Concepts of Thermodynamics
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Lecture – 16
First Law For A Control Mass System: Representative Examples

We have discussed about the First Law of Thermodynamics for a Control Mass System and we will try to work out a few problems to illustrate that.

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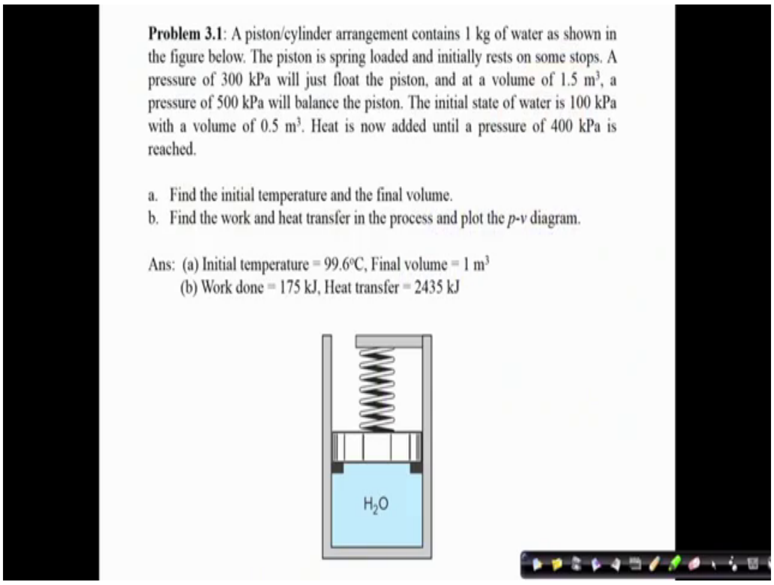

So, the first problem is given here in the screen a piston cylinder arrangement contains 1 kg of water as shown in the figure below. So, the piston is spring loaded and it initially rests on some stops, a pressure of 300 kilo Pascal will just float the piston and a volume of 1.5 at a volume of 1.5 meter cube a pressure of 500 kPa will balance the piston.

The initial state of water is 100 kPa with a volume of 0.5 meter cube. Heat is now added until a pressure of 400 kPa is reached. Find the initial temperature final volume work done and heat transfer and plot the pv diagram. So, as we have done for the previous problems we will do it in the same way we will sketch the setup in the board.

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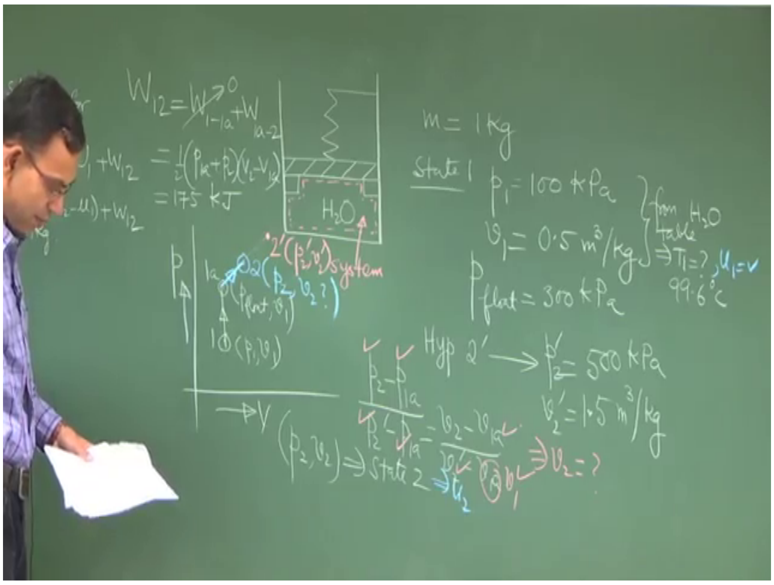

There are stops here and you have water, you have m is equal to 1 kg state 1 p 1 is equal to 100 kilo Pascal v 1 is equal to 0.5 meter cube per kg, p float that is the pressure at which the piston will start floating is 300 kilo Pascal. And a hypothetical point say 2 prime is a point where you have pressure equal to 500 kilo Pascal and volume is equal to this ok.

The final state is not this the final state is 400 kilo Pascal pressure not 500 kilo Pascal pressure. So, we have to find out the initial temperature final volume and work done and heat transfer. So, before doing anything we will just try to draw a pv diagram or the process, in this case in the problem anyway it is asked, but even if it is not asked it is a good practice wherever work done is involved, we will try to draw the PV diagram.

So, state 1; so, what is the substance? The substance is water this is the system. So, from if you know what is p 1 and what is v 1 from table from water table property table, you can find out what is T 1. So, this is 99.6 degree centigrade. So, we can plot the state point 1.

Now, heat is transferred to the system; once heat is transferred to the system this will be energized, but still the piston will not start moving, it will start moving when the pressure gets build up from 100 kilo Pascal to 300 kilo Pascal. So, with heat transfer at constant volume the pressure gets build up from 100 kilo Pascal to 300 kilo Pascal. So, that constant volume process say is up to this.

So, this is p 1 comma v 1 this is p float comma v 1, then from 1 a it will move in a cos equilibrium process, but the resistance pressure will be linear with x, because it is encountering a linear spring. So, the spring constant is not given, but an additional hypothetical point 2 prime is given which will help you to construct the state line along which pressure and volume will vary that is the purpose of giving this data point.

So, this is your state point 2 will lie somewhere in between these two one the state line. So, where will the state point 2 lie; it will lie at a point where the pressure is 500. So, you see here this pressure is 300 sorry this is 500 state point 2 the final pressure what is given final pressure is 400.

So, state point 2 this is 300 this is 500 will be somewhere exactly at the middle, where the pressure is 400. So, this is 2 so the it is the question is the p 2 comma what is this v 2 ok. So, the process ends here at 2 2 2 2 prime this is a hypothetical thing this is just to construct the diagram. So, you can write p 2 minus p 1 a by p 2 prime minus p 1 a is v 2 minus v 1 a by v 2 prime minus v 1 a right.

So, out of these let us see who what are known and what are not known. So, you have v 1 a which is same as v 1 this is known v 2 prime is known v 1 a is known here p 2 is known p 1 a is known v p 2 prime is known and p 1 a is known. So, from here you can find out what is v 2 ok.

So, p 2 and v 2 combination will identify the state point 2. So, p 2 comma v 2 will identify the state point 2. So, from the table of water by using this pressure and volume combination, you can identify what is the state point 2. Once you have identified what is the state point 2 see thermodynamics most of the problems essentially boils down to identification of the state points, because once you have identified the state points you can substitute the corresponding properties in a relevant laws expression of the relevant laws of thermodynamics.

So, in this case what is asked let us see find the work done and heat transfer. So, work done 1 to 1 a the work done is 0 1 to 2 1 a to 2 is half into p 1 a plus p 2 into v 2 minus v 1 a. So, here because the mass is 1 kg total volume and specific volume will be the same ok. So, if you now substitute these values this is 175 kilo joules ok.

Now, in addition what you need to calculate is what is the heat transfer? So, let us calculate the heat transfer here, 1st law for the system for the system by system we mean the controlled mass system here so, this is m into u 2 minus u 1 plus w 1 so, m is 1 kg how do you get u 2 and u 1 so from the table. So, this is the additional thing that you have to do when you are solving for the 1st law problem for the heat transfer.

So, from table you get T 1 similarly you also get u 1. So, whatever table you are using if you are getting u 1 directly it is fine in some tables enthalpy is given and not u. So, you find u 1 is equal to h 1 minus p 1 v 1 ok. So, u 1 can be found out similarly from state 2 u 2 can be found out. So, you can substitute u 2 minus u 1 here and this will be 2 4 3 5 kilo joule.

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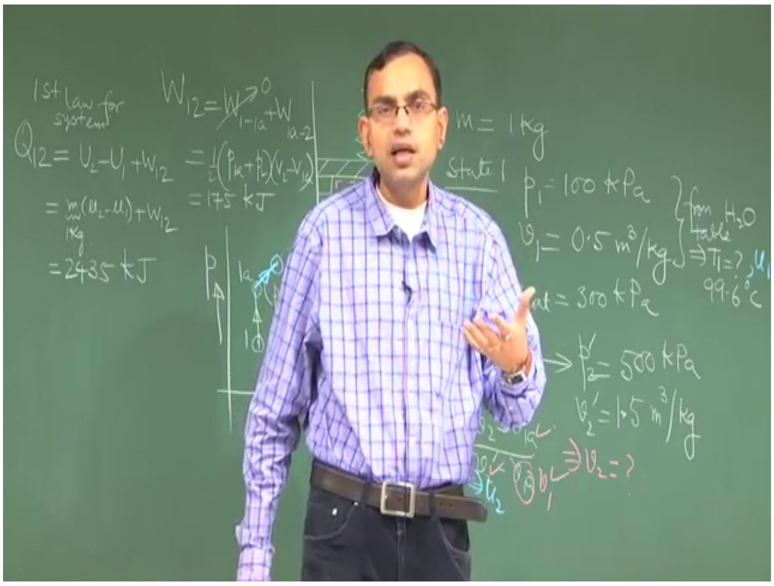

Student: Sir I think we must directly the state point is in the 2 phase region (Refer Time: 13:08).

So, here there is an important question that if what happens if the state point is in the 2 phase region right. So, if the state point is in the 2 phase region the first of all if the state point is in the 2 phase region for state point 2 how do you calculate the internal energy. So, how do you ascertain whether this is in a 2 phase region or not see at this given pressure what is v g and v f? If the v 2 is in between v f and v g, then it is in the 2 phase region ok.

So, if it is in the 2 phase region then you can find out what is the quality x by equating v 2 is equal to 1 minus x into v f plus x v g so, from that you can find out what is x. Once you find out what is x then u 2 will be very similar formula 1 minus x into u f plus x into u g. So, if it is in the 1 phase region you can appropriately calculate the property see property calculation is not the focus of this chapter. The focus of this chapter is how you can apply the first law of thermodynamics to find out the heat transfer for a given process that is the major objective of solving these problems, but I would like to say that using these problems try to familiarize yourself more and more in identifying the state points from the property table.

See the problems that we are solving in the board are done in a little bit of an abstract manner; that means, exactly I am not focusing on where the state point is I am just giving you the concept that if you know this two you can identify the state point. Now, how to identify that state point? We have earlier solved several problems on finding out how to identify state points. In fact, in the very beginning of like how to read thermodynamic tables I worked out one problem with the sole objective of identifying the state points.

So, using that as a template problem try to identify the state point properly, because if you cannot identify the state point properly you cannot get this numerical answers right, I mean this the conceptual way of solving the problem illustrating that is my job as a teacher, but your job as a student is to go through all the details. So, all this details I also went through when I was a student, there is no not enough time in the class in the lecture to actually let you go through the details of the tables and find out the data and substitute the data here.

So, here the problem solution outline is conceptual, from this conceptual to the detailing please take this as a serious job. Because, if you cannot do that just giving the concept will not allow you to get the proper answer in a thermodynamics problem and that must be taken very seriously because for a practical subject, you know it is not just the concept of solving the problem that is important, but the very act of solving the problem that is also equally important. So, we will work out one more problem before we stop for this particular lecture.

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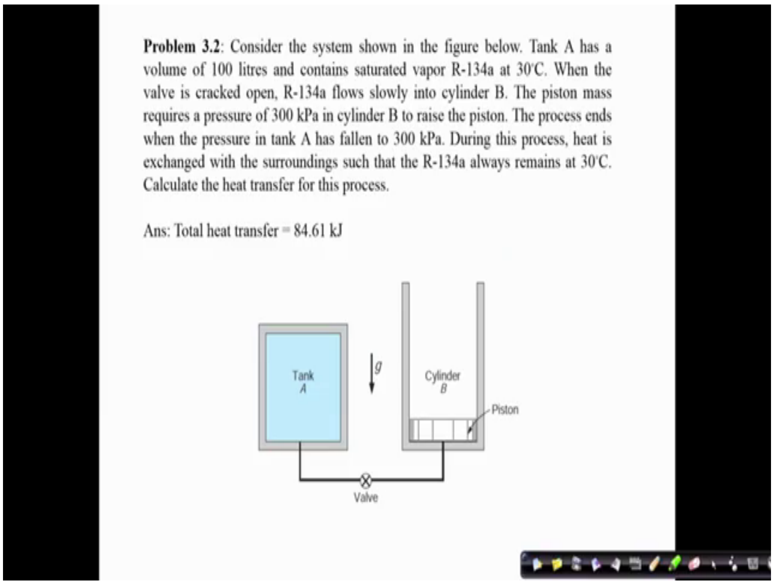

So, the next problem is problem 3.2. So, consider the system as shown in the figure below, tank A has a volume of 100 liters and contains saturated vapor R 134 a at 30 degree centigrade, there is a valve that connects tank A with cylinder B, when the valve is cracked open R 134 a flows slowly into the cylinder B.

The piston mass requires a pressure of 300 kilo Pascal in the cylinder B to raise the piston. The process ends when the pressure in the tank A has fallen to 300 kilo Pascal, during this process heat is exchanged with the surroundings. So, that R 134 a always remains at 30 degree centigrade. Calculate the heat transfer for the process. This is a very interesting problem and let me solve this problem and give you a certain interesting insights about this problem.

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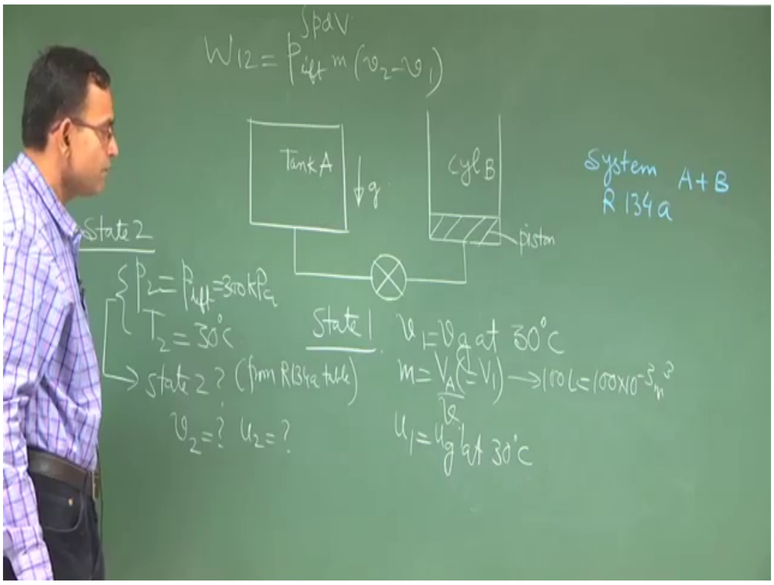

So, there is a tank A this is the direction of gravity the system is R 134 a. Now, first can you tell me what is the control mass system here, the substance in tank A or the substance in tank in cylinder B which one of these?

See first you have to ascertain what is the system here, if you say it is in tank A then I will put an argument that then it is not a control mass system, because when this valve is opened the mass is leaking from tank A to cylinder B. Therefore, the mass of A is not fixed. Similarly, if you say it is cylinder B I will also argue that is not correct, because the mass of the R 134 a in cylinder B is continuously changing. So, it is not individually A or individually B it is A plus B. So, where the total mass remains conserved.

So, then for this A plus B our problem needs to be solved if we want to apply the first law for a control mass system. So, state 1 it contains saturated vapor at 30 degree centigrade so, v 1 is v g at 30 degree centigrade, what is the mass of this system A plus B the volume of tank A initially that is the V 1 divided by mass the volume of tank the volume of R 134 in tank A.

Student: (Refer Time: 21:47).

Yes this volume is 100 liter and this specific volume is v g at 30 degree centigrade that you get from the table. So, this is what you get as the mass. So, this mass will be required for your calculations so, this is state 1 state; 2 so, at state 1 what is so you may also require internal energy this is u g at 30 degree centigrade, because if you require to calculate heat transfer you will require internal energy. State 2 what is p 2?

So, let me read the statement the process ends when pressure in tank A has fallen to 300 kilo Pascal and at the same time the piston mass requires 300 kilo Pascal to raise this. So, finally, the equilibrium pressure is everywhere in the system pressure is 300 kilo Pascal.

So, p 2 is same as p lift this is 300 kilo Pascal, until and unless he pressure here is same as the pressure here, mechanical equilibrium will not be achieved the process will continue. So, process has to you know sees only when the system has come to an equilibrium stage with the pressure everywhere as 300 kilo Pascal. And during the process heat is exchanged so, that temperature remains 30 degree centigrade so, T 2 is 30 degree centigrade.

So, using this you can identify what is state 2, if you can identify what is state 2 from the table then from here you can find out what is v 2 and what is u 2. So, what is the work done this is simply p lift so, this is integral p dV so the because the pressure resistance pressure is same as this p lift, this is p lift into m into v 2 minus v 1 that is the change in volume.

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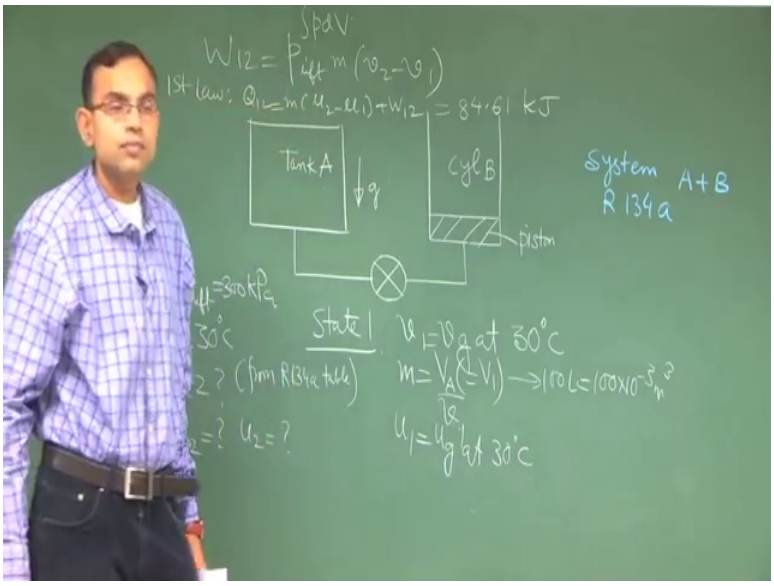

And the 1st law will give you what is the heat transfer. So, the total heat transfer is for this problem is 84.61 kilo joule. So, with this we conclude our discussions for this lecture and we will continue with more problem solving in the next lecture.

Thank you.