Engineering Thermodynamics
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Week-03
Lecture-18
Energy Efficiency

Let's move ahead and solve a problem in which CP will be used. energy calculations. So, this is cylinder piston geometry. Initially, it is nitrogen, which is 0.1-meter cube. The volume is 150 kPa and 300 KT The piston has been moved and compressed to the nitrogen So a work has been done This work has been done at 20 kJ By which your Final pressure is 1 MPa and 440 K and there is a different volume which I don't know yet V2 In this process, of course 20 kJ has been used but some heat transfer has also been done nitrogen system. So, this is the stationary system. E in minus E out is delta E, we can write delta U because delta P and delta K are zero. And E in is work in here. and the E out is Q out Notice that I have not used sign convention I have used the direction given Win is 20 kJ and we have to remove this, and this is delta u, so what will be Q out? 20 kilo joules minus delta u and since this is nitrogen, we will approximate this as ideal gas and the temperature given here is 200 and 440 since this is ideal gas, so u will depend on the internal energy cable temperature So let me see. Delta u You can use table or Cp Delta t but it is best to use table The nitrogen available is 18 in A18 test book. If you notice in table A18 test book, the energy given on it is not given in kilo joules per kg, but in kilo joules per kilomole unit. So, we can change this. 20 kilojoules minus instead of mΔu, we can write the number of moles multiplied by Δu bar where it is written in moles So we can take out n is your moles, initially you know that n is pv by RT. P1V1T1 and P1 is your given. You have 150 kJ per kg, V is 0.1 m3 and 8.314 kJ per kg k and you know the T. So, we can put this information here. And delta u. is your U bar 440 Kelvin to U bar 300 Kelvin and its value is given in table A18 in which you can see 9153 minus 6229 kJ per Kmol and if you multiply the Q out on this then this will 20 kilo joules minus 17.584 kilo joules Qout is the difference So the difference between Q out and Q in the test is 2.41 Approximately 5 KJ So this problem is a very simple problem, in which a simple energy balance is used and you have not used Cp but you have used table and Cp problem was previously discussed in this example how you can solve it.

Now let's talk about incompressible substances. The substance in which the specific volume is constant is usually called solid and the liquid is also an incompressible substance So in such a case where the volume is not changing in such a case, your Cp and Cv will be same in such cases, where your energy is incompressible, we call Cv and Cp as C. And there are no changes in both. Because the volume will not change, the value of Cv will be the same as Cv. So, in such cases, we use C as a constant. Now let's talk about internal energy change for incompressible substance. So we had said earlier that C is dependent on temperature and this thing was said by using the Ideal gas but we are also approximating in this that if C is dependent on temperature whether it is C or Cp then we can write du like this and then you can write delta u directly like this or like this Now, let's look at this expression more carefully. The expression that we will use it. But particularly when we talk about enthalpy, it will make a little difference. And let's pay attention to this. The definition of enthalpy is standard, whether it is real gas or ideal gas. So your first term will be du, second term will be vdp and third term will be pdv Because if you write it like this, then these two terms will come out Because if you consider it as incompressible, then this pdv will become zero So it means that dh can be written as du plus vdp for incompressible substance And we are approximating this like this average delta t and this part is v delta p. This is a total change in enthalpy. So, we can write enthalpy change in incompressible fluid as Cv delta t plus v delta p. You may remember that we have used this term for the ideal gas in different ways because it has relation with the equation of state But for solid, this change is not for the ideal gas We will talk about liquid and solid we can simplify this equation because in solid case this part is less and delta p change is very less in its comparison this part is very less so in solid case we can directly approximate delta h from delta u and we can write cv as delta t Let's talk about liquid This expression will remain in liquid because if you have incompressible, volume is not changing it will change in the pressure There are two examples in this which you can consider as a special case If there is a constant pressure process like we use in heater In such cases, we take delta P0 You are using heater and liquid In this case, if the pressure is constant, then delta P is 0. In this case, delta H is equal to delta U and Cv is average delta T. But in such cases, where the temperature is constant, like we are using the pump, then this part becomes 0 and only V is delta P. Here we are using only pressure difference and specific volume, you will know the change in enthalpy per unit mass. We have already discussed that we can approximate the enthalpy of compressed liquid at T. We can directly approximate the pressure $V\Delta P$ by ignoring it. We can approximate the compression liquid properties of the liquid Fluid at T, Hf at T, Sf at T This is the saturation system of liquid mixture So this is what you can see Delta p is actually approximating but there is one more term that we always miss because we say it is less and it is usually less unless we are using too much pressure this is Vf at T and Delta P this is a more accurate relation we are not deriving this in this lecture but we can use this sometimes if you have the information this is more accurate and you can get the expressions from it you can get out of these expressions. You can also use this expression at constant temperature Hf at T plus Vf at T multiplied by delta P We can use this expression as an example, but this is more accurate, otherwise you can do approximate.

Let's move forward with this discussion and close with a final example This is an example of a 50 kg iron block which is at 80 degrees which we put in water which is at 25 degrees or the volume of water in this tank is 0.5 m3 at 25 degree Celsius The question is, how much is the thermal equilibrium temperature? And all these are insulated There is no heat transfer from outside First of all, this is stationary So if we simply try to balance the energy so this is delta u because this is a stationary system delta kp and delta pe are zero now e in and e out is net energy transfer because there is no temperature from outside so e in is zero q is zero from outside and there is no work so Q in is zero, Q out is zero and W is not in so net in Q is zero, network over work is zero, so basically this is nothing but zero. So, it means delta U is zero. Now what is delta U? It is delta U of system. Change in internal energy. It has two substances; one is water and one is iron. So we can divide delta U in both, delta U iron is mass x2 because it is incompressible both are incompressible So here comes Iron, heat capacity and specifications And here comes T2, final temperature, initial temperature T1 of Iron Plus mc water T2 minus T1 of water Now T2 will be in total equilibrium, Iron and water And T1 is given by 80 degree of Iron and T1 is your 80 degree Celsius and T2 is 25 degree Celsius Now we have to take out the mass The mass of the iron is 50 kg but how much of water is there? To take out the water we can use the volume and the specific volume of the water which is the density You can use inverse of density 1000 kg per meter cube It's inverse So this is your volume Va 0.5 meter cube And specific volume is 0.001 meter cube per kg So you get 500 kg of water Weight So you plug in it Now you have to take out Specific heat So if you want to see iron You can search for it in A3 textbook It is readily available CI iron is 0.45 kJ per kg C-water is 4.18 kJ per kg So you know mass Now we know the Cv value. So, we have to solve this equation which is equal to zero. We know the T1 and T2 IV values. So, if we plug in this information, we will get everything. So, this is 50 kg into 4.0. into 0.45 kilo joules per kg degree Celsius multiplied by T2 minus 80 degree you can also take it in Kelvin but because it is a difference, there is no difference this is 500 into kg into 4.18 T2-25 degree The specific heat is 8 to 9 times higher than iron That is why the temperature absorbs water That is why the temperature changes and the heat absorbs energy from iron That is why the temperature changes to 25.6 degree Celsius So this last lecture series In this video, we will understand what we have learned from this lecture series. Initially, we talked about energy analysis and closed systems in this lecture and in the first one. First of all, we tried to understand the boundary work.

We tried to understand three types of boundary work. First, isothermal, constant pressure, polytropic. After that, we took out the expression of constant pressure expansion and compression process. In which, how to use enthalpy. How to convert the body work with the help of Intel Energy in enthalpy After that we did some examples and then we understood about specific heat We applied it to the ideal gas and finally we did the incompressible substance like solid and liquid How to use the heat capacity and how to solve it using the example I hope you have understood the concept of this course. We will present the assignments in such a way that you can practice these concepts and understand them better. I hope this is clear to you. We will start the next lecture with new topics. We will meet again in the next lecture. Till then, bye.