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NPTEL ONLINE CERTIFICATION COURSE

Course
on
Laws of Thermodynamics

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Lecture 17 – Tutorial: 4 Entropy

Good afternoon I welcome you all to this lecture section of the course laws of thermodynamics now in this section last section we solved two problems this section also we will solve two interesting problems let us see the problem.

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Problem 9: A 12 kg steel container has 0.2 kg superheated water vapor at 1000 kPa, both at 200 C. The total mass is now cooled to ambient temperature 30 C. How much heat transfer was taken out and what is the steel-water entropy change?

This is the problem we have discussed earlier regarding the entropy change now this is a problem a 12 kg steel container has 0.2kg super heated water vapor in super heated steel at 100 kPa both at 200^0 C both this steel container and the super heated steel water vapor the steam at 200^0 C, the total mass that is both this steel and the steam that is water vapor is now cool to ambient temperature of 30^0 C how much heat transfer took place was taken out of the system and what is this steel water both these things upon makes a systems steel water entropy change so let us come to the board and understand the problem.

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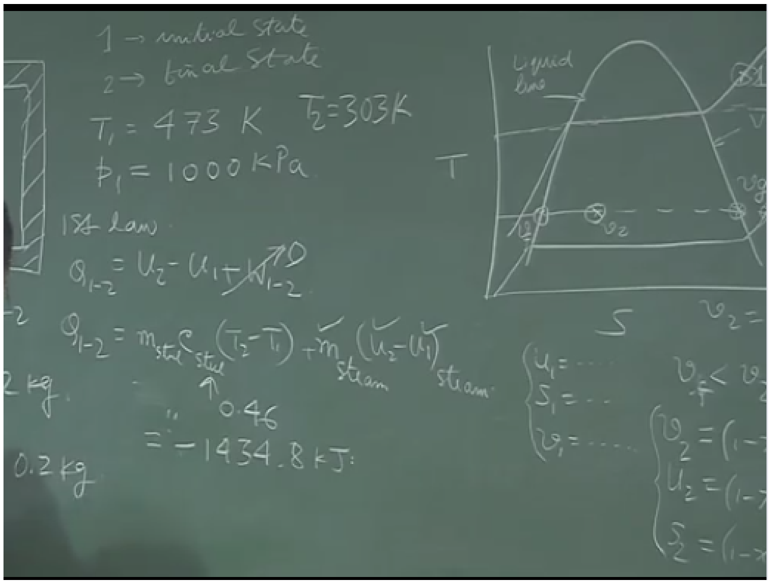

The problem is like this there is a steel container this is the steel container and there is steel, this is steel container let the initial state is 1 is the initial state and let 2 is the final state now in initial state the temperature T is what is given in the problem temperature T is 200^0C that means 473K now the pressure of this steam that is the initial pressure because now the steel and this steam combine contains the system, so steel as a temperature of 200^0 C that is 473K and steam is also 473 K.

And P1 is given by 1000kPa that means 1000kPa now we have to find now to find the property we have to go through steam table but first let us write the equation for 1^{st} law okay 1^{st} law what is 1^{st} law now if we consider Q is given to the system actually it is taken out but we will find the if we get a negative sign then it will be taken out in general we do like this Q_{12} is U_1, u_2- U_1 that is the change in the internal energy of the system plus W_1

But in this case W_{12} is 0 there is no heat transfer because it is rigid steel container and steel heat is transferred out but we have taken it is strong in so that we can write the general link equation so this can be written as $Q1_2$ now this aim U_2- U_1 consists of both steel and the water vapor so for steel it is m steel change in the internal energy of the steel is m steel C steel into t_2- t_1 for solid to change in energy this specific heat into mass into temperature change + the m steam into $U_2 - U_1$ steam.

So now we know c steel c steel is not given but we know it is value I will tell you afterwards m still is known mass of steel is m steel, m steel is 1.2kg m steel is given what is that 0.2kg, 0.2kg so m steel will know T_2 we know T_1 also T_1 we know and T_2 is also we know that T_2 is here I write T_2 is 20^0C 30^0 since here that means 303 so therefore this part is known this part m steel is known but we neither known U_1 known U_2 how to find out, now from steam table you check that 1000kp and this temperature of 73k that is 20^0C here it is super heated.

How to check it if you see this steam table 1000kp you will see the saturation temperature is less than that means it is a super heated steam that means if I draw a diagram TS diagram we come to know this in your earlier class that this a constant pressure line in TS diagram this is the liquid line this is the liquid line saturated liquid state, all the points in this line and this is the vapor line that saturated vapor, now this if this is 1000kp pressure line my state is like this it is at a temperature this is the saturation.

Temperature corresponding to this is the constant temperature corresponding to this pressure so this temperature is higher than this temperature, this is the saturation temperature corresponding to this temperature 1000kp so this is the super heated steam so from super heated steam table I found I find U_2 sorry U_1 here I write I find U_1 I find S_1 these are all specific values this small u are the specific values this will be required and also I find the specific volume of b steam at initial state.

This will be required so this 3 things I found I fond from the super heated steam table, now I have to find out U_2 now how to find out U_2 this is very interesting now only thing I know that this an 303k final state is at 303k now the point I do not know anything else now whether this will be in super heated region and this temperature then this pressure will be lower then this will be it is existing pressure, this may be dry saturated vapor this may be liquid or this may be somewhere here.

Intermediate weight vapor that means a mixture of liquid and steam weight vapor how to do how to check one thing is that this process is a constant volume process because volume remains constant and since the mass remains constant that means this specific volume remains constant that is the flow is that V_2 is V_1 that means I know V_2 this V_2 is same as V_1 now we check this V_2 against Vg and V_f that is the dry saturated liquid and dry saturated vapor in the saturated steam table and we will see in this problem that $V_1 > V_2 < Vg\ V_l$ now V_f that means the specific volume of saturated liquid is less than V_2, V_2 is higher than that but less than Vg that means it is not super heated it is not saturated liquid that is in between.

That means heat as a dryness fraction x2 with some dryness fraction x2 now when we determine this it is in this state so dryness fraction x2 can be calculated by equating these,V_2 is 1 – x V_f + x Vg these two things we get from steam table and V2 we know so that V2 is V1 from which we have checked that it is in the saturated that is vapour domed that means saturated state but with mixture of liquid and vapor so if we quit this then we get the value of x2 sorry x2.

When we know x2 point is here for u2 also we can find out 1 – x2 x U_f + x2 x U_g and for S2 also specific entropy 1 – x2 x he wave x2 x Ug so this U_f U_g sorry SF it is SF x SG so these are from steam tables that the saturated liquid and dry saturated vapor for specific volume for internal energy and for entropy that means I get V2 U2 S2 similar to these V2 V1 S1 U1 like this so this sets are known at both inlet and outlet.

So therefore if I put this U2, U1 and in steam we get the value of Q12 and this value equals to if you put all these value that is T2, T1 m-steal C- steal and if you consider these till specific it as point this as 0.46 the applicant and this value equals to -1434.8 kilo joule minus that means the minus sign is the heat is coming out, now the entropy part is very simple I can rub these thing so entropy change is entropy change of this steal + the entropy change of the total entropy change total system is ΔS steal + ΔS steam.

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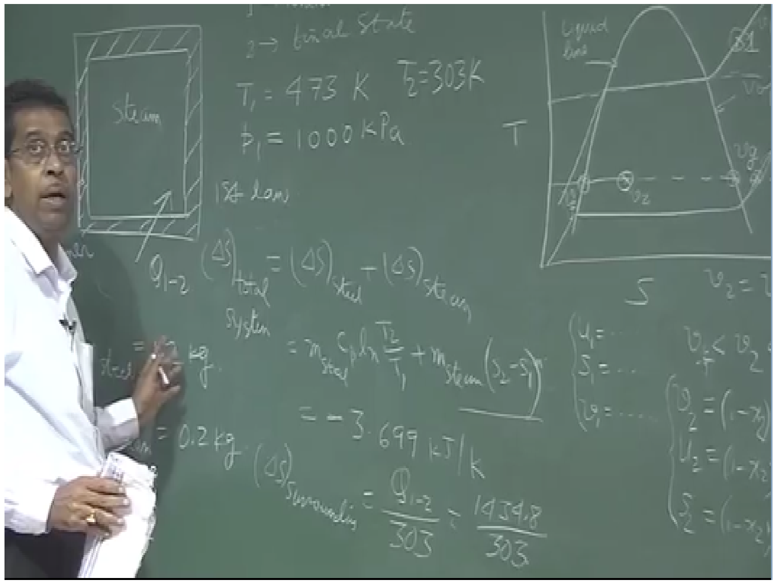

And this is equal to mass of steal is specific heal L_n T2/T1 + mass of steam x specific heat x Oh no, mass of steam specific heat I am sorry so this is ΔS steam is M. M steam x S2 – S1 this is already obtained S2 value you know S1 value we know because from the superheated steam table I get this from the saturated steam table I get this with this check and then we can find out and this becomes equal to I tell you that equals to -3.699 kilo joule\K.

Now one interesting thing is there that this problem has not told you to find out the entropy change of the universe this is the entropy change of the system this is minus because obviously heat has been lost this is minus sign that mean heat has come out it is ΔS of this system is like that, if you find out ΔS surrounding then you have to find out that is a heat that is rejected that is Q12 that is received by the surrounding.

Divided by the surrounding temperature that is 30^0 C, 303 the value of Q1 to which I got earlier 1434.8 this is be plus sign because surrounding is taken, so this quantity minus this quantity is always positive we do it kept as an exercise so Q2, Q12 if you put that value 1434.8 that is 1434.8/303 then you will get this is more than this by magnitude, so this minus this is positive that means entropy change of the reverse is positive.

This is not aspect of course in this problem okay I hope you have understood this problem well okay, now I can rub this. Next problem is tremendously interesting.

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Problem 10:A computer chip dissipates 2 kJ of electric work over time and rejects that as heat transfer from its surface at a steady state temperature of 50 °C to the ambient air at 25 °C.

Determine

(a) Entropy change of the chip

(b) Entropy change of the universe

(c) Entropy generated within the chip

(d) Entropy generated outside the chip

(e) Total entropy generated

This problem you see very carefully this gives you the concept of internally reversiblility externally reversibility and entropy generated very, vert conceptual problem see that. A computer chip dissipates 2kJ of electrical work, electric work over time over some time and rejects that as heat transfer from its surface at a steady state temperature of 50°C to the ambient air at 25°C. Now what we have to find out entropy change of the chip, entropy change of the universe, entropy genearated within the chip, entropy generated outside the chip, total entropy genearted all these things entropy change of the chip, entropy change of the universe, entropy genearated within the chip, entropy genearated outisde the chip and total entropy generated which is obviously C+D. This problem is very, very interesting problem, now you come to the board work.

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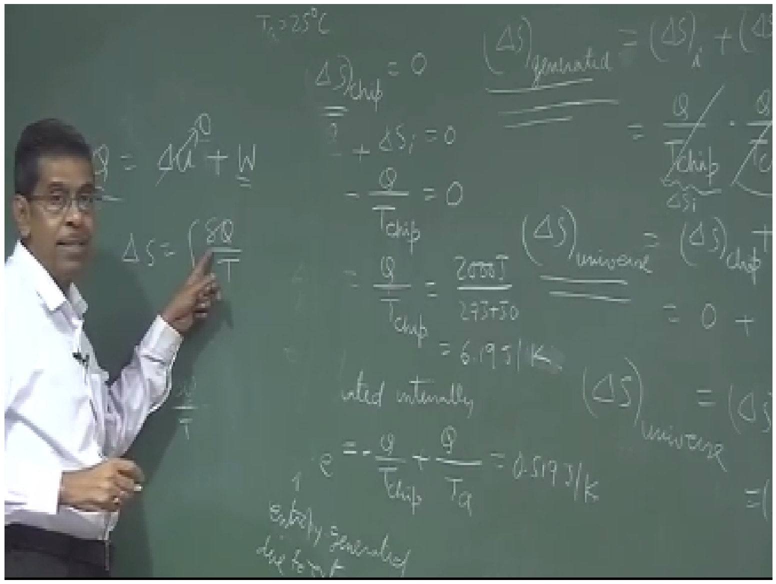

The problem is like this there is a chip which is at steady state temperature 50°C because of an electrical work transffered to be that means work electrical work, that means some voltage some electric current passes through it i across the voltage, that means some electrical work simply register concept you consider a chip which gets heated, heated means this electrical work is converted into heat molecular elements.

But at the same time it gives heat Q to the surrounding which is at work temperatures surounding at 25°C temperature Ta at 25°C and in such a way that the temperature 50°C at the chip surface consider at in the of the chip itself, chip is a very thin material that it is at 50°C the steady state does not change that means the heat which is transferred is given by the electrical work steady state that means by first law that Q= if you write the first law $Q=\Delta u+W$ chip is at steady state means Δu0 that means Q it is from common sense that keep the temperature cost and for the chip

Electrical work at a must be equal to the heat transfer that means electrical work change the intermolecular energy but at the same time heat transfer out makes the intermolecular energy remains the same so chip is at this steady state and the steady state temperature is 50°C this is very important point that chip is at steady state, so Δu0 so Q=W that means inter electical work is finally transferred as heat to the surrounding.

First dissipated in terms of intermolecular energy which raise this temperature then dissipated to the surrounding and they are equal so that temperature remains same. Now we write this expression Δs, now this is a highly irreversible process because of this internal irreversiblilty in the chip the temperature is increased. Well, by virtue of which it transfers heat to the surrounding so there is a which is highly and irreversible process I told you the example this exist, this is because of the chip resistnace.

That electrical work is being dissipated in terms of or transferred in terms of converted in terms of intermolecular energy, highly irreversible process so Δsi but now since the chip is at steady state Δs is 0 so first question is Δs chip = 0 since = 0 Δ si is Δ q/ t now in this case we can write δ Q / T + Δ si = 0 or Δ si that entropy change due to internal irreversibility is equal to this is first time I am writing this plus this ΔQ / T is negative since it is going out and since t is constant it is q/T chip.

I am writing this her and this here, so Δ si is q/ T chip that means q which is going out to this surrounding divided by the chip temperature gives you the Δ si that means this is the entropy generated due to internal irreversibility within the chip. So another answer is there one answer is there. So this is the entropy change due to internal irreversibility of the chip but this is not the entropy change of the chip entropy change of the chip is this so this is entropy generated sorry not entropy change I am sorry entropy generated if the watt is not entropy change sorry entropy generated during the chip because of inter that means within the chip entropy is generated because of the internal irreversibility but the entropy change is 0 this is because Δ si and Δq / T balance each other.

Δ is 0 I have got is your steady state from other point of view we can explain that entropy is generated due to internal irreversibility and I told you in the last class just last but one class last before the last class that there may be a situation that heat lose and the internal irreversibility may balance each other so the Δs is 0. So that this is balance so entropy generated is q / T which you can find out by this q is 2kilo joule 2000j / 273+50 and this becomes equal to you can find out the value that entropy change entropy generated in the chip is 6.19j/k.

Now what is the entropy generated next one outside the chip entropy generated that means this we call this is because of the external irreversibility I told because of the heat transfer due to a finite temperature difference 50 and 25 that means this will be q/T chip this is minus plus the same q / Ta now q = 2000j q = w = 2kj 2000j and you put the value of T chip that is 50+273 and value of Ta what is ta, ta 25, 273 + 25 and you get that value of entropy generated externally that is entropy generated internally due to internal irreversibility and this is entropy generated due to external entropy generated due to external irreversibility.

This is due to internal irreversibility due to external so total entropy generated total the entropy generated Δ is total I am not writing total generated total is entropy generated due to internal irreversibility and external irreversibility. So internal irreversibility entropy generated is q / T Chip and external generated you can calculated in that but I am writing in this –Q/Tchip+Q/Ta and this cancels out so the total insufficient becomes Q/Ta this entropy generated externally if you calculate you get this value, you get this value that .519Joule per K entropy generated externally .519 that means if you equal it.519joule per K.

So you can add this two but it is written in first equation to show that it simply becomes Q/Ta if you calculate Q/Ta it will be this plus this obviously because this and this cancels out so this plus this can get but by formula it is Q/Ta here now if you see from other point of view if I write ΔS is universe that is without the concept of entropy generation internally and externally just I find out entropy change of universe.

I know the entropy change of the universe which is chip plus entropy change of the surroundings and entropy change of the chip is 0 surrounding will be Q/Ta Q is equal to 2000 Joule that means we see that entropy change of the universe are total entropy generated are the same that means the classical statement in classical reversible thermodynamic in terms of entropy generated of the universe becomes the equal to the ΔS generated total entropy generated which equals to ΔSi+ΔSe

That means if you look this problem from two angle one is reversible thermodynamics angle we find out that is why so many things have been asked to find out that entropy change of the COP is 0 so entropy generated due to internally reversibility is by this equations very important equation I have told you the earlier class that ΔS is 0 then ΔSi is -ΔQ/t here in this case ΔQ/t is negative so this is ΔQ/t becomes Q/t.

Because this temperature is constant otherwise you have to integrated if this temperature put a barrier it is simply Q/ta this is the numerical value now entropy change due to externally reversibility I told that you externally reversibility theses re similar due to heat transfer through infinite temperature difference so therefore through a finite temperature difference heat transfer through the entropy change for this type of reversibility heat transfer to a finite temperature difference will be like this.

The chip has this entropy decrease and this has entropy increase so therefore ΔS is like this, this is the boundary temperature of the chip were you transfers the heat through the immediate surroundings so this is ΔS entropy generated due to externally reversibility so total entropy generation both due to internal and external reversibility is this that this cancels out ΔSi+ΔSe this is ΔSe.

And this is ΔSi so that becomes Q/t now if you calculate Δ is universe at ΔS chip is surrounding that is chip plus surrounding then this becomes equal to again Q/Ta because ΔS chip is 0 that means ΔS is universe is equal to ΔS generated ΔSi+ΔSe so therefore we will see that all these aspects have been covered here that entropy generated and the entropy change of the universe.

So in the conclusion of this lecture I like to tell this aims your lecture on entropy has whole of this second law thermo dynamics I just summaries it in brief that we started from second law concept has a directional constraint or the uni-relation characteristics of a process and there we saw, that there are some process occurring spontaneously in nature or man mad which are one directional, but process which are both way possible to occur the make a permanent indentation, that we will finally come at the end, that occurs in such way that entropy is generated in the universe is greater than 0. We learnt Kelvin Planck statement and the celosia statement that a heat engine to develop work continuously from heat it has to interact with 2 reservoirs.

Heat had to be rejected that continuously conversion heat into R is not possible in a cyclic process but heat can be converted into work by it is not possible by the same amount that means the same heat the equal amount of heat cannot be converted into the same amount of the work. Heat cannot be converted into work by the same amount in a continuous process by a cycle, thermodynamic cycle required for continuous conversion but any process heat can be converted into work.

That concept should be there after that I will tell you certain little bit of concept of thermodynamic many people have that Q = Δ u + W in any process single process. Now there me a process where Δ may be 0, for example if you take an ideal gas and if you supply heat and get work in a way that the temperature remains constant and ideal gas internal energy of temperature source, so therefore internal energy remains constant, so there may be process where Δis 0 Q can be converted into W in the same amount.

But you cannot be converting into W continuously in the cycle process that is the restriction in the Kelvin Plank statement, celosia statement is very simple it cannot be converted spontaneously from low temperature to high temperature, the most important theorem of the second law is the canots theorem, that the reversible engine operating between two temperature level source and sink.

As the higher efficiency then the irreversible engine and all reversible engine have the same efficiency, whereas all irreversible engine efficiency has different efficiency, even the maximum of that is less than that of reversible engine same as the thermal engine from which we finally reduced the concept of absolute temperature which is define as ratio of the absolute temperature two system equal to the heat added and heat rejected by a heat engine.

From one the heat is added and from other the heat is rejected and then from that we had the concept of entropy which is defined in the terms of change in entropy change in process is given by the integral δ2/t if the process connecting to two states is connected by the reversible process, that means it is defined as ΔQ/t in a reversible process integral of ΔQ/t in a reversible process is less than ΔQ/t reversible process and therefore it is less than ΔS.

Just now we solve the problem entropy is the change of the system is express ΔQ/t + some quantity which entropy change internal irreversibility okay, so this is the concept celosias this is celosias in equality cyclic integrating of ΔQ/t is 0, if t is the temperature of the working system operating in the cycle then this is indo reversible cycle, that means internal reversibility is 0, so that case you can tell that ΔQ/t = 0 t is the working system temperature.

But if t is the temperature of the surroundings source and sink the cycle has to be both internally and externally reversible, so this is very good concept, very useful concept you have to remember for the 2^{nd} law the thermodynamics. We have solved some problem in 2^{nd} law the thermodynamics and I think this is all and for 2^{nd} law upto this but next class, this is all for not 2^{nd} law but in the next class we will be discussing entropy transport for the open system.

So long which I have discussed related entropy change and entropy generated in a close sytem but you will discuss the entropy transport in a open system which is very important. In oa we discussed the first law apply to the close system and the first law conservational energy principle apply to a open system and then we will discuss that our discussion of second law will end okay thank you.