Concepts of Thermodynamics

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Lecture – 46
Supplementary Lecture: Problem Solving with the Aid of a Computer

Hello everyone, welcome to this session in which we will solve another problem pertaining to the topic of entropy by means of a computer.

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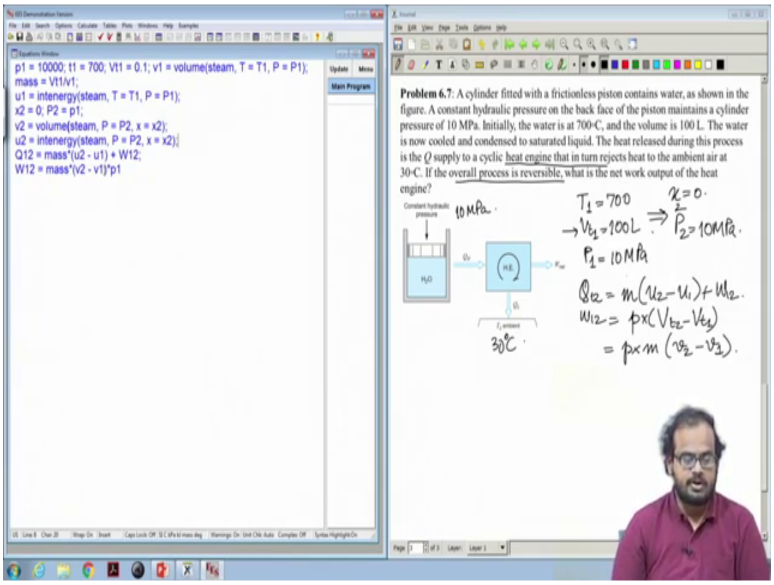

A cylinder is fitted with a frictionless piston which contains water and back face maintains a pressure of 10 mega Pascal. Initially, the water is at 700 degree Celsius. So, T 1 is 700 and the volume of the whole container is 100 liter. It is now cooled to saturated liquid. So, what is the quantity here we have? So, we total is not a independent quantity.

So, the quantity is actually the pressure and it is going from this state to state 2 where it is a sub called liquid as saturated liquid. And so, here the pressure remains constant. So, P 2 is 10 mega Pascal, the heat release during this process is now used to sub is now supplied to a heat engine that rejects to the ambient at 30 degrees Celsius.

If the overall process is reversible, what is the network output of the heat engine? That is the question. So, let us see how we can do this. So, we have p1 is equal to 10 mega Pascal, we have t1 is equal to 700 degrees Celsius and Vt 1 is equal to 100 liter.

So, it is basically 0.1 meter cube. So, v1 equal to volume steam T equal to T1 P equal to P1 this gives a specific volume. So, the mass is equal to the total volume divided by the specific volume that is the mass. State 2 x2 is equal to 0 and we have P2 is equal to p1.

So, now, Q 12 which is if I consider this particular mass as a control mass then I can write Q 12 is equal to m u2 minus u1 plus W 12. But what will be W 12? W 12 will simply be, the external pressure multiplied by the change in volume. So, if I can write it in terms of the total volume, alternatively I can also write it in terms of the mass multiplied by the specific volume is one and the same.

So, then let me write down Q 12 is equal to mass times u2 minus u1 plus W 12; where W 12 is mass times v2 minus v1 times the pressure. So, v2 is equal to volume steam. We can use the pressure at state 2 and the state and the quality to find out the specific volume. So, with this you also need to fetch the internal energies. So, u1 equal to intenergy steam T equal to T1 and P equal to P1. Similarly, we have u2 equal to intenergy steam P equal to P2 and x equal to x2 is basically the internal energy of the fluid ok. It is its completely saturated liquid.

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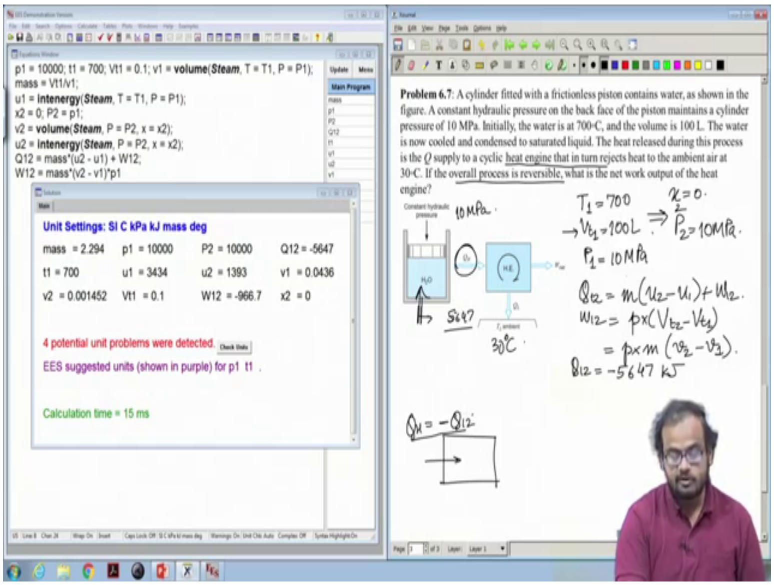

So, with this we have Q 12 equal to minus 5647 kilo Joules. So, that is heat transferred to the system. So, if this was the heat this much amount of heat would be minus 5 6 4 7 which means, if I draw the arrow like this it would be 5647. So, basically this particular Q is nothing but 5 6 4 7.

So, if I draw the heat engine now, this particular heat to the heat engine basically which is Q H is nothing but minus of Q 12. Try to understand, because I have considered the control mass as H 2 O the sign convention tells me, that if I take it as positive, than heat is to the system pardon me. So, that is why I have drawn there like this.

So, the numerical value comes out to be negative, it means actually the heat is going out of the system ok, the system is losing heat. So, Q H is actually the Qh to the heat engine is actually minus of Q 12. Let us just keep that in mind.

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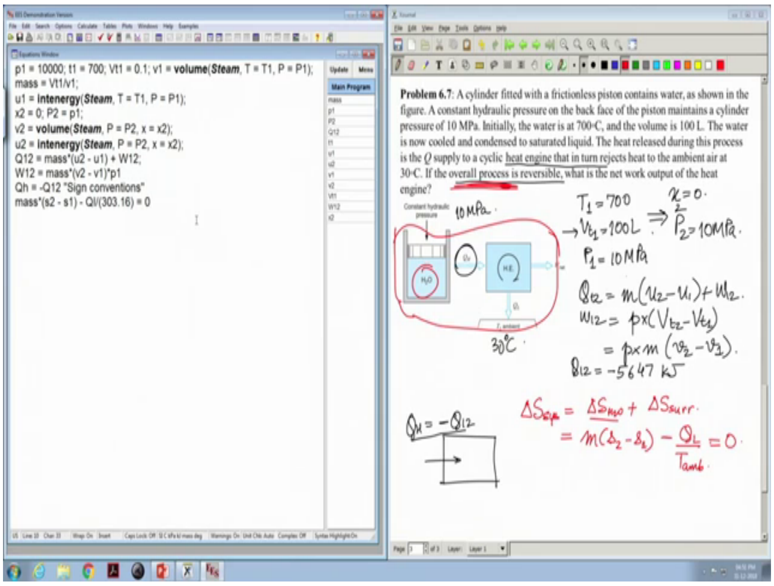

So, we write it over here. Qh is basically minus of Q 12. So, now, it is given the overall process is reversible. So, what is the strategy we adopt over here? We consider this; so, forget about this arrow. We consider this to be the control volume. So, for this particular control volume we have some water which is changing its state from state 1 to state 2, and we have some heat rejection and some work.

So, the work does not contribute to the change of entropy. So, if I write down delta S of the system is equal to delta S of water plus delta S because of the heat transfer. So, this let us include, because we have been given that the overall process is reversible, we have to also include the heat transfer to the ambient delta S of the surrounding.

So, what do we have? So, delta S of the water is mass times s 2 minus s 1 and what is the entropy change of the surrounding? It will be equal to minus of Q L by the T ambient in Kelvin as per the sign convention. So, we write here and this overall as; obviously 0. So, then we have mass times s 2 minus s 1 minus of Ql by T ambient which is basically 303.16 Kelvin which is equal to 0 ok. So, let us see what Ql we obtain.

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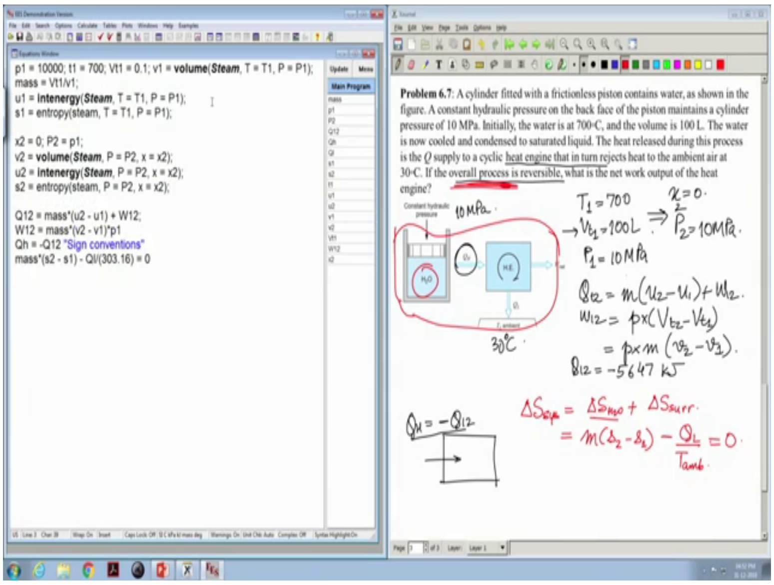

So, we have forgotten to fetch the properties of the property entropy s 1 is this s 2 equal to entropy steam P equal to P2 x equal to x2. So, let us see what Ql is.

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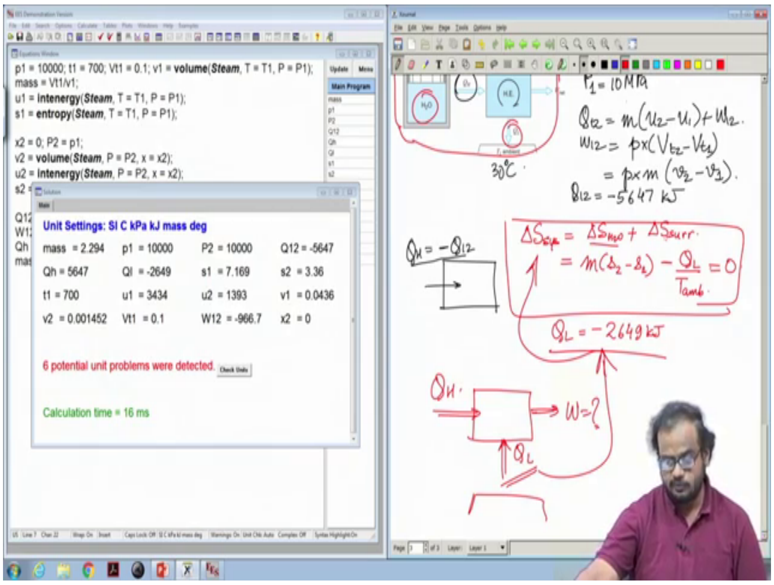

So, Ql as per this equation is minus 2649 kilo Joule. So, this was the ambient, if the ambient is absorbing and amount of heat Ql, then the surrounding is losing an amount of it minus Ql. So, this is that Ql over here. So, this is the heat, this Ql is the heat going into the system, because Ql is negative it means that this sign this arrow is actually correct anyway, this is the sign convention that we have used to evaluate this part.

So, evaluate this particular equation. This as we have discussed several times in the previous problems this is the delta s of the total system. When Ql is positive more over Qh is like this. So, then what is W?

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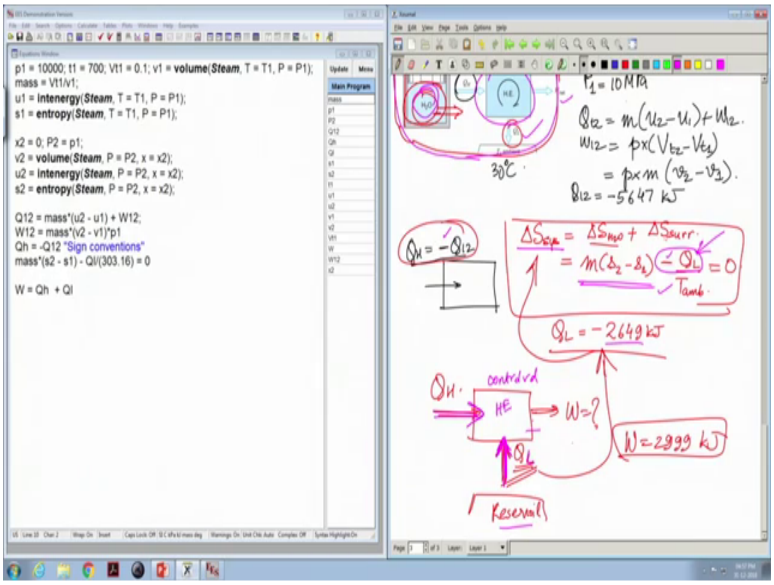

So, as per the sign convention Qh and Ql are both positive and W will then simply be Qh plus Ql.

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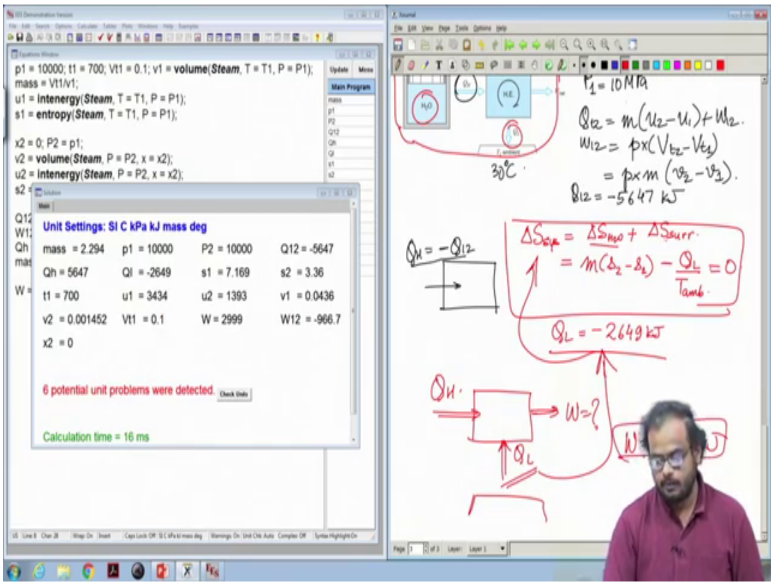

So, W comes out to be 2999 kilo Joule, that is the answer. So, in this; so, in both of the problems that we discussed a moments a few moments ago in this particular problem, one has to be very careful about what control mass what control volume we are choosing. For one control volume if the heat absorbed is positive; then obviously, for the other control volume it is losing that amount of heat maybe. So, in this particular case this control mass was losing an amount of heat Qh.

But that amount of heat lost is gained by the heat engine; hence we had this particular equation ok. Then if for this entire control volume we had some amount of heat entering into the control volume Ql, then the reservoir is actually losing an amount of heat. So, the reservoir has a heat transfer of minus Ql, which is appearing in the entropy equation. So, minus Ql by T ambient is the deltas for the surrounding, this is the entropy change for the system m into s 2 minus s 1.

So, combining this, we have delta s of the system which is 0, because the overall process is set to be reversible there is no entropy generation in the entire process. The entire process is free of any entropy generation; and hence we could find out, what this final heat transfer should be? See, because in this particular control volume the only interactions are heat and work. This thing is internal and hence it does not figure, whatever is there inside the control volume is only water it is changing state from 1 to 2.

So, the change in entropy of water is known because, entropy is a state property we do not need to bother how that water went it is a constant pressure process, we do not need to really bother about that. As soon as I know states 1 and 2 I know what the change in the entropy of the water is. Now, because there is a heat transfer heat interaction with the ambient, this particular this particular sign means, if the system is absorbing an amount of heat Ql. Then the reservoir is losing an amount of it minus Q1.

Hence it comes over here that gave us Ql and once that is known I can now take only this thing as the control volume the heat engine. So, for the heat engine you have Qh going into the system which is basically minus of Q1, because of the reasons we just discussed that, heat lost by the mass is heat gained by the heat engine. So, because of this Qh is like this Ql we just found out using the sign convention as like this minus 2649 and this if we consider the heat engine as the control volume, the work is nothing but Qh plus Ql and that is what we did. Please do this problem on your own try to understand which control volume is to analyze here we analyzed H2O first, the whole system of the surrounding second and then the heat engine third.

Using this we were able to find out the work output of this particular heat engine this is the work done by the system, because as per convention work is coming out of this control volume ok, work is coming out of this control volume. So, with this we stop here we conclude this particular example and I hope you will go through similar problems and try to have an intuition of which control mass, control volume to take to solve the various problem.

It is all very conceptual there is nothing fantastical about this the problem has to be first conceptualize and then you can just fix the values it does not matter how you fix the values you can use a table you can use a computer. The computer is very convenient, because you do not have to interpolate, you do not have to think about what the values will be. So, with this we conclude this session and I will be back next time with another question.

Thank you.