**Concepts of Thermodynamics**
**Prof. Suman Chakraborty**
**Department of Mechanical Engineering**
**Indian Institute of Technology, Kharagpur**

**Lecture - 43**
**Entropy Change in Closed System: Examples**

In our previous lectures, we have we have discussed about 2nd law and Entropy. And it is I think a very appropriate time that we start solving some problems on entropy of course, by first considering a control mass system. So, we will start with the problems in entropy, the first problem that is going to be displayed in the slide.

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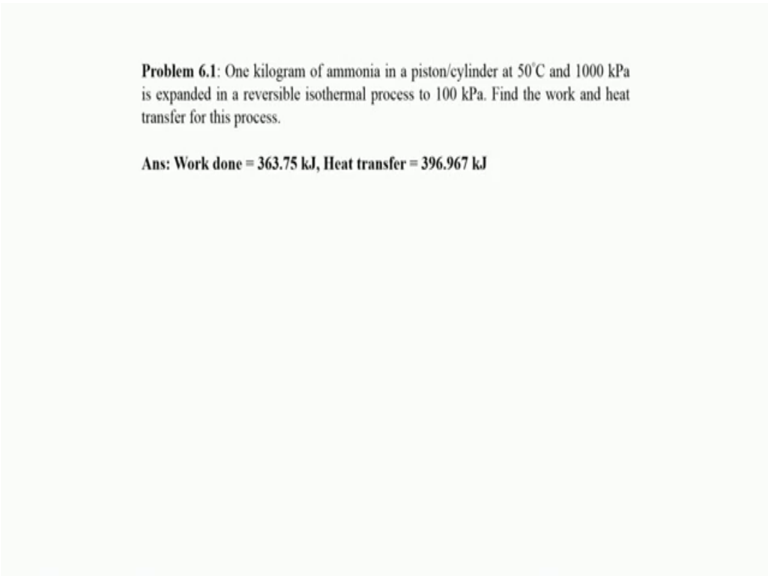


So, you can refer to this problem 6.1. So, 1 kilogram of ammonia in a piston cylinder at 50 degree centigrade 1000 kilo Pascal is expanded in a reversible isothermal process to 100 kilo Pascal. Find the work done and the heat transferred during the process. So, this problem appears to be very simple, but I will show you where you know the novice students fall in trap in solving this kind of problem. So, let me go to the board and try to solve this.

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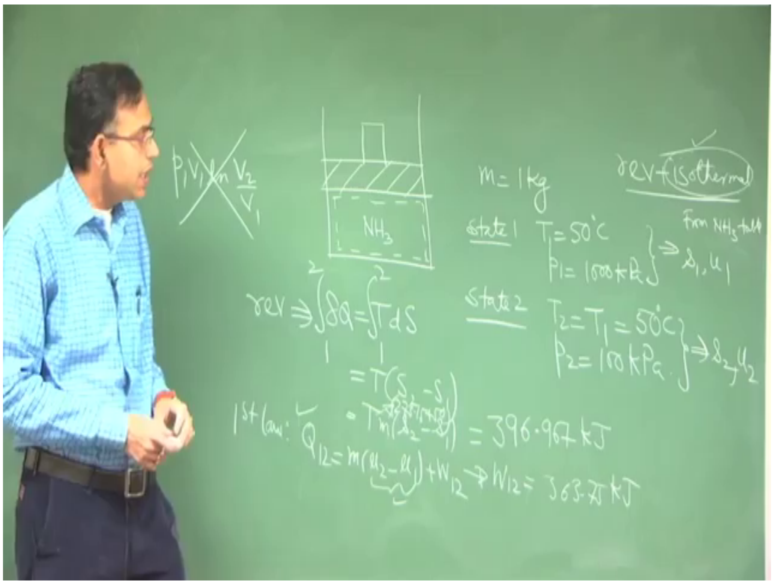


So, there is a piston cylinder arrangement. So, the system is ammonia, mass is 1 kg this is at 50 degree centigrade and 1000 kilo Pascal. So, state 1, T 1 is equal to 50 degree centigrade, p 1 is equal to 1000 kilo Pascal, it is expanded in a reversible isothermal process.

So, T 2 is equal to T 1 is equal to 50 degree centigrade and p 2 is 100 kilo Pascal; find the work done and the heat transfer. So, I will solve the problem in the intuitive way, the way in which it should be done and then I will tell you that where do students make mistake in solving this problem.

So, what is given about the process from 1 to 2 that is it is reversible plus isothermal; when it is reversible you can use del Q equal to TdS. So, the total heat transfer from 1 to 2 is integral of TdS and here temperature remains constant during. So, this is T into S 2 minus s 1.

So, this is T into m into s 2 minus s 1. So, how do you know s 2 and s 1? From ammonia table; so, the substance is ammonia. So, from, so, you will knows 1, you will require other things also from ammonia table and this will give you what is s 2; m is 1 kg and T is. So, when you write it is here it is 273.15 plus 50.

Any expression that has evolved from the 2nd law the temperature as to be put in the absolute scale, because the absolute scale has its basis or genesis in the 2nd law itself.

So, then if you substitute these values you will get the heat transfer. So, I am giving you the answer. The heat transfer is 396.967 kilo Joule. How do you get the work done? Now you apply the 1st law.

So, this heat transfer you already know; internal energy from table. So, not just s 1 you also require u 1. So, these are from table. So, this will give you what is w 1 2. So, w 1 2 is equal to 363.75 kilo Joule ok.

Now, I mean I have some experience of teaching thermodynamics over the years and I have tested several times by giving the students this problem to solve and once this problem is given to the students their eyes light up because this appears to be such an easy problem, everybody wants to solve it immediately. And the answer that the students write is p 1 v 1 l n v 2 by v 1 is the work. Why?

Like the keyword isothermal; for an isothermal process from school they have learned this formula that integral p d v for an isothermal process this will give you p 1 v 1 l n v 2 by v 1. So, they will do that and this is completely wrong here. The reason is that formula that is learned from school level for an isothermal process is for an ideal gas and here this is I mean nobody has told that this is an ideal gas.

So, first you calculate the heat transfer then you calculate the work done and you can clearly check that this is not equal to p 1 v 1 l n v 2 by v 1. You have clear data of v 2 v 1 p 1 v 1 from the table and you can check that is not happening. So, these are you know very simple traps where students can fall and you have to be very careful and judicious before using a formula that whether that formula is appropriate for that kind of a situation.

Student: Sir, we could as per use integral p d v (Refer Time: 07:52)?

You could use integral p d v, but integral p d v is not a problem, but how do you know the path; p v is not equal to constant. This is an isothermal process, but all isothermal processes will not have p v equal to constant. So, integral p d v you use, but integral p d v in this case will not boil down to p 1 v 1 l n v 2 by v 1 because p v is not constant. So, I will erase the board before solving the next problem.

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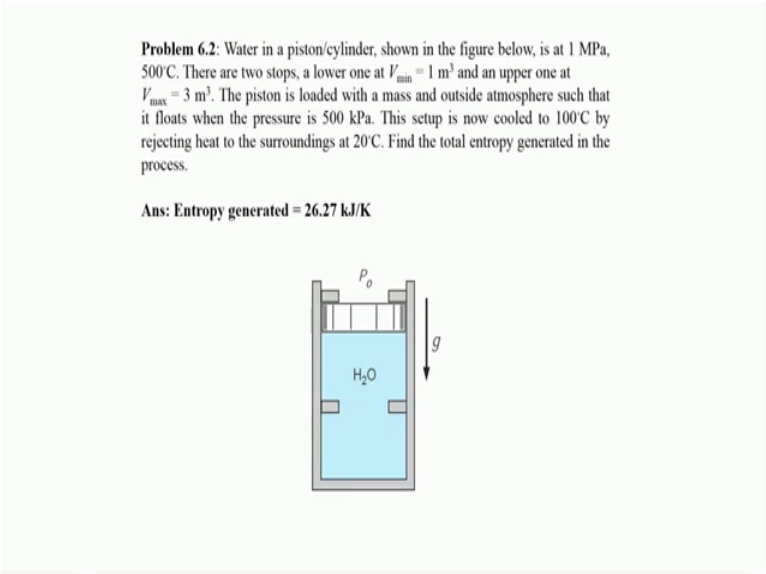


So, problem number 6.2; water in a piston cylinder shown in the figure which is below the statement is at 1 mega Pascal 500 degree centigrade. There are two stops, a lower one with V minimum as 1 meter cube and upper one with V maximum 3 meter cube. The piston is loaded with a mass and outside atmosphere such that it floats when the pressure is 500 kilo Pascal. So, all these full statement is given just to make sure that when the piston moves in a quasi equilibrium process, the pressure that is resisting is same as 500 kilo Pascal. The setup is now cooled to 100 degree centigrade by rejecting heat to the surroundings at 20 degree centigrade. Find the total entropy generated in the process.

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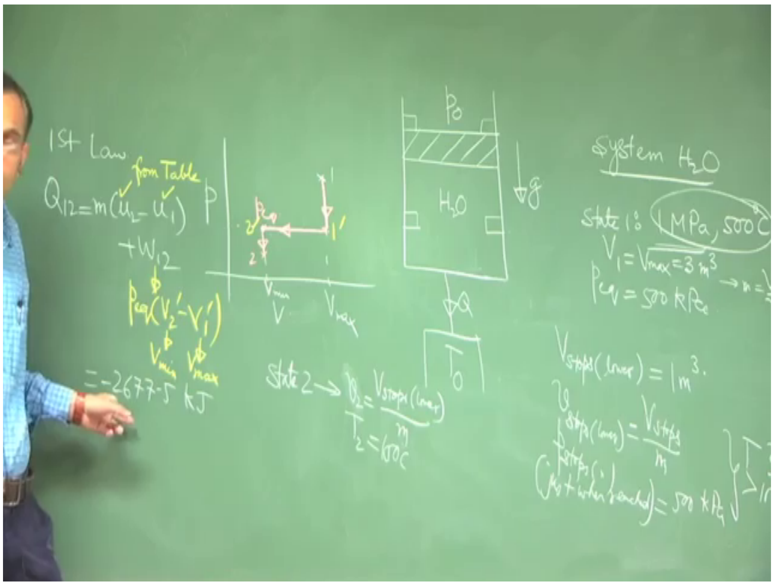

So, to work out this problem we will go to the board and draw the schematic. There is water, this is the gravity direction. So, the system is water state 1: 1 MPa 500 degree centigrade ok. So, then what is physically happening let us try to understand it. When heat is transferred from this to a thermal reservoir located may be here at temperature T 0 there is a heat transfer. So, when this heat transfer is taking place when heat is being lost what will happen? This piston will start coming down right because it loses energy, so, it will come down

So, in the process the question is that will it heat this stops because if it heats this stops then its volume cannot change further. So, let us check that. So, it says that the setup cools to 100 degree centigrade. So, let us try to draw p v diagram, it starts with state 1. At state 1 the pressure is 1 mega Pascal, but it starts moving. When does it start moving?

It starts moving when the equilibrium pressure is 500 kilo Pascal. So, till the pressure becomes 500 kilo Pascal this will not start moving. So, as heat is rejected from this, the pressure inside will drop and when the pressure drops from 1 ampere to 500 kPa till that time the volume remains constant, the piston does not move.

So, this is your V max. In this V max state it remains like this. Then when the pressure has become 500 kilo Pascal that is p equilibrium then it starts moving. When it starts moving, it will move with this equilibrium pressure because the resistance pressure does not change, the internal pressure also will not change during the quasi equilibrium process.

Question is does it heat the stop because if it heats the stops then its volume cannot change further. So, when it reach the stops, what is its volume? Lower. So, that volume is given. The volume given here is what? 1 meter cube. By the way how do you know what is the mass of water in the in this cylinder?

So, state 1 also has V 1. So, V 1 is V max which is 3 meter cube. So, you can find out the specific volume of these from table. So, the mass which does not change during this process is volume by V 1 by specific volume at state 1. So, V is stops you know. So, what is specific volume at stops lower is equal to V stops by m.

What is the pressure? Just as it you know just when reached is equal to 500 kilo Pascal. With this combination you see what is the temperature, is it greater than 100 degree centigrade or less than 100 degree centigrade because your final temperature is 100 degree centigrade.

So, check with these what is T? It will come out to be greater than 100 degree centigrade for this problem if you work out. So, see that is why thermodynamics is such an interesting subject. Had it come to 100 or less than 100 degree centigrade the process would stop may be even before this less than 100 degree centigrade; I mean if this is less than 100 degree centigrade.

So, whether the process will continue up to this lower stop and continue further that depends on what numerical value you are getting from this answer. So, there is no formula by which you can solve this problem, you have to assess the numerical value and based on that take a decision. Here the temperature is 100 degrees greater than the 100 degree centigrade when it reaches the V minimum.

So, this is your V minimum. So, when it reaches V minimum its temperature is greater than 100 degree centigrade. As per given data of the problem state 2 will be the temperature condition at which it becomes 100 degree centigrade. So, heat is now because it has already reached the lower stops it will reject heat now at constant volume till the pressure comes down and also temperature comes down. So, the state 2 is somewhere here. So, how do you identify state 2? State 2 is you have v 2 is equal to V stops lower by m and T 2 is 100 degree centigrade. These two property values will identify state 2 ok.

So, identifying the state point is all about solving the problem then it is a matter of using the 1st law and 2nd law. So, 1st law; so, the structure of this problems is to calculate entropy generation you require what? Heat transfer. To calculate heat transfer you require 1st law. So, to solve these problems you require combination of 1st law and 2nd law.

So, 1st law Q 12 ok; so, u 2 and u 1 you get from table. And work done what is that? So, let us say this is 1 prime this is 2 prime. Work done is integral p d v between 1 prime to 2 prime. So, this is nothing but p equilibrium into V 2 prime minus V 1 prime.

So, this is V minimum, this is V maximum. So, we will get the heat transfer. Let me see if I have the value? Heat transfer is minus 2677.5 kilo Joule. As I have told you earlier that it is absolutely important to make sure that you have got its sign physically consistent.

Here heat is rejected, so, heat transfer should come out to be negative. If it does not come out to be negative, you must get the first alarm that your solution is not correct and then please revisit the calculations. These are commonsense checks that you can make to make sure that the solution that you are doing is you know consistent physically.

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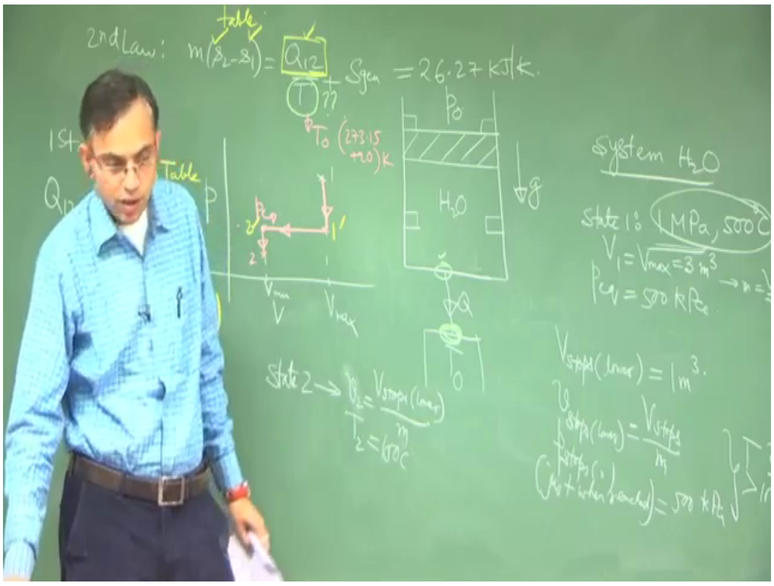


And then we will apply the 2nd law. So, m into s 2 minus s 1 is equal to Q 12 by T plus S gen right. Now the big question is, see everything we know; s 2 s 1 these are from table, heat transfer also we have calculated from 1st law. The big question and I will discuss a little bit about that is what is this T?

Well, this is the very important question. It depends on what you want to find out. You want to find out entropy generation only due to internal irreversibility. If you want to find out entropy generation only due to internal irreversibility that T is the temperature at the system boundary. If you want to find out net entropy generation in the system and surrounding together as a universe then your system boundary shifts from here to here because then that includes this heat transfer also.

So, here what is asked is find the total entropy generated in the process. Total entropy generated in the process means not just due to internal irreversibility that entropy generated due to internally irreversibility plus entropy generated due to the external heat transfer and that is why you have to substitute here T equal to T 0 and that also in Kelvin. So, what temperature you substitute here depends on entropy generation for what you are calculating ok. So, this is 273.15 plus 20 Kelvin and then the final answer to this is 26.27 kilo Joule per Kelvin ok.

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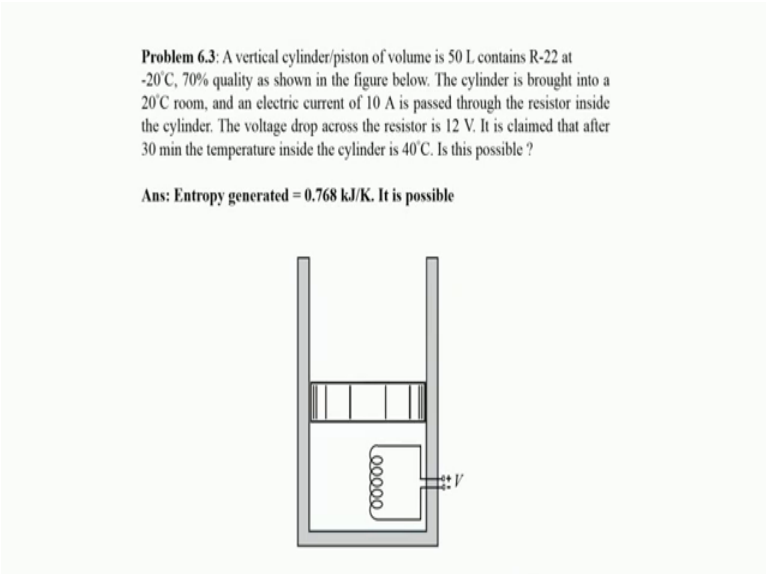


So, we will continue with the problem solving, let us let me erase the board for this problem. So, problem 6.3; there is a vertical cylinder piston of volume 50 liter, it contains R 22; R 22 is a refrigerant, R for refrigerant at minus 20 degree centigrade 70 percent quality. The cylinder is brought into a 20 degree centigrade room and then electric current of 10 ampere is passed through the resistor inside the cylinder.

The volt the voltage drop across the resistor is 12 volt. It is claimed that after 30 minutes the temperature inside the cylinder is 40 degree centigrade. Is it possible? So, to assess whether it is possible or not we have to check whether it satisfies the 2nd law; that means, entropy generation whether it is positive or not. If entropy generation somehow comes out to be negative then that means such a process cannot be feasible.

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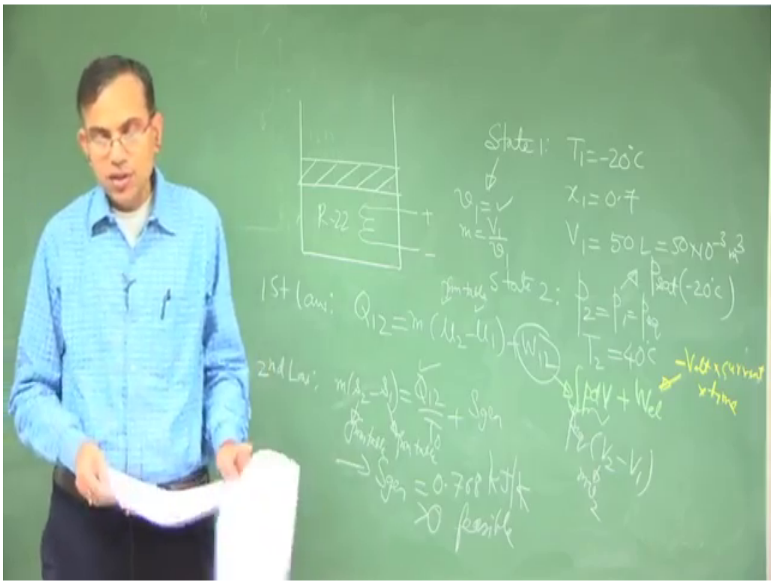


So, let me go to the board, draw the schematic and solve this problem. So, the fluid is R22. State 1: T 1 is minus 20 degree centigrade, x 1 is 0.7, V 1 is 50 liter that is 50 into 10 to the power minus 3 meter cube. State 2; see this piston it moves it floats freely right, so, it is moving in a quasi equilibrium process without any change in the external resistance.

So, p 2 is equal to p 1 is equal to p equilibrium. So, p 1 you can p 1 is what? Because this is in the 2 phase region, p 1 is saturation pressure at minus 20 degree centigrade, this is p 2 and T 2 is 40 degree centigrade; this is the claim.

So, let us find out the entropy generation. Again it is a 2 step process. First we will calculate the heat transfer using the 1st law and using that heat transfer we will calculate the entropy generation. See this is a very important understanding, entropy generation is not associated with work done, but it is associated with heat transfer and entropy generation essentially talks about lost opportunity of doing work.

So, work is considered to be a high grade energy, high grade form of energy where there is no dissipation due to entropy generation, but heat transfer always will have a lost opportunity of work associated with that and that therefore, leads to entropy generation.

So, then let us apply the 1st law. How do you calculate the mass? So, you calculate the mass by noting that you have total volume V 1. So, from state 1 property table you know what is specific volume, so, mass is this one; u 2 and u 1 also from table. The key to this problem solving is the expression for work done. So, here you also have an electrical work because of the flow of current against a voltage.

So, it is also like a displacement against a resistance. So, here this will be integral p d v plus W electrical. What is this W electrical? The electrical work is minus voltage into current into time. Why minus? Because you are inputting some energy to the system by creating a current across this voltage.

So, if energy is supplied in the form of work to the system, it is negative work. If energy comes out of the system due to work that is positive work, so, that is why negative. Volt into current is the power, the power into time is the total energy right. So, voltage etcetera voltage current all those things are given 12 volt, 10 ampere and 30 minute should be converted into second.

So, integral p d v is p equilibrium into V 2 minus V 1; V 2 is mass into specific volume at state 2, specific volume at state 2 from table. So, then you can calculate what is heat transfer. I do not have the value of the you know the expression, but you can always calculate it numerically then the only step is 2nd law.

So, m into s 2 minus s 1; I am straight away writing T 0 because if you want to calculate the total entropy generation due to heat transfer plus internal process then T has to be T 0. And here also T 0 just a like the previous problem it is 20 degree centigrade that is 273.15 plus 20 Kelvin. So, all these can be substituted, this is from table, this is from table. So, from here you can find out what is entropy generation.

And the entropy generation is 0.768 kilo Joule per Kelvin right. This is lowercase k for kilo; this is uppercase K for Kelvin; this things you have to be little bit particular. So, because entropy generation for the net process is greater than 0, this is definitely feasible. At least the claim cannot be ruled out that after 30 minutes, the temperature inside the cylinder is 40 degree centigrade that heating is a feasible heating.

So, we have solved 3 problems on entropy today, we will continue with more problem solving in the next lecture.

Thank you very much.