Concepts of Thermodynamics
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Lecture – 18
First Law for A Control Mass System: Representative Examples (Contd)

We have been working out problems related to the First Law of Thermodynamics, applied to Control Mass Systems and we will continue with the problem solving exercise.

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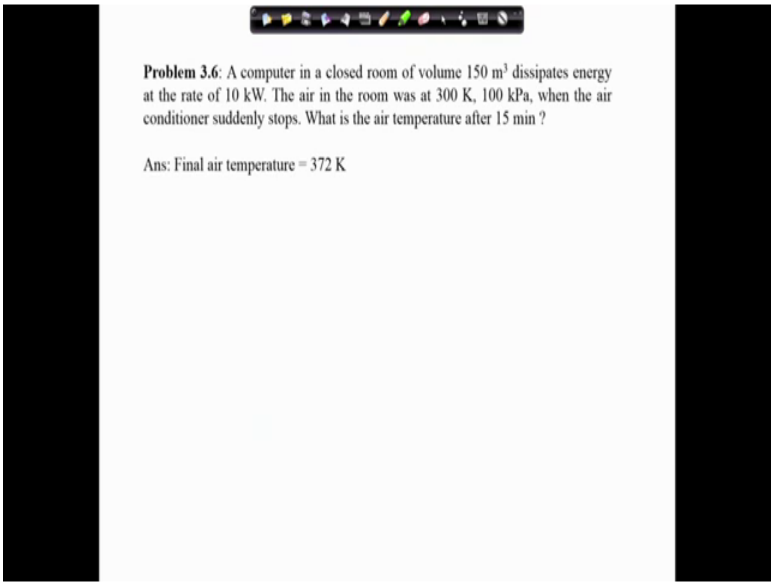

Let us look into the problem 3.6; a computer in a closed room of volume 150 meter cube dissipates energy at the rate of 10 kilowatt. The air in the room was at 300 Kelvin, 100 kilo Pascal when the air conditioner suddenly stops, what is the temperature after 15 minutes?

So, this is a typical situation when the computer is in a Ac room and suddenly the Ac stops working. So, the room will start getting heated, because of heat dissipation from the computer. So, after 15 minutes, what will be the temperature? So, here the control volume so, you can make a schematic.

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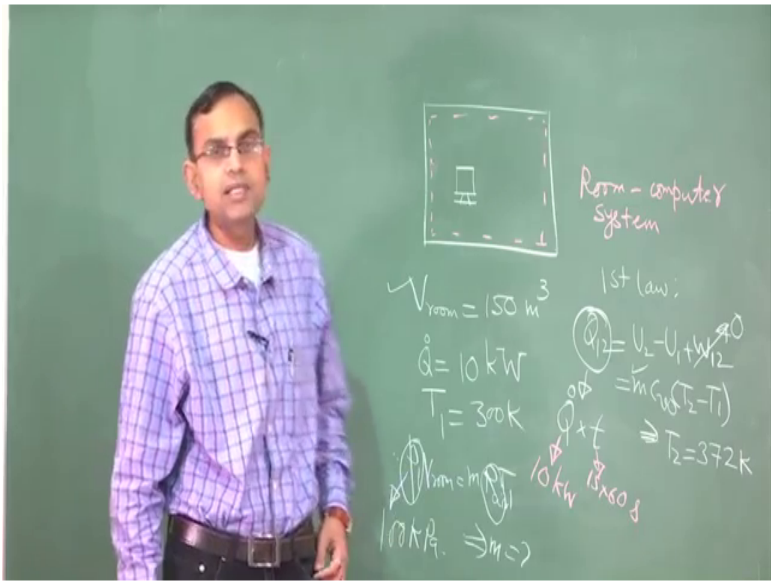

So, you have a computer like this, your control mass system is this region, so the region minus the computer. So, room minus computer is the system. So, here is the computer, room minus computer is the system. So, let us apply the 1st law of thermodynamics for this system. So, what is given, V room T 1 is 300 Kelvin and pressure is 100 kilo Pascal, it shows that it is reasonably low pressure. So, air can be treated as an ideal gas without much of a problem.

So, Q 1 2 the 1st law if you apply; so, here there is no work done and this Q 1 2 is the heat dissipation rate of the computer times the time. So, heat dissipation rate of the computer is given as 10 kilowatt and the time is 15 into 60 seconds.

So, U 2 minus U 1, if we treat air as a calorically perfect gas, then this is mCv into T 2 minus T 1. So, what is mass? The volume of the room is given and what is P 1? P 1 is 100 kilo Pascal R of air is 0.287 kilo joule per kg Kelvin and T 1 is 300 Kelvin. So, from here you will get what is m?

So, that n if you substitute here Cv of air you can calculate by noting Cp minus Cv is equal to R and gamma equal to Cp by Cv, which is roughly 1.44 air. So, from that you can calculate Cv and T 1 is 300 Kelvin. So, from here you can calculate, what is T 2? This is 372 Kelvin.

So, you can see that in a room, where computer is working, if the AC stops how quickly the room can get heated.

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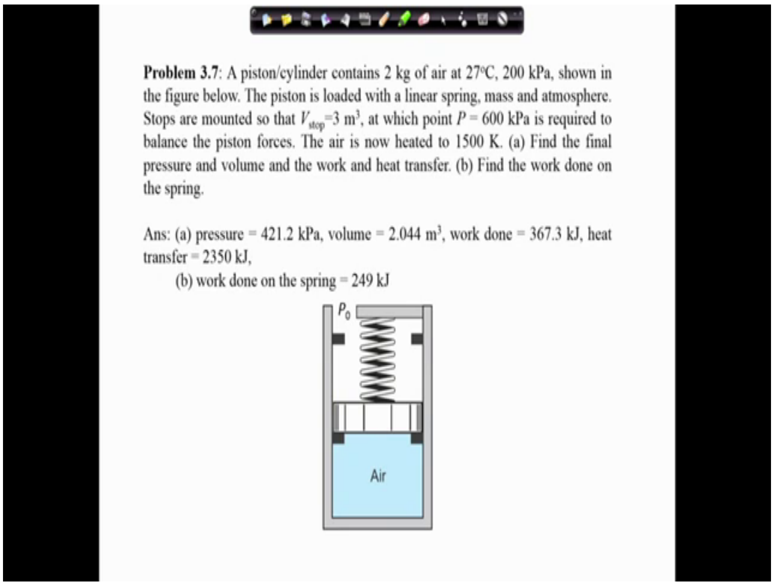

We will work out another problem, the next problem . A piston cylinder contains 2 kg of air at 27 degree centigrade, 200 kilo Pascal as shown in the figure. The piston is loaded with a linear spring mass and atmosphere. Stops amounted so that V stop is equal to 3 meter cube, at which point 600 kPa is required to balance the piston forces. The air is now heated to 1500 Kelvin. Find the final pressure volume and work done and heat transfer and work done on the spring ok.

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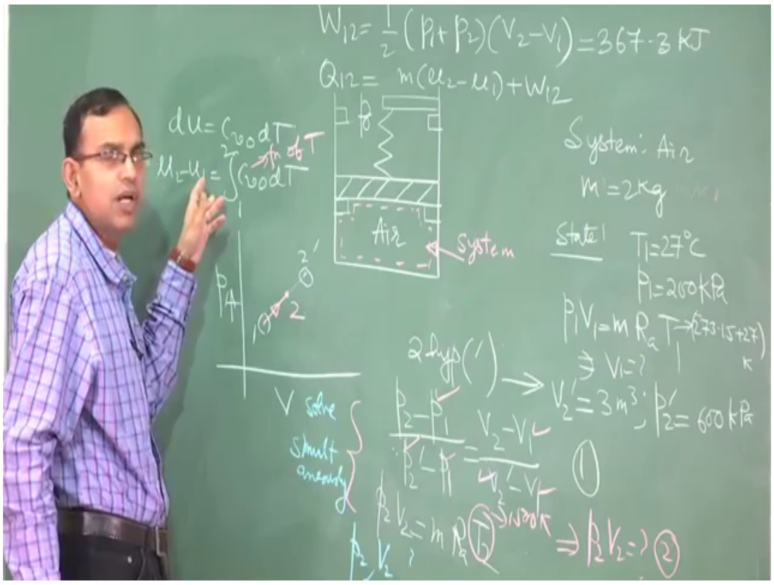

So, let us draw the schematic so, our system is this air, m is 2 kg state 1, T 1 is 27 degree centigrade p 1 is 200 kilo Pascal. So, you can find out what is the volume at state 1 p 1 V 1 is equal to m R air into T 1. This is 27 plus 273.15, this has to be in Kelvin.

So, you will get what is V 1? So, completely specify state 1. Another hypothetical state is given that at V stop; that is 3 meter cube 600 kilo Pascal is required to balance the piston forces. So, 2 hypothetical dash; this is as we have seen earlier that such hypothetical states are given to construct the pV diagram, the locus of pressure versus volume data.

So, you have V 2 prime. So, let us draw the pV diagram. So, you start with state point 1, you end with state 0.2, but you, the locus of the pV state points between 1 and 2, is guided by this linear spring and the state 0.2 prime is located on this. The actual state 0.2, is somewhere in between these 2.

So, in means it could be on the other side or this side that we do not know, but it is we know that it is located on one the straight line want to 2 prime. So, from the equation of the straight line we know. So, let us see what is known here, p 2 is not known. At state 2, only temperature is known which is 1500 Kelvin p 1 is known, p 2 prime is known and p 1 is known V 1 is known, V 2 prime is known.

So, you can write here p 2 as a function of V 2, but you do not know separately p 2 as function of V 2. So, this is equation number 1, but you have another equation connecting p 2 and V 2. What is that? You have p 2 V 2 is equal to mR T 2, this T 2 is this 1500 Kelvin. So, you have p 2 V 2, you know this is 2. So, you solve 1 and 2 simultaneously. There are two equations and two unknowns, which are p 2 and V 2.

So, you solve this simultaneously. So, you will get what is p 2 and what is V 2? So, once you get p 2 and V 2, you can identify state point 2. So, what is your work done, this is 367.3 kilo joule, heat transfer. Now, here is an important point, the point is that air is an ideal gas, I mean it, air can be approximated as an ideal gas under these conditions.

So, you can write du is equal to C v 0 dT. So, you 2 minus u 1 is integral of C v 0 dT and this Cv 0 is a function of T, it cannot be taken as a constant for this problem for the reason, why? It cannot be taken as a constant for this problem, because think of the temperature range, T 1 is 27 degree centigrade that is 300 around 300 Kelvin and T 2 is 1500 Kelvin. So, you can see, this is 1500 Kelvin.

So, from 300 to 1500 Kelvin this wide range of temperature is such that you cannot assume this Cv to be a constant. So, Cv as a function of temperature has to be known and once this is integrated between states 1 and 2 u 2 minus u 1 can be obtained for saving this label. This numerical integration values are tabulated in the form of a table called as air property table in any thermodynamic data book. So, you will see it in the appendix of any thermodynamics book that you are referring to.

So, once you do that once you refer to the air table you can calculate this u 2 minus u 1. So, the key to getting the correct answer is do not assume Cv as constant here, but look into the air table to calculate u 2 minus u 1.

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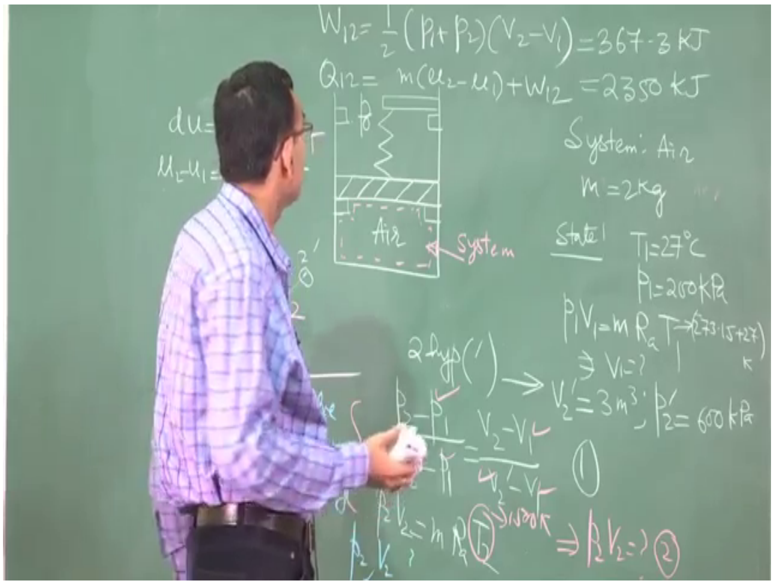

So, once you do that the net heat transfer is ok. So, we will work out perhaps one more problem before, we call it a day for this particular lecture. Let me erase the board first, before we look into the problem.

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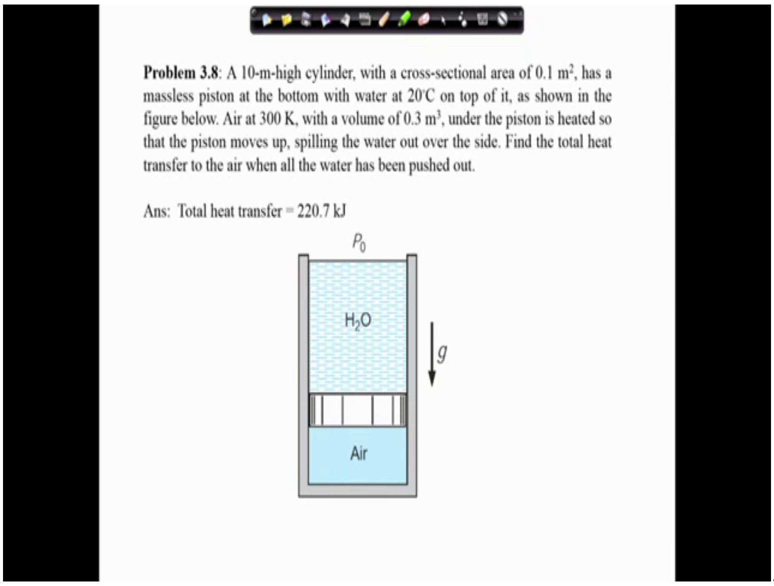

So, the problem is, problem 3.8. So, here you have a 10 meter high cylinder, with a cross sectional area of 0.1 meter square. It has a massless piston at the bottom with water at 20 degree centigrade on the top here, at 300 Kelvin with a volume of 0.3 meter cube and the piston is heated. So, that the piston moves up, spilling the water over water out over the side. Find the total heat transfer as all the water has been pushed out ok. So, let us draw a schematic of the problem.

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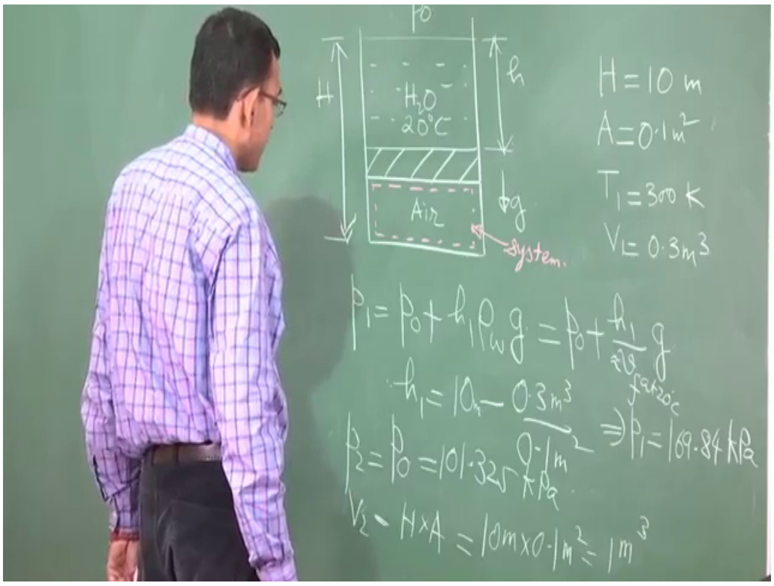

So, this h is a variable h as the water is filling, this height is decreasing. The gravity is in this direction. So, the height of the cylinder, let us call it capital H, out of which we neglect the small thing, because capital H is 10 meter. So, 10 meter out from 10 meter, this will be maybe at the most few centimeters that can be neglected, area of cross section is 0.1 meter square, this water is there at 20 degree centigrade.

Now, you tell me what will be the control mass system for this problem? Air, water, air plus water, what? See, water cannot be a control system here, because water is continuously spilling. So, because water is spilling, the mass of water is not remaining the same here, but air is trapped under the piston. So, although the piston is moving the air is remaining same in mass and identity.

So, this is the system ok. So, for this system we have T 1 as 300 Kelvin and V 1 as 0.3 meter cube. What is p 1? Atmospheric pressure plus pressure due to the water column, so h 1 rho water g, rho is 1 by specific volume. So, how do you estimate the specific volume? This is approximately vf at 20 degrees centigrade ok.

So, now what is this h 1? So, you have 10 meter high cylinder minus the height of the air. So, air has a volume of 0.3 meter cube and it has a cross sectional area of the cylinder has a cross sectional area of 0.1 meter square height of this one is 0.3 by, 0.3 by 0.1. So, h 1 is 10 meter minus that ok. So, if you calculate put all these data you will get p 1 as 169.84 kilo Pascal.

What is p 2? When state 2 is when all the water spill. So, p 2 is nothing, but p atmosphere, which is given for this problem as 101.325 kilo Pascal. What is V 2? V 2 is now, this entire volume is air, all water has gone so, it is H into A. So, this is 10 meter into 0.1 meter square so, that is 1 meter cube.

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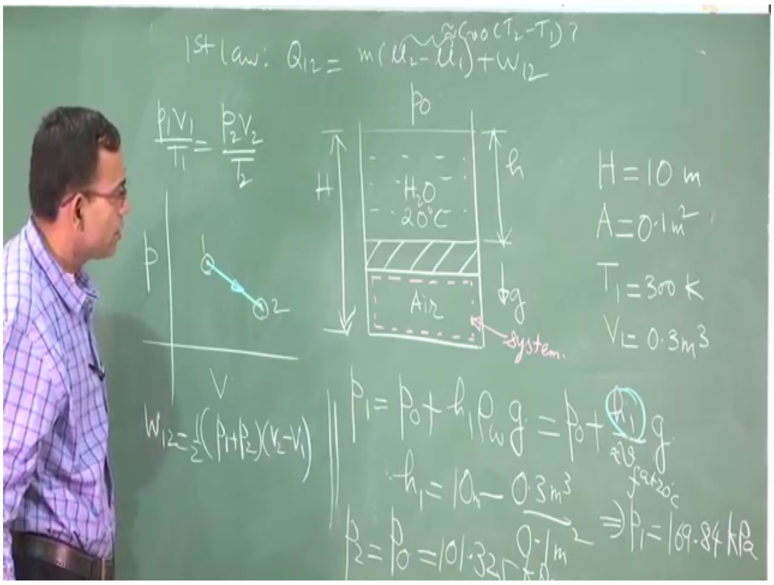

So, if you draw a pV diagram for this process, this is state 1 and the final state, more volume less pressure. What will be the locus of this? The locus will be a straight line. Why straight line? This is no linear spring. So, why straight line, because the pressure varies linearly with height. So, the displacement volume V is nothing, but this height into the cross sectional area, cross sectional area remaining fix the pressure is linearly related to the volume. So, this is the pV diagram, one of the most important parts of this problem. So, work done, so that is not a part of the problem. Part of the problem is what is the heat transfer?

So, if you apply the first law; in this case you can approximate, the temperature range is not supposed to be that high. So, you can approximate this as possibly Cv 0 in T 2 minus T 1, but that you can check only after you obtain T 1 and see whether, this range is very large or not. So, how do you obtain T 1 you know p 1 V 1 by T 1 sorry, how do you obtain T 2, you know p 1 V 1 by T 1 is equal to p 2 V 2 by T 2.

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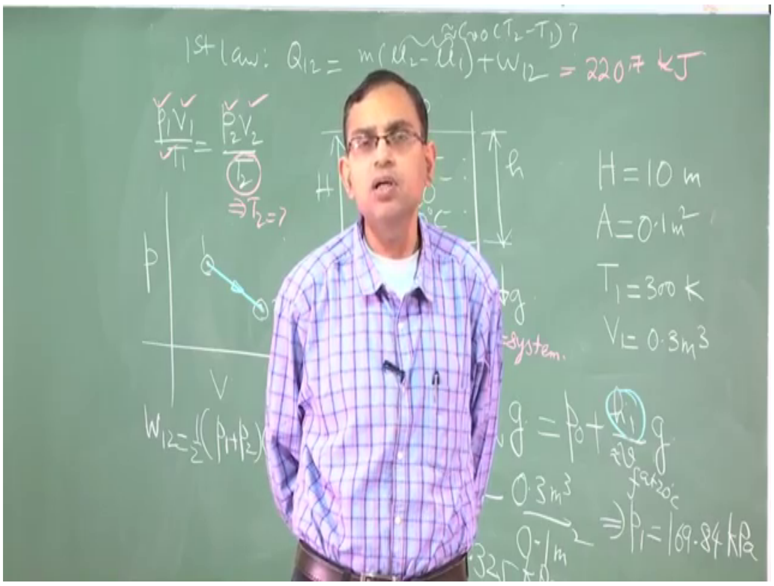

So, p 1 V 1 T 1 everything is given, p 2 and V 2 are known. So, from here you will get what is T 2. So, if you substitute all these values, you will get what is the total heat transfer. So, this is equal to 220.7 kilo joule ok.

So, to sum it up, we have worked out various problems related to the 1st law of thermodynamics and in this problems, we have mainly focused on control mass system. The issue is that, instead of a control mass system, if we deal with control volume, what will be the change in the mathematical paradigm of expressing the first law. We will take up that in one of our next lecture.

Thank you.