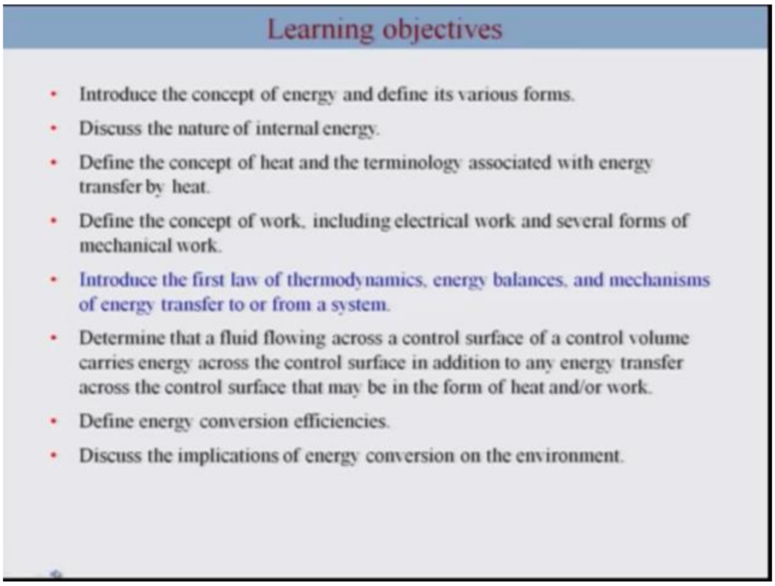
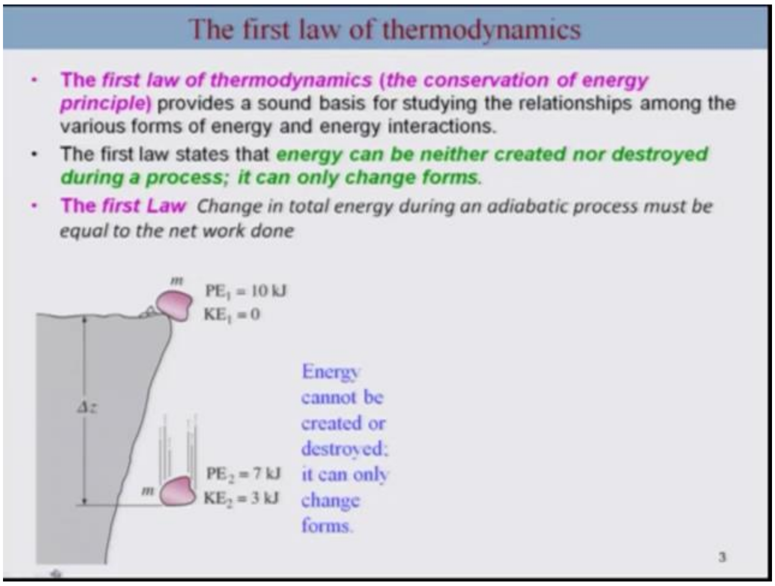
Engineering Thermodynamics
Professor Jayant K Singh
Department of Chemical Engineering
Indian Institute of Technology Kanpur
Lecture 06
First Law of Thermodynamic and Energy Balance

(Refer Slide Time: 0:23)



So, welcome back! So you were going through the energy and energy analysis, this is a third part of the module. So, until now we have covered the concept of energy and energy transformation and particularly internal energy and different forms of internal energy and the work and heat which is recognized only at the boundary of the system. Now we will go in details of the first law of thermodynamic okay. So, what is says that the first law of thermodynamic that the energy cannot be created or destroy it can only change its from.

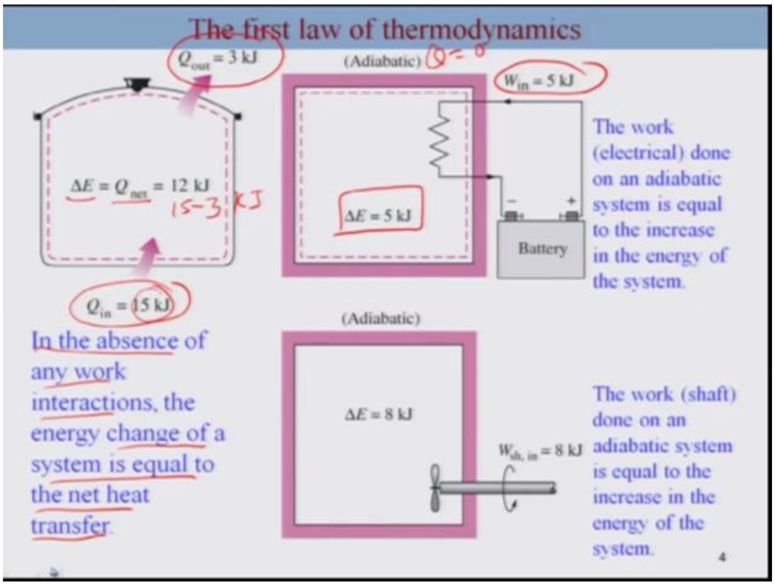
(Refer Slide Time: 0:46)



So, we have already given this example of rock following from a cliff where the potential energy of the rock gets converted into the kinetic energy okay. Now it depends whether your system is isolated or whether the heat is can be supplied or not depending on that the change of energy can be calculated. So, for example you take a case of potato which you put it in oven. Now potato does have its a internal energy, but when you transfer heat in a oven such as, for example this value which is given 5 kilojoules, then the thermal energy of the potato is increased to the same amount assuming that there is no loss in the energy.

So this dash line represent the system, so this becomes a system and you are getting Q in from the surrounding or in from the device which is oven in this case. If you take a system such that no heat can be transferred from the system to the surrounding or surrounding to the system and if there is any change in energy it has to be due to the network done on the system or by the system. So, the that is the another way of stating the first law that change in the total energy during an adiabatic process, where Q is equal to zero must be equal to the network done.

(Refer Slide Time: 2:20)



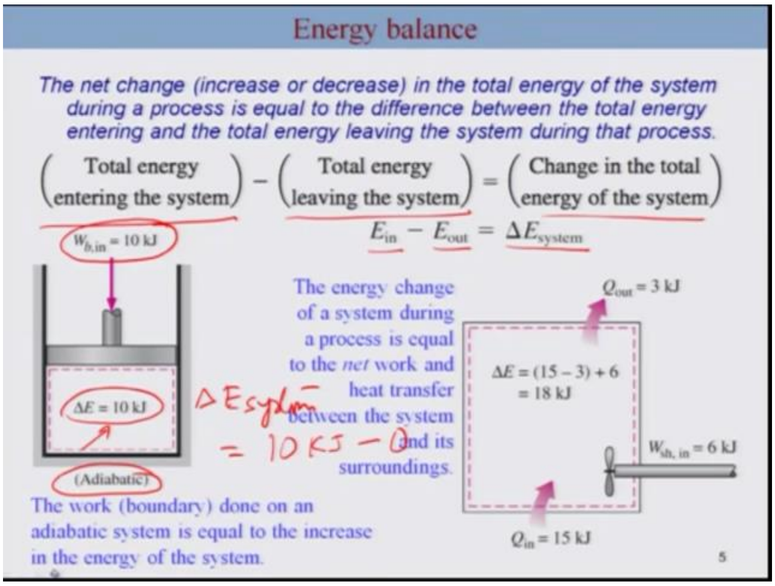
Now let us take couple of more examples okay. So, this is an example here again this could be a reactor, for example where or container okay anything you which you can consider this or the dash line again represents the system. So, what is being a given here there is heat provided to the system which is given a 15 kilojoules there is a heat loss, which is transfer to the surrounding which is a 3 kilojoules thus your delta E which is a net change in the energy is simply the Q net which is nothing but 15 Q in - Q out okay.

Now there is no work done in the system because work interaction is not given. So, in the absence of any work interaction the energy change is simply equal to the net heat transfer. Now you can consider case where the system itself the adiabatic meaning that a heat is transfer cannot be possible. So, the only possibility to change the energy of the system is by doing a work. Now work can be done either through electrical mean through mechanical mean. So, that some examples two examples we are going to consider, this is an example where the electrical work through battery is done on the system.

So, here you have a system is adiabatic which means Q is equal to 0 and the work in is 5 kilojoules and if you do the energy balance simply find out that the energy change of the system should be equal to W in so that is 5 kilojoules. We can take another case and in this case work done is through shaft. So, that is the work shaft information this is the representation of shaft in is 8 kilojoules okay, thus your delta E is nothing but shaft work shaft in okay.

So, the work done on an adiabatic system is equal to the increase in the energy of the system. And for the case of the work done on an adiabatic system which is electrical one is also equal to the increase in the energy of system. So, we can write a very formal definition of the first law okay. And that is how we are going to go about it in this course. So, here is the total energy entering the system - total energy leaving the system and that should be change in the total energy of the system.

(Refer Slide Time: 4:42)

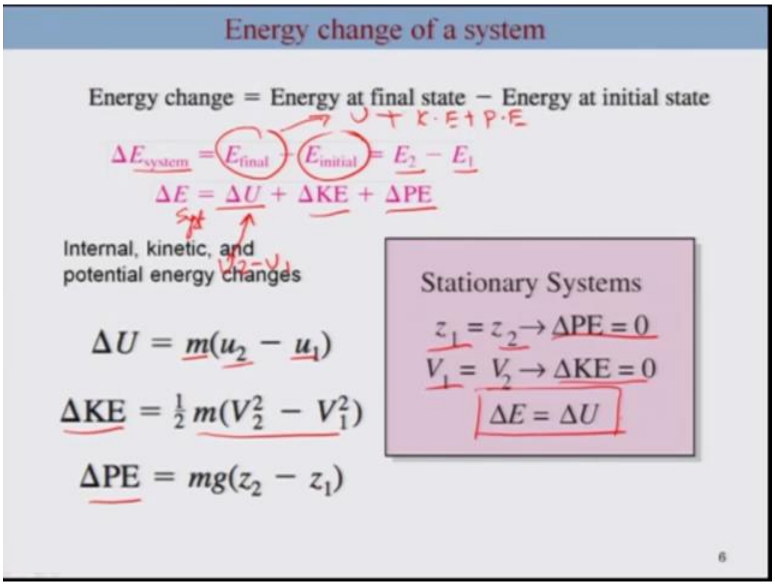


So, it is E in - E out and delta E system. So, we will talk in more detail what is E in what are the component which constitute energy in and what about delta E system, what is the energy of this system. So, this is something which we will describe more in detail. So, you can use this expression this to find out delta E of the system for the case of adiabatic system, where the Qin or Q out is 0. And the change in energy here delta E of system should be E in in this case what is E in, there is a piston which is moving the boundaries moveable.

So, that there is a boundary work which is done or which is equal to 10 kilojoules. So, E in is 10 kilojoules - E out there is no E out so E out is zero, so delta E system should be equal to 10 kilojoules and that is why it is. So, you simply applying energy balanced based on this expression. You can do the same thing now in a little more complicated where the work is also included. So, here you have a shaft in work due to shaft in, in means you over doing a work on the system and then you have a Q in as well as Q out.

Now what is a delta E system change in the system, so it should be delta E system should be E in , E in is your Q in + W shaft in - E out, in this case E out is Q out. So, that makes your answer is 15 + 6 okay kilojoules - 3 kilojoules okay that should be your 18 kilojoules. Now we will little bit talk about the E of the system now energy of the system is a point function, so essentially it does not matter how it was achieved that state was achieved you simply it is a is a difference between the final state and the initial state that would the change in the energy of the system.

(Refer Slide Time: 6:55)

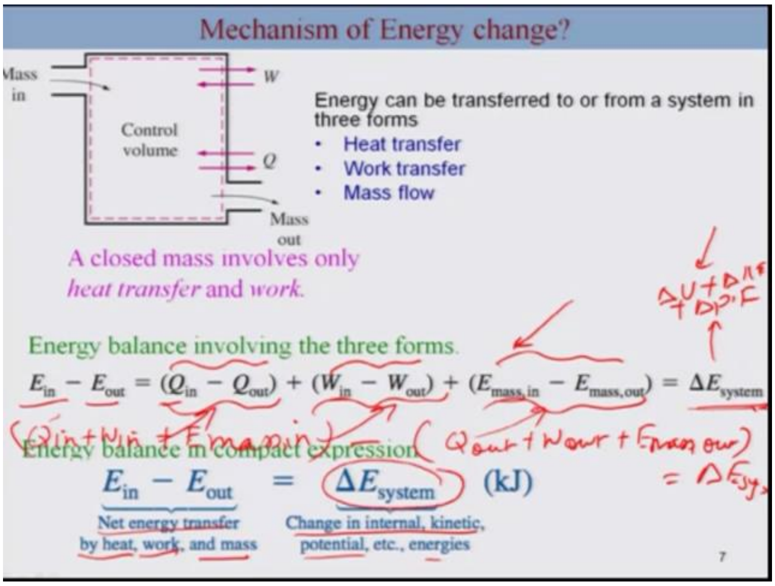


So, that something we are emphasizing again, so this and this is fixed once you have a state fixed once you know exactly the state, but this consist of many components. So, this consist of your internal energy the potential energy and kinetic energy. If magnetic and other components like surface tensions are components are missing or absent. So, E final + - E initial can be written as E 2 - E 1 in other word, you can also write delta E of the system as simply the change in different components of the energy.

So, this would be the change in the internal energy okay that means this would be U 2 - U 1 and similarly for delta K E and delta P E. So, the other component we assuming that there is no magnetic effect, there is no electrical effect, there is no surface tension effect okay because gravity is considered as a part of potential energy also. So, you can write this expression in more detail delta U is nothing but mass multiplied by specific internal energy. So, that means this is per kg form and this delta K is given in terms of velocity P is given okay.

Now in case of a stationary system, so you have a z 1, z 2 is a fixed V 1 and V 2 is a fixed it that means they are also equal and same, which leads to your zero potential energy difference, zero kinetic energy difference and thus your total energy change of the system should be same as that of the internal energy. So, that something which is obvious based on this expression.

(Refer Slide Time: 8:36)



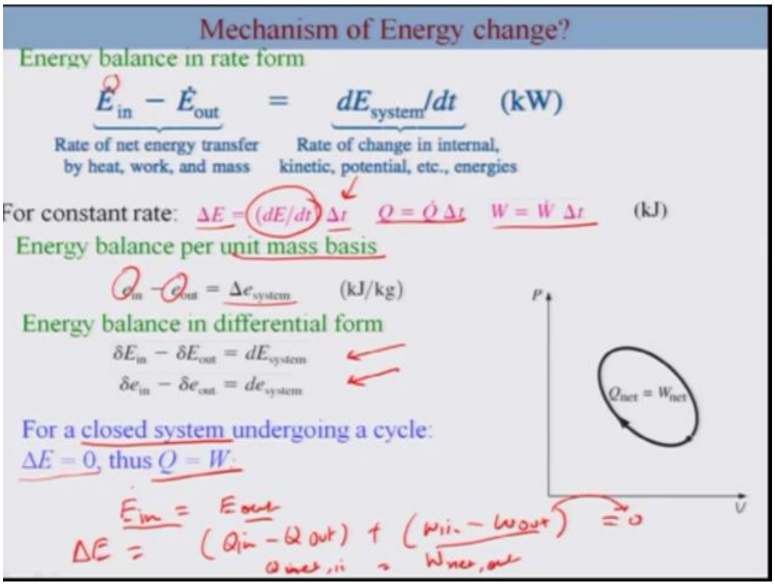
Now how do you achieve these changes, we talk about the change of the system okay but how do we achieve it, there are 3 ways to change their energy of this system okay. Either you provide heat or you take out the heat from the system or you do a work on the system or you make use of the flow, mass flow and mass out okay there are 3 ways to do that and that is why we are going to use this control volume showing this open system as an example.

So, as I said energy can be transferred to or from a system in 3 forms, heat transfer, work transfer and mass flow. If you close the system okay, then the only way to that is heat transfer and the work okay. We already talked about delta E system which is nothing but your delta U + delta K E + delta P E. Now this delta U is essentially of the system what about E in and E out or this is the transfer mechanism okay. This is the system information, this is a transfer mechanism. So, what is coming in what is coming out, it does not talk about the system, it talks about what is going on at the boundary.

So, at the boundary either the mass is entering or the heat is being transferred or the work is being done. So, this gives you information of the heat, work or mass okay so, we can write this in this form. So, E in - E out you can take different contribution, this is due to the heat transfer due to the work transfer due to the mass flow. So, you can also write in this form also like Q in + W in + E mass in as component E in - Q out + W out + E mass out, this equal to delta E system.

So, you can also do that, so it is a same expression. So, is this can be generalized in a very simple way where we write E in - E out, where this represent net energy transfer of heat. And that is the reason why this expression here was used, because this is a net heat transfer, this is a net work transfer; this is a net mass flow. So, these are different component of it, you can generalize it here and make it like net energy transfer by heat , work and mass and that should be equal to your change in internal energy, potential energy that would be your delta E system.

(Refer Slide Time: 11:21)

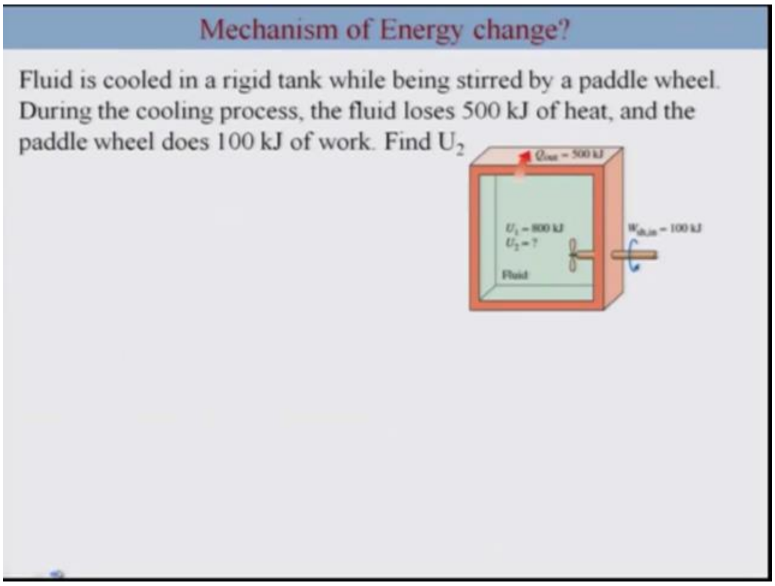


So, you can also write in the weight form that would be in the form of change in energy per unit time and that is why this dot comes into the expression okay. So, this that would be E dot in - E dot out equal to d E system by dt okay. So, if there rate is constant, then you can find the change in the energy of the system by simply multiplying this rate by the specific time difference and same with the heat same with the work.

You can also write the expression in unit mass by using a small e as an a expression and here becomes E in - E out and delta E system you can use this unit mass basis in the form of rate that also you can do that, you can also write in differential form as done here. Now what about the closed system, when you undergo process which is closed and as well as it is a cyclic process which essentially means such that doing a process for a closed system such that you come back again to the same state.

And such case you know that energy is property which is a point function. So, delta E of the system should be 0 because coming back to the same state. So, delta E should be 0, now which means your E in should be E out should be equal to E out write. So, on you can consider in this form or you can write that delta E was your Q in - Q out + W in - W out and considering is a close system the mass term is not there, when this is zero which essentially means Q net in should be W net out okay because the - sign if you take the second term here to the other side brings -s, so this becomes Q net in equal to Q net out okay that is why your Q is should be equal to W okay, so that is for the closed and cyclic process.

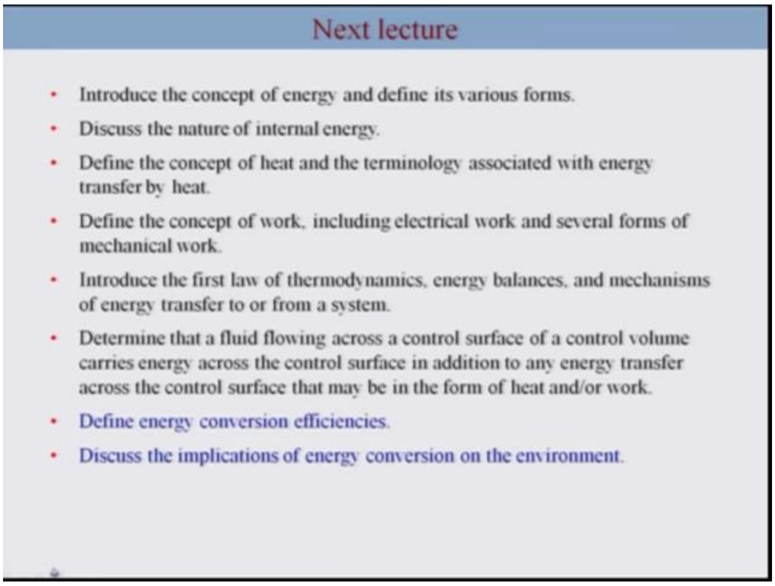
(Refer Slide Time: 13:38)



So, let us take a example and then I will end this lecture. This is an example of a fluid which is cooled in a rigid tank while being stirred by a paddle. So, the paddle wheel is here okay. And the shaft work done is 100 kilojoules, fluid loses 500 kilojoules of heat and initially the internal energy of the system was 800 kilojoules, so we have to find the final internal energy. So, what we are going to do we are going to just apply the first law of thermodynamics here okay. So, we can simply consider delta E so delta E is you E in - E out, and delta E is nothing but your delta U + delta P E + delta K E, salivations is not changing in the there is no or no change in the velocity in fact there is no velocity it is a stationary system so these 2 terms should be zero, so you have delta U as E in - E out. So, what is E in here, is nothing but shaft in okay.

And there is no heat supply to the system and what is E out, it is simply Q out. So, you have 100 - 500. So, this is nothing but - 400, so this should be your U 2 - U 1 which essentially means U 2 should be 800 - 400 kilojoules okay. So, this should be kilojoules here, so that is 400 kilojoules. So, that is answer for this based on first law of thermodynamics okay.

(Refer Slide Time: 15:38)



So, that would be the end of the lecture and the next lecture we are going to talk about the conversion efficiency as relevance for environment.