Engineering Thermodynamics

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Week-01
Lecture-6
First law of Thermodynamics

Namaskar! Welcome to the 3rd lecture on Energy and Energy Transfer. In this lecture, we will learn about the first law of thermodynamics and try to understand it with some examples. You all know the first law of thermodynamics, but we will try to understand it using engineering examples. The law only talks about conservation of energy principle. It says that energy cannot be created, not destroyed during a process. If there is a process, then the energy form can change but it cannot be destroyed. And you cannot create new energy. Whatever is already there or is being transferred, after that whatever changes are coming, it will be conserved. Even if the system gets 100% energy, it may lose energy in the surrounding area. But effectively, your energy will be conserved. So suppose you have an adiabatic process, meaning your heat is not lost, your energy is not lost outside the system. So whatever energy change you have made, it will be equivalent to whatever work you have done. So as an example, it will be better if you understand. As we have discussed earlier, if there is a stone or an object, how does that potential energy which is associated with this particular object which is at a very high gravitational field at delta z and when it falls, some part gets converted into kinetic energy and the rest stays in potential energy and as it goes down, kinetic energy will increase and potential energy will decrease we also assume that the energy loss in the air is minimal So, potential energy will be less, kinetic energy will be less than 100% and the other loss is in the air system.

So, in general, the first law means that energy will never disappear, it will not be lost, it will be somewhere, in some form or the other, total energy will be conserved. Because this is a simple course, that's why we are trying to make it more complex. We will always assume that it is an adiabatic process, energy is not being lost, all these things. Let's move on to the potato example. If this is potato and you heat the potato with a specific heat and the heat transferred to the potato is 5 kJ, then the internal energy of the potato will change to 5 kJ. That means your internal energy will increase to 5 kJ. So, the amount of heat transferred will increase. So, this is an energy conservation of first law. Let's take another example. Let's say that there is another system. In this system, we have transferred heat to 15 kJ. But the thing is that this system is not adiabatic. It means that it loses energy in the form of heat. So, the Q is out, which is 3 kJ. means that your 3 kJ is lost in the surroundings. You have transferred 15 kJ to the system and 3 kJ is lost. So, the total difference is 12 kJ. So, the internal energy of the system will definitely change according to conservation. And this total is Q net. The total heat given in the system is Q net means Qin minus Q out, okay. Remember, we said that the heat generated by the system is positive. The heat generated by the system is negative. But since the direction is known, the absolute value is known. This is 15 and this is 3. So, this is minus 3. So, this is 12 kilojoules. Similarly, we see another example in which we work rather than heat. There is a system which is adiabatic. This transfer is not heat. It is not coming in. So, there is no heat interaction. But your electrical work is doing here. So naturally when your work is done, the work done on the system, the same work will increase its internal energy. So, this 5 kJ will increase its internal energy. This can also be called E2-E1, i.e. the internal energy of the final state of the system minus the initial state that is 5 kJ. Okay, is equal to 5 kJ. So, the work done on an adiabatic system is equal to the increase in the energy of the system. The more the increase in the energy of the system, the more electrical work you have done, the more the energy of the internal energy of the system. That's how your system energy is changed. So, the amount of work you have done in the adiabatic system will be equivalent to the amount of energy you have used in the adiabatic system. Let's take another example. Here we have taken electrical work. Now we are taking shaft work. You have a shaft here, and its total work is 8 kJ. When you are working on the system, its energy will naturally increase by the same amount. Delta E is positive 8 kJ because its energy has increased. The work shaft done on an adiabatic system is equal to an increase in the energy of the system. So, the more work you do, the more energy you get. So now we can summarize this. What we can call it in the summary is that the energy that is changing, the total change of your energy, if we call it the delta E system, then we can write that the total energy that has entered into your system, minus the one that has gone out, the energy that will come will change in your system which means the total energy entering the system which is the energy entering the system minus the total energy leaving the system is equal to change in total energy of the system ok so the amount of energy that came into the system suppose this is your E in and the amount that went out So this A, you will subtract this from this this E in will be minus E out then your net will come in and that will be equal to net change ok and this energy will be the forms of energy it is not just one energy it can be work, it can be heat and if this open system is open then mass will also flow right, so your mass can also flow so in this case your work with flow will also be added. I will try to understand this a little more.

Let's take another example. Here, specifically, what you have done is a piston-cylinder arrangement. Meaning, you have a system, and you have this movable piston. Meaning, this piston can move. And you have worked on it. Since it is a piston, you have worked on it, so if the total work is done is 10 kJ So this 10 kJ is compressing your system So the amount of 10 kJ is the same amount of delta E which will change in your system, So this is your Win Means the total energy part is done by work in Total energy entering the system. This is the kind of... But no one is going out in this. Because total energy is leaving the system. Meaning no one is going out. Because this is adiabatic. So in this case, what will you do? WB in. This is your part of energy. Minus zero. Because no one is going out. Is equal to delta E system. So that's why this is your 10 kJ. Right? So, as I applied E in minus E out, E in is WB in, this is zero, so no one goes out and this is your delta E system. So, this is why your 10 kJ is your answer. Now, let's take another example. This piston cylinder was working, and this boundary was working. Similarly, here we take the example of shaft work. So, this is your shaft work. In this, you have worked on the system. Now, we have to be a little careful here because we are not putting the convention here. Because the directions are given here. Okay, when we say that this is shaft work, then this kind of work comes in the part of EIN. Okay, this comes in the part of EIN. It shows that the Q in is 15 kg more means 15 kJ Q in is the heat that is entering the system and that amount is 15 kJ and Q out which is going out that is 3 kJ so if this use the definition and use this particular energy balance which is E in minus E out is equal to delta E system so here what are the forms of E in? this is your form of 6 kJ this is your maximum so this is W shaft E in plus 15 kJ this is your E in minus 3 kJ and this is your delta E system so what is delta E system this is your 6 plus 15 minus

3 which is 18 kJ so this is your energy balance application so this is written in the same form definition say just make it total energy entering the system minus total energy living the system is equal to change in the total energy of the system your total energy Joe in the career system joy remember system come Nick yeah they're coming to discuss get out of the system common daughter line care and yes system or get system it Disney form can I G have a car and then you enter the form of energy that is leaving the system and that is the total energy change in the system let's discuss more about it so the energy change of the system is E final minus E initial which is E2 minus E1 This is energy, we have discussed this in our previous form. One is molecular energy, which is called internal energy. Plus, the potential energy in the gravitational field or if the total system is moving, then kinetic energy is there. So, the total change is delta U plus delta K plus delta E.

The total change of energy will be in the change of internal energy, plus kinetic energy, plus potential energy. Okay? We can write it like this, per unit mass also. Like delta U is the mass of the system, multiplied by the internal energy per unit mass minus internal energy per unit mass for state 2 minus internal energy of the system per unit mass at state 1. So, this is specific internal energy, specific means per unit mass. Similarly, we can write kinetic energy as half m square, change in kinetic energy as half m v2 square minus v1 square, and delta Pe can be written as simple mg z2 minus z1, which is z means elevation. Z1 will be Z2, Delta P will be 0, if the system is stationary, it means that kinetic energy will be 0 because it is not moving. So, we can simply call Delta E a change in internal energy. Remember, this is a system. We are talking about a system. We are not going to put the concept of internal energy in the things coming from the boundary. Because our system is fixed and the changes in the system are basically talking about it. And when it is stationary, we can call delta E as a simple change in internal energy. Now we will talk about the mechanism of energy change.

What forms are you entering into the system? Energy forms and what is going out. So, we have already discussed the boundary interactions that energy is transferred either from the work side or from the Q side. Q means heat. If it is an open system, then mass also brings flow work. So, we consider that as a part of the energy in. And the mass out is basically part of the energy out. So energy is transferred from the system or system which comes with mask right? and similarly you can say e out is q out plus w out plus e mask Now we can write this as well because we can combine this part and it will come out like this. Net in. How much total amount has been used in the system. You will find out when it is out. Why is it net? You can also think of it as a Q-net. Because we are saying that if we want to use sign convention, then we said that the heat supplied in the system is positive. If we work, the work that the system does, that is positive, otherwise if the work is working on the system, it is negative. If we out network from it, then... network conventionally negative W out minus Win plus E in mass net Mass in. You can also say this. But in general, we can say Q in minus Q out plus E out. Because there are directions, it becomes easier. There is no need to say much. But many times, different test books, different problem statements are written like this. So now we can generalize this. This E in minus E out is basically net energy transfer. Net energy transfer by heat, work and mass. This is one part of both the systems. Net energy by heat, Net energy transfer by work, Net energy transfer by mass. Net energy transfer by work, when we add these three, we will get delta E system which is the change in internal kinetic and potential energy. In the station, we will connect the kinetic energy potential. It is also written in the rate. If you think it is in the rate, then you will notice dots. And here the changes in the system will be deal DE by DT. If there is a constant rate, then it means that everything is constant. If q. is also constant, then qt will be q delta So if you multiply it with delta t, you will get the work and delta e will come. You can also take the energy balance per unit mass. So, we write everything small. When we write per unit mass, we change the symbol and do not write big capital. So, we convert it too small. So, e in minus e out is equal to delta e system. So again, this is the net energy transfer by different forms, but this is per unit mass. So, unit changes to kg per kg joules. This can be written in differential form. That small delta E in, small delta E out is equal to dA. If you are getting changes in the system and you want to write in differential small element, then you can write like this. You can write in this form. You can write in point mass as well. All this is in differential form. Now the thing is that if suppose your... The process is cyclic. You start from one point and then go back to the first point. So, 2 and 1 are the same. When this happens, because it is closed, it is a complete cycle. If it is a closed system, so if this is a closed system and this process is cyclic, then what is going to happen? Because it is cyclic and closed, what does closed mean? That energy is not flowing, only the transfer of energy can be done either by heat or by work. Because it is closed, it means that first of all you removed the part of the mask. You only have one energy, Q and W. If we try to understand what we have read earlier that E in net E in minus E out is equal to delta E system Okay? Now if you pay attention to this then there are three parts of this that we have written First, Q in minus q out plus w in minus w out plus e mass in minus e mass out. This is your delta E. If it is closed, then this is your zero but if it is cyclic, then delta E will be equal to E2-E1 That will be your zero Why? Because the system is back to the state from which you started This is a state property If the state is same, then delta E will be zero If system 1 and system 2 are same, there should be no difference in the energy. So, the system's energy came back to the same place from where it started. Now what does this mean? This means that your Q, which is net in, and I had written earlier that W net out, this is zero. This means Qnet it is W net. So, the more you enter the Q, the more you will get the total work done in the system. So, if the Sackler is closed, then W net out is equal to W net in. So, we have discussed this.

Now let's close this lecture with an example. So, this is your fluid which is in a rigid tank. So, this is a tank. and you have a fluid inside it that you can see is a fluid its initial energy is 800 kJ and this you have put a paddle on it this is a paddle which is moving and stirring, and its total shaft energy is 100 kJ you have worked on it But this tank is not adiabatic, it is losing energy. So, the total amount of energy that has been lost is 500 kJ of heat in the process in which you have worked 100 kJ on the shaft. So, what will be the internal energy of this tank which was initially 800 kJ? What will be U2? So, the first thing is that We will assume that this is a stationary tank because it is a rigid tank The tank is big and it is not moving and the elevation is not changing So delta P and delta K will be zero So E, the representative E is basically your delta A system Your delta U is your system Which is your U2-U1 So what you will do is, first you take this assumption After that you have E in minus E out is equal to delta E system and you have called this U2 minus U1 Now E in minus E out, because this is closed system there is no flow in it so this is your Q in minus Q out okay plus W in minus W out this is equal to U2 minus U1 so Q in minus Q out plus W in minus W out this was your net energy transfer due to heat, work and mass so since there is no mass flow so simply Q in minus Q out plus W in minus W out Q in is zero, Q out is 500 kJ okay plus WIN which is shaft work which is 100 kJ minus WOUT which is 0 because it is not working anywhere outside and U2 you have to remove and U1 you have 800 kJ so U2 will be 800 minus 500 plus 100 kJ and this is your 800 kJ and this is your 400 kJ So this is your specific answer. So let's close this lecture. And then we will meet you in the next lecture where we will talk about energy conversion efficiency. Thank you.