Thermodynamics of Fluid Phase Equilibria
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Lecture - 03
Energy conservation (First law of thermodynamics)

Welcome back. In this review lecture, we will be covering energy conservation particularly the first law of thermodynamics.

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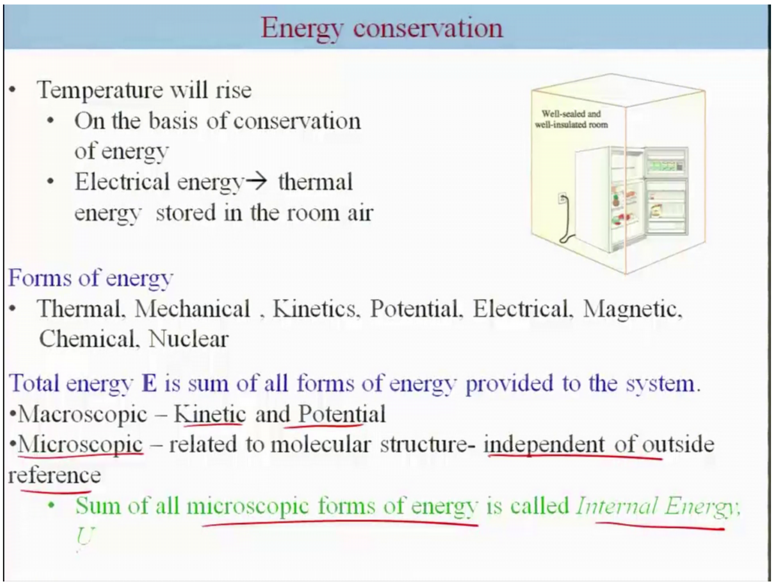

So, let us simply take a case and some example a very primitive example. So, this is basically room well sealed and well insulated having a refrigerator with a open door. So, what do you expect? Do you expect the room to get cooled or you expect the room to get warmed up.

So, intuitively you may thing that you know the because of the purpose of the refrigerator, you may assume that the room will get much more colder, but in practice what is happening because this is a well sealed and insulated; the electrical energy is being used in a order to run the refrigerator now which is now open. So, thus your thermal energy of the room gets replaced. So, this is one form of conversion of electrical energy into different form of energy. So, temperature should rise in such case.

Now, there are many examples, but when we talk about thermodynamics we often deal with energy and its transformation ok. So, let me just for first talk about different forms of energy ok. So, these are thermal, mechanical, kinetics, potential, electrical, magnetic, chemical and equilibrium. Now the total energy of the system consists of all forms of energy provided to the system.

So, there are two parts of the energy one is the macroscopic energy, which is kinetic and potential energy and other one is which is related to the molecular motions are or related to the molecular structure are called microscopic one which is independent of outside reference whereas, of course, macroscopic will does depend on the outside reference. The sum of all this microscopic form of energy is called internal energy which we often use u to represent ok.

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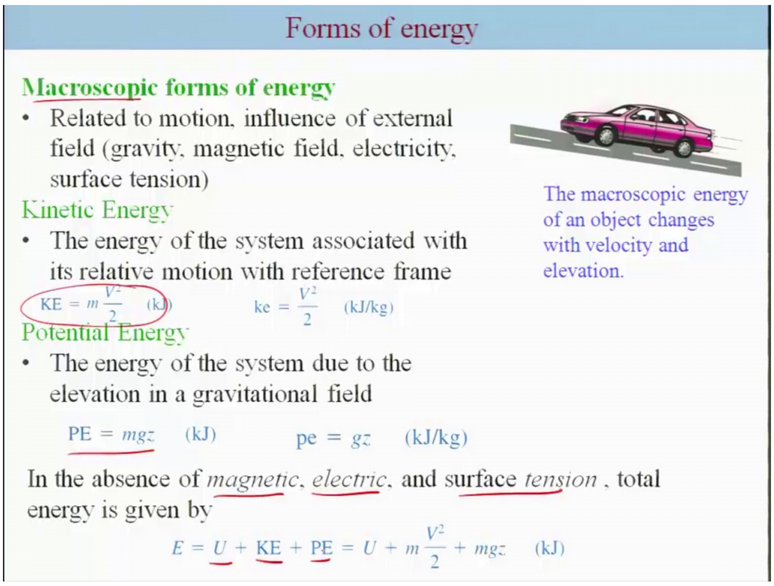

So, let me just describe quickly what are macroscopic for of energy ok. Now these are related to the motion influence of external phase such as gravity, magnetic field, electricity, surface tension. Kinetic energy is part of the microscopic form of energy kinetic energy and potential energy. Kinetic energy as we know is simply this the kinetic energy system associated with its relative motion with reference frame.

Potential energy is due to the elevation in a gravity gravitational field given usually by mgh. In the absence of magnetic electrical and surface tension terms or effects, the total energy consist of internal energy plus the macroscopic energy kinetic energy and potential energy and. So, this is the total energy of the system in absence of magnetic electrical and surface tension total.

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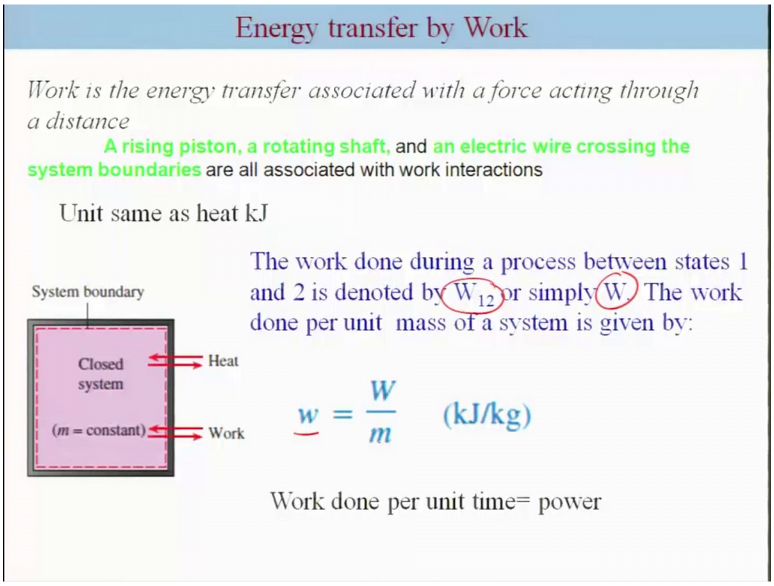

Now, if you consider system such as this particular closed system. Now since it ius a closed system mass does not get exchanged with the surrounding, but you can exchange heat in work or exchange energy with the surrounding which can be in the form of heat or work.

So, let me just focus first on the work. So, work is basically the energy transfer associated with the force acting through a distance. So, rising piston rotating shaft and an electrical wire crossing the system boundaries all work interaction with the surrounding one can prove that also. A typically what we prefer work or the symbol which we refer from state 1 to state 2 is given by W 1 2 or simply we use W.

Sometimes we often use small w to represent work done per unit mass work done per unit time is of course, power ok.

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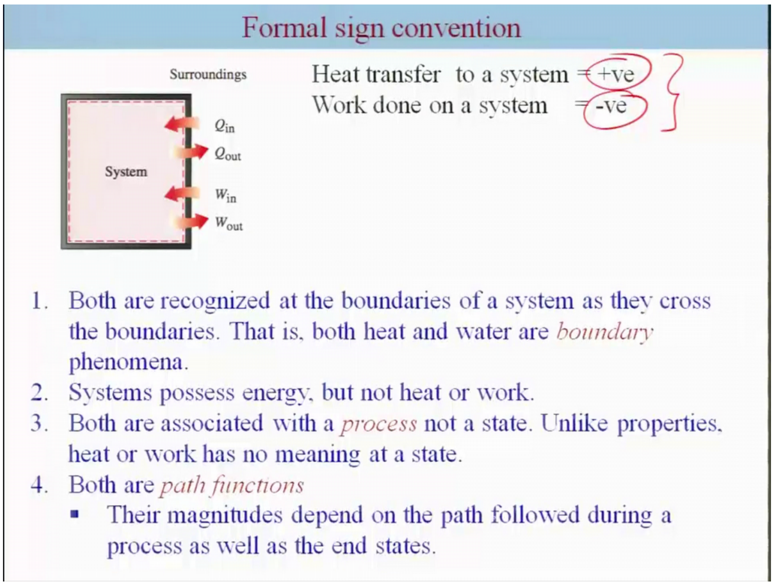

So formally there are many sign conventions, it primarily depends on the textbook which we follow, but it is just to make our life little easier. So, we will be using one of the signs convention, but one of the way to do that is we consider heat transfer to a system positive and the work done on a system negative ok. Or if you know the exact interaction with the surrounding, you may not use the sign the way we have use stated here, we can simply write it based on their actual sign. Now usually the signs are used when we do not or we are not aware of the effective interaction with the surrounding, and thus this assumption helps us in solving the problem.

So, both heat and work are recognized at the boundary of a system as they cross the boundary; that means, they are boundary phenomena, remember that the system poses energy, but not heat or work they get realized only at the boundary both are associated with the process not a state, unlike property heat or work has no meaning at a state and both are path function. So, this is the reason that the change we do not consider the change in the work on, change in the heat.

So, both hidden work or path function and their magnitude depend on the path followed during a process as well as at the end set.

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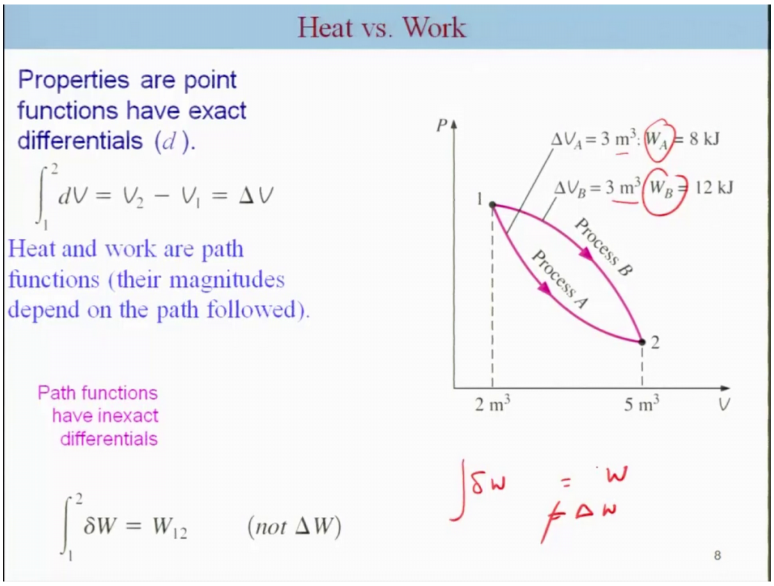

So, let us consider a process diagram here this P and V and this is process 1 and 2. So, in this case the change the volume is 3 meter cube and the change the volume for the process B is also 3 meter cube. Because volume is the property of the system and hence the final and initial state even though it has these two processes are falling at different path, the change in the volume are going to be same. But the work associated with this which actually depend on the area under this curve will be different ok. And this is the reason that we actually write the work usually in differential form delta W and absolute form W and never we write w when you integrate ok.

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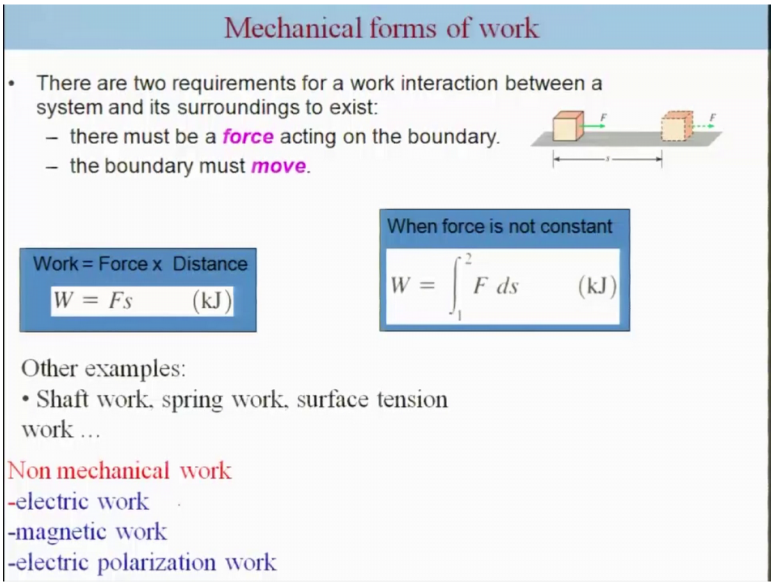

Now, what are the mechanical forms of work because work can be mechanical and non mechanical forms. So, what are the typical definition of the mechanical form is simply the force into distance, you need a force in order to move the boundary you can move the object here. So, force and distance is nothing, but work examples are shaft work spring work surface tension work and in addition to the mechanical work, we have electrical mechanical work electric polarizable work and so forth ok.

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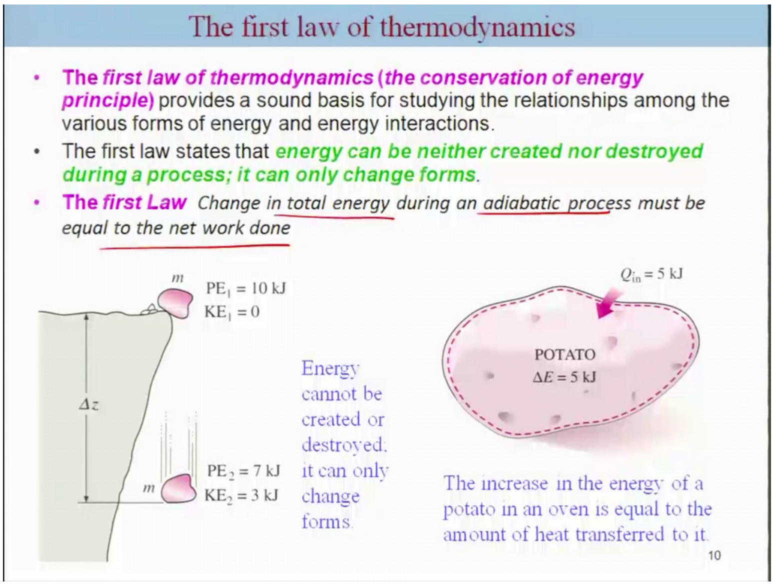

So, let me just come to the formal definition of the first law of thermodynamics. So, first law of thermodynamics state that energy can be neither created, nor destroyed during a process, it can change only its form ok.

So, in other word a first law says that change in the total energy during an adiabatic process, must be equal to the network done. Because adiabatic means there is no heat supplied to it.

So, if there is a change in the system and there is no heat supplied to it. So, it will be associated with the work ok. So, this is an example of the first law representation. So, for example, if your mass falling from a cliff, having a potential energy as ten kilo joules with no velocity or kinetic energy, after reaching a certain distance, it will you know assuming there is no friction loss and so forth, some of the potential energy will get converted into kinetic energy.

This is a classical example a textbook examples of that. Or you take an example of the heat supplied to the potato any change in the energy of the potato would be due to the heat, and if there is no losses, it would be exactly the same.

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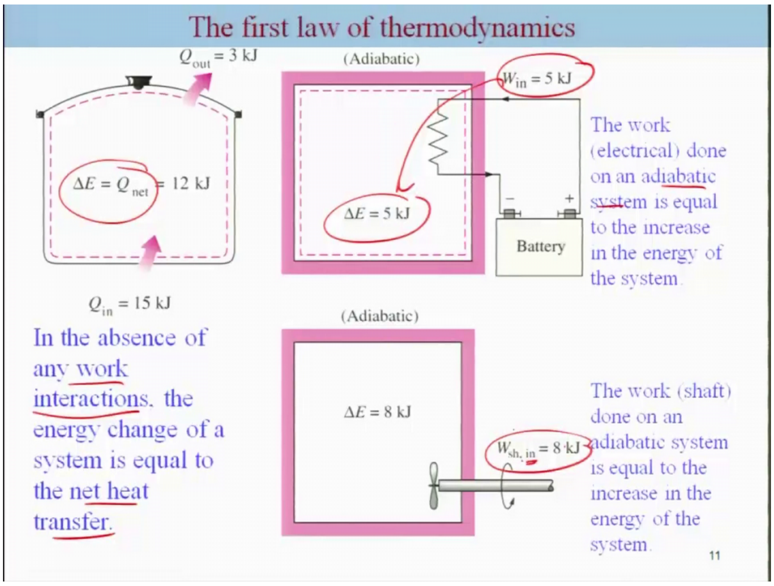

Now take an example of let us say container or the boiler are supplied here ah. So, in this case if there is no work interaction, which is surrounding; that means no work supplied or provided to it done by the system, then the change the energy change of the system is equal to net heat transfer.

So, that is a statement directly from the first law ok. Similarly, if you consider an adiabatic system where the electrical work is done on this adiabatic system. So, whatever is the work being done will get affected by the change in energy by the same amount ok. And that is the same thing as for as the work shaft work is concerned; shaft work in supplied to the system the amount here would be same as the change in energy of the system ok.

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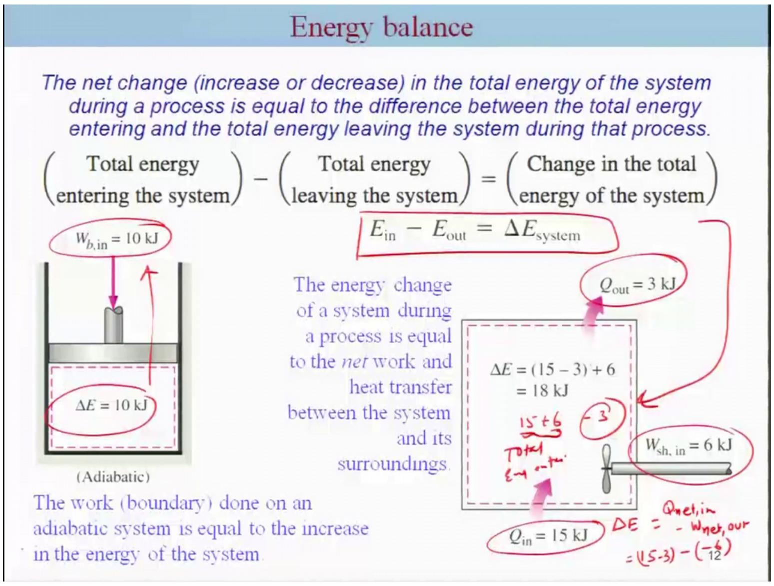

So, that means we can formally write that total energy entering the system minus total energy leaving the system, should be equal to change in the total energy of the system.

So, in other word E in minus E out is delta E system. So, an E is compete your e is basically the internal the potential energy and the kinetic energy. So, let us take an example of this piston, where the boundary work here which basically is the energy with the work supplied to this piston is 10 kilojoules and if it is adiabatic; that means, the change in energy of this system would be same as this.

There is no heat interaction here. In this case you have a system where the shaft work is supplied, but there is a heat interaction certain heat is being supplied here and certain heat is lost to the surrounding. So, considering this basic definition the E in minus E out is equal to E system. So, what si delta S system this out be 15 minus 3 plus 6 is equal to 18 kilojoules.

Now, this is where one has to you know little bit consider whether one has to directly take use of a standard sign convention or simply the sign of this. So, for the simple sign of course, we know that the Q in is 15 plus 6 minus 3; that means, the quick heat in work in minus work heat out that would be equal to the change that is one way of looking into it. So, this is total energy supplied you know total energy entering and this is your total energy leaving the system that is based on that.

But if you consider the sign convention then sign convention says that well heat supplied is positive and work done by the system is negative. So, in other word delta E is Q net in minus W net out ok. So, what is the Q net in is nothing, but 15 minus 15 minus 3 what is the w net out is minus 6 and the minus of minus 6 is nothing, but plus 6. And thus you can use this sign convention as well as the basic definition without considering the sign just looking into known interaction directions.

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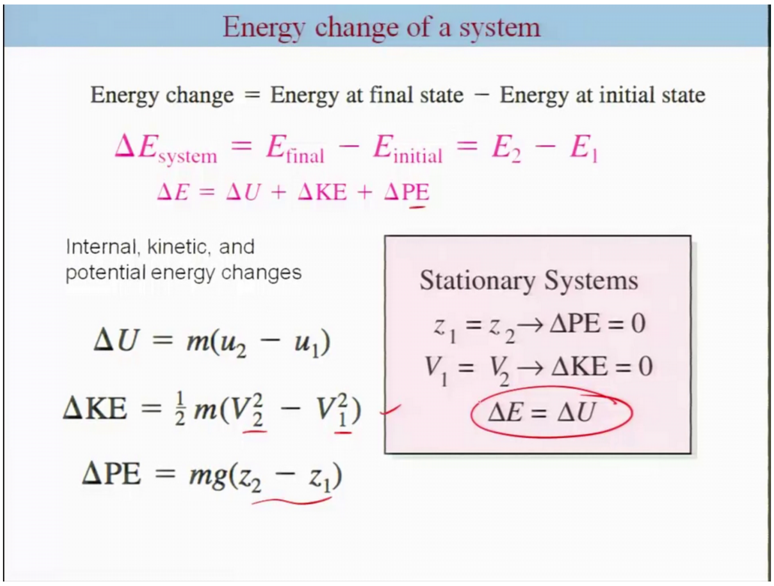

So, let me just further continue, here the energy change is nothing, but E final minus E initial of the system and delta E is nothing, but delta U plus delta KE plus delta PE of course, that kinetic energy is related to this if there is a change in the velocity the system then of course, you are going to consider that, if there is a change in this elevation of this system you will be considering the delta P. But most of the time we ignore that for the stationary system you. So, there is inner change in the elevation. So, delta P is equal to 0, delta V is going to be 0 and hence delta E is nothing, but the change in the internal energy ok.

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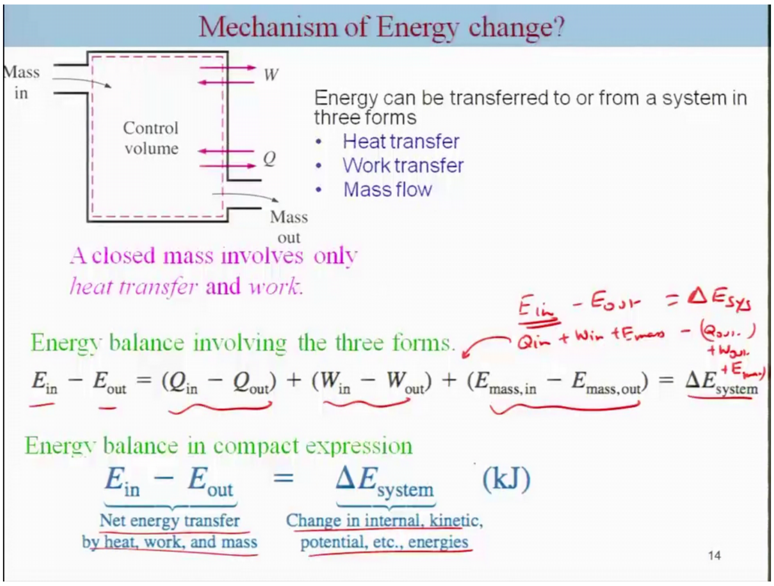

So, but that was the we had considered earlier was basically for the closed system, where the mass interaction was not there, but in generally there could be a mass interaction. So, we consider the control volume for the flow system. So, we have mass interaction masses can come in and out and work in as well as the heat interaction. So, energy can be transferred to or from a system in the form of heat transfer, work transfer and mass flow ok.

Whereas for a closed mass or closed system, which involves only heat transfer and work ok. So, a general definition in that case would be E in minus E out is equal to E delta E system. So, E in minus E out is delta E system and where what is E in here? E in is equal to is nothing, but Q in plus W in plus E mass in minus Q out plus W out and plus E of mass out and so, you can rearrange this in this form Q in minus Q out plus W in minus W out plus E mass in minus E mass out ok.

So, this would be useful if you are aware of the already their interaction directions the way it is happening, otherwise, you can always use net effect and net transfer. So, this would be also like you know net in net this will be net in, net work in mass in is equal to E system delta E system. And that is the reason that you can write in a compact expression as net energy transfer by work and mass is equal to change in the internal energy, kinetic energy, potential energy of the system ok.

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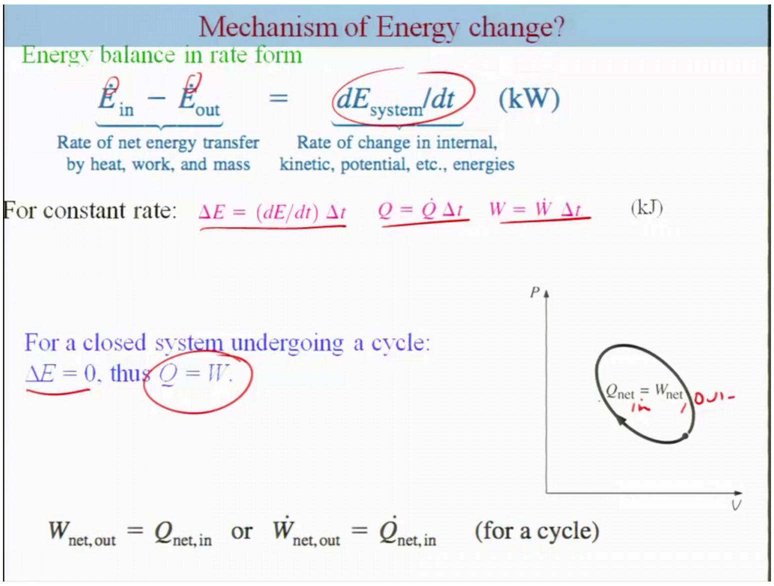

One can write in the rate form this ok. So, this is the rate form expression, we put it here dot which essentially means for a constant rate; that means, delta E system this will be the case you can find out delta E by considering delta t multiplying this expression by delta t.

For a closed system undergoing a cycle of course, delta E is equal to 0 and in that case the heat the net heat supplied is equal to net work out ok; that means, Q is equal to W that is what is written net Q net is equal to W net ok. Remember this is nothing, but , but this in and this is going to be out for a cycle; that means, heat net heat supplied is equal to net work out done by the system.

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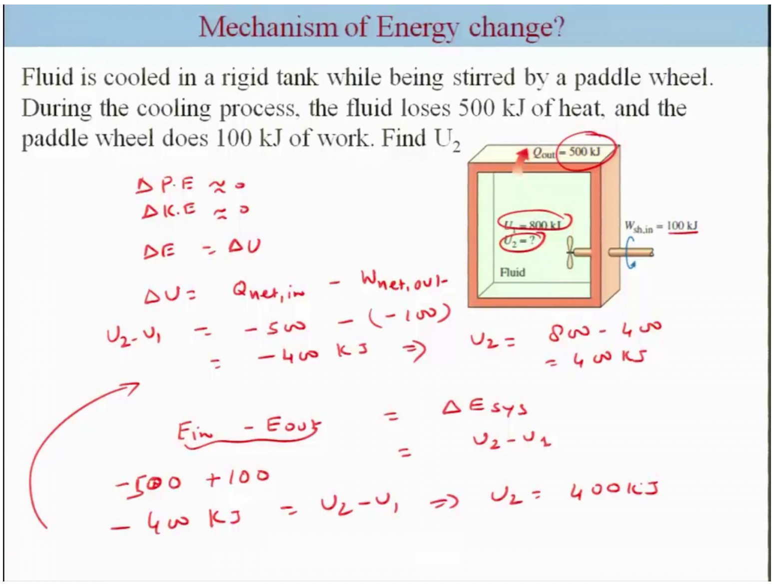

So with this basic definitions and review of the first law, we are going to end this lecture with a simple example. So, this is an example of a fluid within this rigid tank is cooled while being stirred by a paddle wheel ok, which supplied work of 100 kilojoules and during the cooling process the fluid looses 500 kilojoules f heat and the paddle will as I said does hundred kilojoules of work. So, find U2.

Initial internal energy is given to us. So, of course, the system is stationary is not moving, and considering that we will be considering of course, the changes in the potential energy changes in the kinetic energy is going to be 0 so; that means, delta E is nothing, but delta U. So, with this. So, we can use two sign two ways to solve this problem one considering again sign convention which says that delta u is nothing, but Q net in minus W net out; delta U is nothing, but u two minus U 1 and Q net in is minus 500 and Q W net out is minus 100 ok. So, which means this is minus 400 kilojoules and thus your U2 is 800 minus 400 this is 400 kilo joules.

So, this is one way of solving. So, we also said in other expression that we can write E in minus E out is delta E system ok. So, this net energy neat heat in net heat out net mass in that would be delta E system.

So, delta Esystem is of course, U2 minus U1 and net heat in is. So, this is compact form. So, net heat in is again minus 500, net work in is 100. So, on other word this is minus 400 kilo joules is U2 minus U1 and this is same as this. So, this also gives us 400 kilojoules ok. So, that is the end of this particular lecture.

So, we will continue this fundamental understanding in initial few lectures and I will see you next time.