notes of the principle 1- Q/Q 1 is less than the Q 1 / Q 2 is less that means Q1 that means Q 2 –Q1 and the higher than T 2 / Q1 are Q2 is less than T 1 / T 2 Q1 / Q2 is less than that means the t is less than the Q 2 by T so that Q 1 T 1 – Q 2 / T 2 less than the 0 not equal less than the 0 that means the cyclic integral δ Q t is less than it.

Again it can provide by taking a general loop as the thermal thermodynamic cycle for the reversible cycle and the comparing to the reversible one and you get the same answer this is the for the ;logical proof I do it is the formation like and this is very important information from the fundamental concept of view clauses equality tell that δ Q / T cyclic integral is less than that the consider part that in the counter in the reversible process and the δ Q for the giving process is less and the less than the counterpart do the R / T in the reversible process that is = to δ and it is like concept we alive the this once in a different way this way were can write in a different way for an reversible process and the reversible process we can write just now let us consider and the reversible process which is internally.

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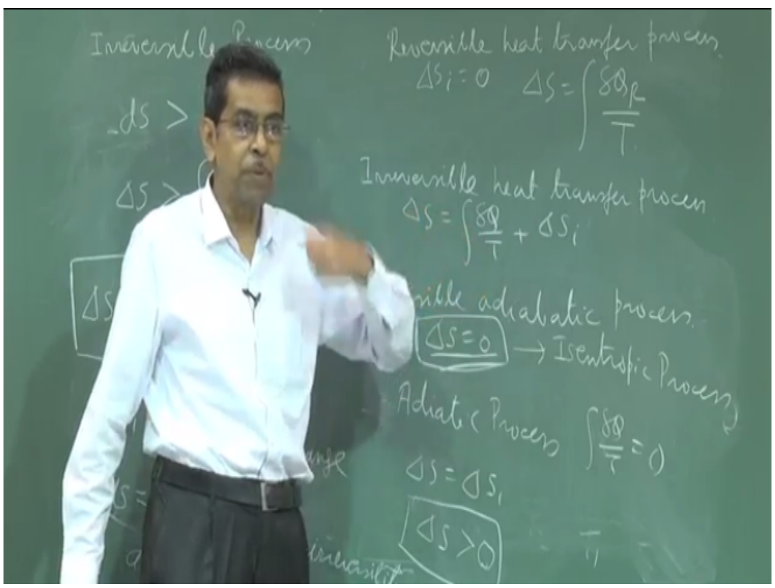

For the reversible process δ is other I can write differential term D S is greater than δ Q / T for that the reversible process from the clauses in equality δ Q is less than the δ S or the δ S is written than the δ Q R / T process, that means the change of the entropy that means the corresponding the δ Q / R in the reversible process is always greater than the reversible process the differential form in the finite difference from and in the change of the entropy, I am the process is always greater than the δ Q R / T clear.

Now if I write for an reversible process δ is always reversible δ is greater than the δ Q / T is the is greater than the integral by the integral and the reversible process we can write this some positive quantities which I write as Δ S I , which is always greater than 0 the Δ is an any process is more than the Δ Q / T is over than they process is integral + Δ is greater than the 0 this can be written in the differential form , D S is Δ Q/ T= D S I where the D S I differential form greater than 0 and this is known as entropy change due to an internally reversible.

This is known as entropy change due to reversibility it is this kind were in due to the internal reversibility it which is the hollow entropy change due to the reversibility is always greater than 0 so this is one very important relation in classical reversal thermodynamics, that the Δ is process entropy it is the Δ Q and the δ Q/T.

Now you consider certain special and in the certain case for example in the certain case it is reversible heat transfer process that means the heat transfer process with but the process it is reverses then the δ is a be the 0 then the Δ S I will be o and the result will be Δ Sis the integral which is the basic definition of the Δ S change in the enthalpy entropy is always define from it inception in the change and the Δ S δ Q R/T so for any reversible process for the heat transfer it is the added to the system and the Δ S is positive and the system that is negative now you consider reversible in the reversible heat transfer in it.

You consider it heat transfer process the heat reversible heat transfer process it will be the reversible process in that case the ∂it is the reversible heat transfer that is the reversible heat transfer and the equation on the and the Δ S is and the ΔV / t now you consider reversible without the heat transfer and the adiabatic process and these are the special case now in the reversible adiabatic process it is beautiful because of the reversible internal reverse in the land that is the 0 and the form is also this also 0 but in this case is that is the o.

And the entropy is the and we get in the reversible and the change in the reversible process with it without the heat transfer it is the adiabatic process and the simple adiabatic v f we want the reverse adiabatic and the adiabatic simple and the adiabatic proceeds without the reversible in the that is the natural adiabatic process if you add the reverse able it is the reversible adiabatic process without the process and the process in the without the reversible is that case and that is always greater than the end it has the value in there for the adiabatic process in the without the heat transfer to the surrounding and the change of the entropy is always greater than the 0.

So these two these one and this one very reversibleadiabtic process entropy and the in that case it will be the reversible process for the definition and the reversible heat transfer process and that will be that is the important thing in this case that is the certain and the special case it will be the reversible case in the which expect to the surrounding this is the negative in the internal reversible rigidity this is positive always there is greater than the o.

And the it all will be the final entropy is the same as this and there will be the reversible possible with the passes through the series of the equilibrium and it takes in the reversible adiabatic process entropy remains in the entire process and there in the this is known as isometric process that means that all points of the process in entropy remains here but here in the change will be 0 be balancing here and the reversible process in the regain s at the same is positive in explain this now today it is up to this.