Basic Thermodynamics

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Lecture - 03

Different kind of Energy and First Low – I

Good afternoon. I welcome you all to this session of basic thermodynamics. The last class, we discussed the concept of energy from thermodynamic view point. Energy is in two forms: one is energy in transit, that is, work and heat transfer which are part functions; and, another form of energy is energy in storage, that means, stored in a system; they are point functions and they describe the property of a system.

Today, before starting the first law, we will discuss the different forms of work transfer. In this connection, I tell you that we have already appreciated that all energy transfer, that means, energy in transit is categorized in two forms: one is heat transfer that is why hot spot temperature difference; another is work transfer, so, electrical work, mechanical work, magnetic work and all are there. Conventionally, when you call work transfer without any other adjective, heat into mechanical work transfer. Otherwise, we tell electrical work transfer, magnetic work transfer and all these things

Now, we will recognize some important forms of work transfer, mechanical work transfer, first. Then, we will switch over to the first law of thermodynamics.

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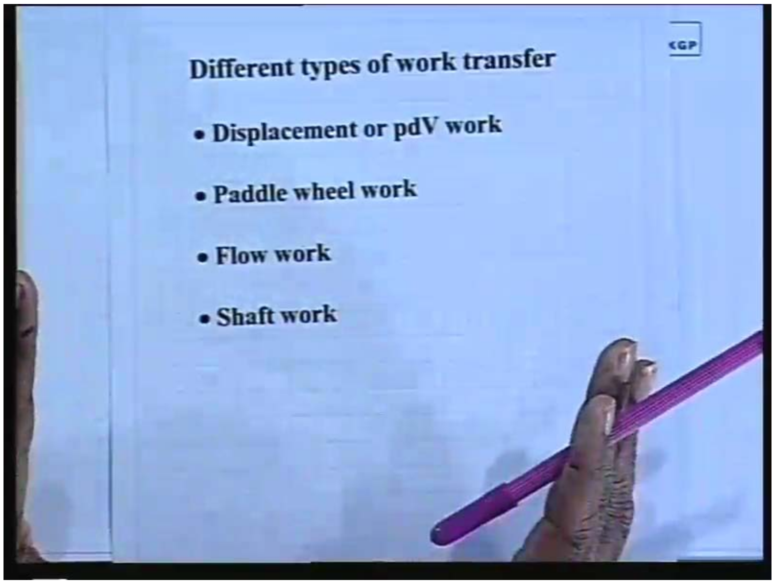

Different types of work transfer: This is like this, displacement or pdV work, I will explain each and every one, paddle wheel work, you can write this, flow work and shaft work. These are the different types of work transfer: displacement or pdV work, paddle wheel work, flow work and shaft work. These are all mechanical work transfer between the system and its surrounding. The only work transfer is mechanical work transfer between the system and the surrounding. Now out of these, the most important and difficult to understand at certain stage is the displacement or pdV work, the first one.

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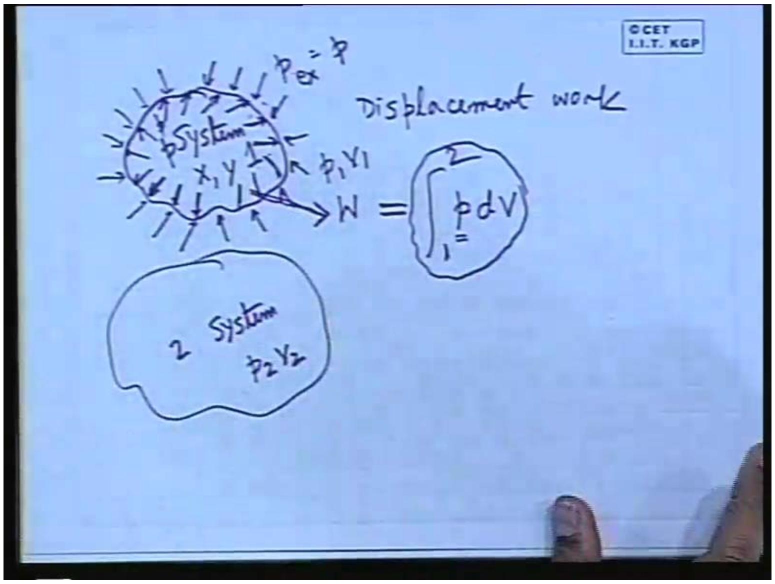

Let us see, what is the displacement or pdV work. Displacement or pdV work is associated with a closed system. Let us consider a closed system, specified by some properties; let X, Y be the two independent properties, two fixed state. This displacement work is because of the displacement of the system bounded that means, this is the closed system; there is no restriction whether its volume will be fixed; the system boundary can either expand or collapse. Because of the displacement of the system boundary, containing a fixed mass of fixed identity, the work transfer which takes place with the surrounding is the displacement work. But there is a specific theme in between what is that? The displacement work specifically implies the work because of the displacement of the system boundary in a quasi equilibrium process, why that work pdV comes will be understood after, that means, system has to expand or collapsed slowly through limited equilibrium states. If you consider a system like this where pressure is exerted on the boundary. Let the system is at equilibrium state and a pressure p is exerted at the system boundary

Now, we consider it equilibrium when the system boundary is at that it cannot be standard stress if there is a difference in pressure it will expand or collapse. So, it will be equilibrium when the external pressure imposed on this boundary. Let me denote it p_{ex}, external pressure equals to the pressure inside the system which is uniform throughout the system and external pressure is also uniform throughout the system; under this situation only, the system will be in equilibrium

If we consider the system expands for example, the boundary expands, in such a way that all the time there is an infinite small pressure imbalance, that means, In the theoretical sense, we consider at the system expands when both the internal pressure and the external pressure that is, internal force due to this pressure and the external force due to this external pressure always balance each other. Under this condition, the system boundary expands or collapses. Then this work is known as displacement work. By doing so the system attains another state for example, state one to state two. The state one is characterized by pressure p_1v_1 and state two is characterized by pressure p_2v_2. It attains the state like this where the volume is increased and the pressure is decreased. Through such quasi equilibrium state, that means, it expands slowly when infinite small amount always in a theoretical sense with a balance between the internal and external pressure.

In a limiting case, in practice to conceive it, we consider the imbalance as infinite small, so that it finally attains this stage. Then the work which is finally transferred to the surrounding, in this case, when it expands the work will come out of the system which is given by integral of p into dV. We cannot evaluate this integral until or unless we know p has a function of v. That will be found out from some concerning law of the process, but this work done can be written as integral pdV from state one to two, so this equals to the work done. That is why this displacement work is told or named as pdV work.

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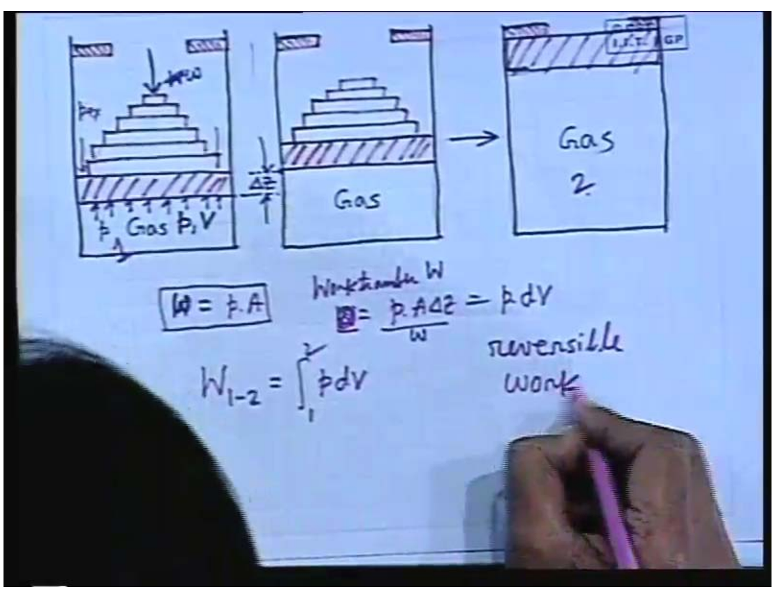

But to understand this, I think it will be better if we follow this one which we discussed last class, in relation to quasi equilibrium process. Let us consider this, how to understand this? Because here if I describe these, this thing works as information, understanding is less.

Let us understand how this work becomes pdV work. Let us consider quasi equilibrium expansion of a gas in a cylinder; this is the resting piston. Now, this is a stage when this piston carries somewhere w which is divided into number of infinite small amount of works that means, infinite large number of works divided like this. Now, this gas has a pressure p and volume v. Let us consider this as the initial stage. This gas is within the cylinder and piston represents a closed system bounded by the system boundary. One of the boundary pistons is movable so that displacement work comes into picture, that is, the system boundary is displaced

As I explained in the last class, what we can do is let us think that there are stops like that, that if we gradually release the way so the gas expands slowly in a gradual manner. First, let us go through like this. Initially, at the first moment, the weight and the external pressure if any, they balance the internal pressure force. That means, this weight plus the force due to any external pressure, if there is any external pressure, is p external. They balance the force caused by the internal pressure on the cylinder. So this is in equilibrium position, the simple mechanics. If we release a small weight so that an infinite small imbalance is created; then, the piston moves by an amount delta z which is very small

In this case what we do? If we make the small movement and slow movement of the piston, the dissipative effect is absent; friction is all most absent. In the ideal case, we can consider the piston to be frictionless, but even if there is friction in a slow motion, the friction is almost absent. So, what happens? This moves by a distance delta z. What is the work done in this case? The work done is that now this weight w, let us consider the weight w is the net force that includes both the forces weight: this weight and the forces due to external pressure; this weight balance the p into the area

When this is moved to a distance delta z, this means that this force has a displacement delta z as if this total weight w, which is been balanced by the pressure force this side of the piston is being lifted against gravity by an amount delta z. So, that is the work done? Work done is p A deltaz that means p into dV, dV is the volume; it is the short of non-dissipative work, the change in the potential energy of the weight is w into delta z, that is, w is delta z p into A. This is w, work transfer is also w. The nomenclature is confusing, so let us consider this as small w otherwise there will be confusing. This is the small w weight; so, small w is p into A. So, work transfer w will be p into A delta z, which will be equal to the small weight

If we do so in infinite small interval and number of infinite number of paths so that ultimately it comes to this stage where we attained as state two for example this is state one this is state two from state one to state two then we can write that w from state 1 to 2 is the integral of pdV from 1 to 2. This is the work done, that is, the pdV work.

Always, we consider a small distance slowly. If you cause a large displacement of the piston then force into displacement; that work is a dissipative work in nature. This is a non-dissipative work like the work done in a conservative force paid. Always the work which is been done to leave this weight to a small incremental distance delta z that means, all these works are at non-dissipative work. When you consider some weight this is coming from this position to this position, the difference in potential energy is actually the work delivered by the piston because no work is being dissipated. This is the way one can conceive that if there is a closed system which has a pressure p and volume v initially, for example p_1 and v_1 and come to a state p_2 and v_2 by expansion through a series of quasi equilibrium states. Then the non-dissipative work which comes out is equal to integral p dV and this work is known as displacement work or pdV work and sometimes this is known as reversible work. We will discuss the word reversible while i teach you the second law of thermodynamics because this process is the reversible process. If you want to go back from this position again to the initial position through same quasi equilibrium states you will get back this work which you will not be doing so. Because if there is a mass of gas, there is a piston, if you just expand first not through quasi equilibrium state and natural expansion of gas from one state one to state two, if you measure the work done by any work measuring instrument and if you compress the piston again from state two to state one and if you measure the work required to return its step one, similar to the initial state from state two, you will see the two works are not required. This is because the dissipative work which has been lost in friction is not the same for both forward and reverse processes

Because of these stresses, I will explain the process is not reversible. Though the system comes back through initial state there is a change from the surrounding because surrounding got some work earlier and surrounding has given some different work afterwards to return the system to its initial state. Keep it in mind when I discuss the reversible process, I will come to the same point. If you consider a non stresses work through quasi equilibrium states this work equals to integral pdV when the displacement of the system boundary of a closed system takes place. So, we come to the next one. This is very simple, paddle wheel work.

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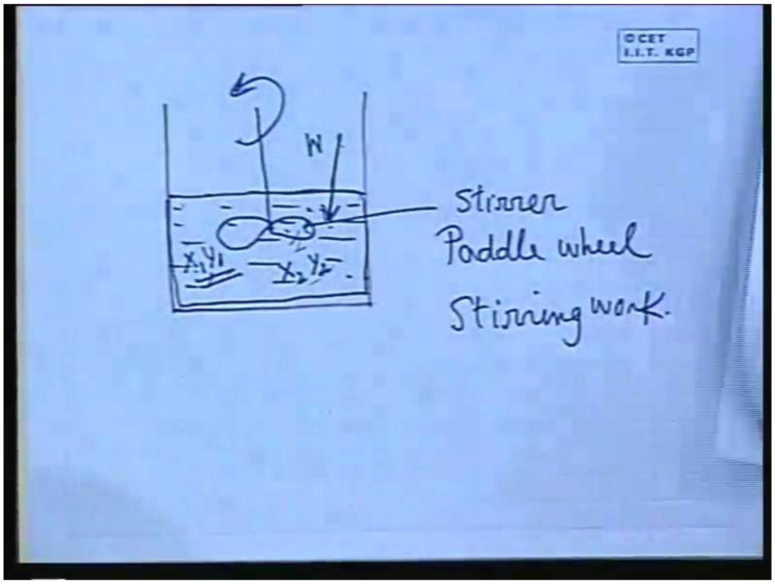

Paddle wheel work is very simple as the name itself tells what a paddle wheel work is. If we consider some liquid or some fluid, better to consider liquid, some liquid in a container and if you stir it with a stirrer or paddle wheel, rotate it. What is this? By physics, very simple, you stir a paddle wheel or a stirrer in a liquid, its temperature is less. What is done basically? Work is been transferred to this system that means we take this as a system then we can tell what transfer takes place across the system boundary. Work has come from the surrounding to the system which has caused this property to change. It may be denoted by initial property x_1, y_1, any two thermodynamic property, the properties are change to x_2, y_2.

In fact we know what happens; the temperature is increased. Today we can tell that because of the work transfer the internal energy increases, but this type of work transfer is known as paddle work or stirring work. One of the very important difference between the pdV work and this work is here friction is very important. Because of the friction the work is done. Because if you want to rotate the stirrer or paddle wheel within a fluid as a system. If the fluid has no friction no viscosity, so no work is required to rotate it. Here friction is the agent for the work to be transferred to the system. This is the dissipative work but it is a work transfer. If you think from the thermodynamic point of view, if you define these are the system and if i ask what is the energy transfer, you tell work transfer because of the rotation of the paddle wheel. This work transfer cause a change in the state of the system from any two independent thermodynamic properties to other two independent thermodynamic properties to define the different states

In fact, what happens is that the temperature is changed and if the temperature is changed some other properties will be changing according to the relationship of the different properties. So this is a kind of work transfer which is the irreversible work transfer which means this is dissipative in nature and here friction is the agent for transferring the work. This is known as paddle wheel work or stirrer work, sometimes stirring work. These stirring energies are important. When you solve problems you will see some paddle wheel work among this, so this is paddle wheel work

Another is the flow work. Flow work, probably, you have already heard or you have already read in fluid mechanics. What is flow work? Flow work is the work required to maintain a flow. What happens when there is a continuous flow? You see paddle wheel work and the pdV work part into closed system. Now, the flow work part into a control volume and there is a steady flow of fluid, a steady flow of masses and steady flow of matter; coming into the system, going out of the system, control volume system or control volume

When a steady flow occurs or it may be unsteady flow, any flow occurs at any section to maintain the flow, if you consider a layer at any section it has to continuously move. That means if you make a Lagrangean approach, for example, of fluid mechanics we tell layer, you see the layer has to always push the neighboring layer to make it go through just like you going in a queue that when you are in a queue you have to always push your neighboring person in front of you to make your way through. Therefore, each and every section does some work in the neighboring fluid, that means, the adjacent section, downstream to make it so a through. So by this it does work on its adjacent neighboring downstream layer. This work is known as flow work and because of this work, again, the adjacent neighboring layer which receives this work stores some form of energy. We can tell always that at any section there is some stored energy in the fluid by virtue of which it can do work on its neighboring layer to make it so a through. This is the basic concept. This work is known as flow work and the energy by which it can do so is known as pressured energy. So, pressured energy and flow work are the two synonymous things. In case of fluid mechanics, we call it is as pressured energy, this is the convention. In case of thermodynamics, dealing with this thing, we tell it as flow work. Let us again recapitulate this flow work and you know probably from fluid mechanics, the expression of the flow work in a flowing system, if you denote the pressure at a section p and density of the fluid is rho then flow work or pressured energy is p by rho or p into small v, where small v is the specific volume one by rho. Let us recapitulate this again.

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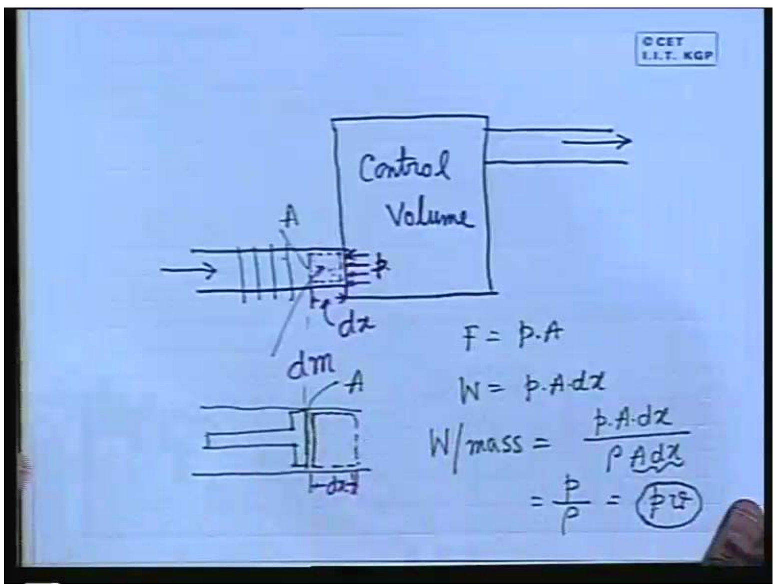

This is the basic definition. Now, let us consider a control volume. We know what a control volume is. There is a continuous mass coming in. Let us consider this is the inlet and let us consider this is the outlet. This is a typical practical control volume. The practical examples are like a control volume may be an air compressor as you know what the function of air compression is. It receives air at low pressure and temperature continuously; then, compress it because of some thermo machinery action within it that I am not going to discuss here because that is beyond the subject of basic thermodynamic, we consider this as a black box.

Finally, it delivers the work, air at high pressure and temperature. It can be a turbine where high pressure and high temperature gas or air is received and it is been delivered at a lower pressure and temperature. In doing so, the control volume either develops work in case of turbine or receives work in case of compression.

There are other examples, heat exchangers where there is a continuous in flow of material and continuous out flow of material. So they are the examples of control volume systems turbines, compressors and heat exchanger. Let us consider such a control volume and we too understand the flow work. Let us consider some amount of mass here at the adjacent boundary of the control volume; this is dx; let this mass amount be dm. Let us consider this amount of mass has to be forced into the control volume by against the pressure that means this has to be done. For example, here a pressure existing against at this boundary of the control volume let it be p. The situation is like that to understand it again, that against a pressure p here, we have to force this amount of mass into the control volume whose amount is dm. How to do it? To conceive it, for understanding, you can think this way that for example, this is the fluid; the fluid in this left side that means, upstream side of this identified mass acts as the piston to force it through the control volume. If we do that you can draw the diagram again. We can consider this mass like dx and here we can conceive the fluid acting as a piston, just for our understanding, hypothetical piston which is pushing. This is nothing but the fluid behind this upstream pushing this, through this. So, what is the work done? The force on this piston will be against this pressure p which is prevailing here also, the small elemental mass; let the cross sectional area is A, so p into A. The work done is p into A into dx. This work, while it is done on this layer, on this element of fluid, not layer, we have identified a small amount of mass. This is stored in the mass as energy which is pressure energy; this causes the control volume. This is usually expressed per unit mass; this is the convention work done on this mass per unit mass or the energy stored in this elemental mass per unit; mass will be p A dx divided by, what is the mass, rho into A dx A, where dx is the volume, rho is the density. This comes out to be p by rho in thermodynamics. We do not deal with rho; we usually deal with specific volume, one by rho.

Therefore, this p v is the flow work. The definition of flow work is the work that is required to push certain amount of fluid across a section in a flow process or in a control volume. If in a limiting case and dx tends to zero, we can define the flow work per unit mass at each and every section because these are the point functions. This is the expression of flow work.

Next is the shaft work. What is a shaft work? Shaft work is again pertaining to a control volume or a steady flow process that we will appreciate afterwards.

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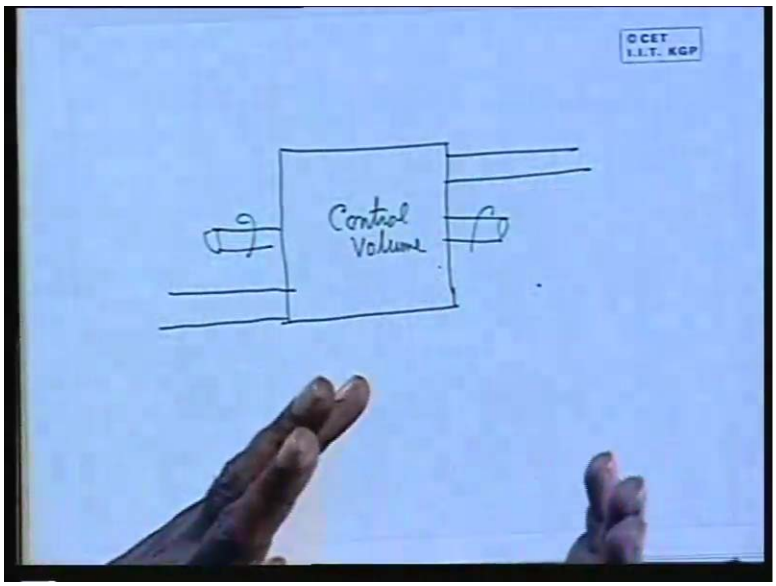

Sometimes what happens when there is a control volume, again we will see because of continuous in flow of matter, as i have told, in case of air compressor or turbine some work is delivered by the control volume or some work is taken by the control volume in case of work interacting devices like air compression and turbine and this work has been obtained or has been given through a rotating shaft against a resistance torque and that is known as shaft work. We make a diagram like that. There is a shaft rotating turbine; it develops power or work to the surrounding through the rotation of a shaft against a resistance torque. Similar case for air compressor or any compressor or a pump, when the work is being given to the control volume, this is, giving through the rotation of a shaft against a resistance torque. This work is named or categorized as shaft work. These are the different forms of mechanical work transfer.

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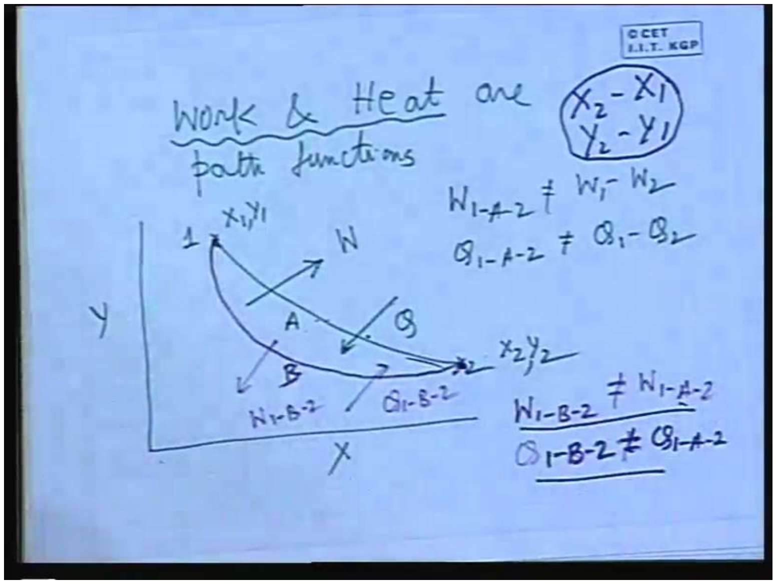

At the end of this discussion, I like to mention very emphatically this thing we now know that work and heat are very important path functions. What does it mean? These are the work energy in transit; let us think that a thermodynamic coordinate diagram y x and if a process starts from state one and goes to state two with property X_1, Y_1 and any two independent intensity property X_2, Y_2. If there is a work and heat interactions let us consider work is coming out in this process w and heat is being given Q in a different direction i assume, then the thing is that this work for this path is fixed but it depends upon these two paths. We can write this W as W_1 if we specify the path as some middle quantity A_1 A_2 which is not equal to W_1- W_2; though this is very simple today, but still you should be aware in mind.

Similarly, $Q_{1\text{-}A\text{-}2}$ is the heat which is been given to the system in this process but which is not equal to $Q_{1\text{-}Q\text{-}2}$ which means that if we have an another path for example we make the system to go through another path from state one to state two through a path 1B2, in that case $W_{1\text{-}B\text{-}2}$ will not be equal to $W_{1\text{-}A\text{-}2}$ because they are path function. If the work develops is $W_{1\text{-}B\text{-}2}$ then this is not same; if the heat given in this path is $Q_{1\text{-}B\text{-}2}$. So, $Q_{1\text{-}B\text{-}2}$ is not equal to $Q_{1\text{-}A\text{-}2}$ means that even if the system connects to terminal state points same to terminal state point, but through different path, work and heat interactions through different paths are not same because they are not path functions. But if anybody asks what is the change in its property in this path 1A2 you tell the change in property is X_2-X_1, property X; property Y is Y_2-Y_1 if anybody ask what is the change in property X and Y when a system performs a path 1B2 from the same state point A to the same state point B, then the change will be same because they are point functions their values are associated with this state point.

so whichever may be the path, their changes will remain the same; whereas, work and heat are not path functions; they depend only on the path so the work interactions in different paths will be differ and they depend only on the path. They are not described to the state of the system, this is very important while the internal energy or energy stored within the system, that is, the point function which is stored at the state points. I will come afterwards while discussing the first law of thermodynamics.

Now I come to the first law of thermodynamics. Let us ask what is first law of thermodynamics? First law of thermodynamics is nothing different from the conservation of energy; it is a look from a different angle. So, first law of thermodynamics, first line of definition, if anybody asks, what is the first law of thermodynamics? It is conservation of energy.

The first law of thermodynamics is stated in the thermodynamic field of thermodynamics in a different way. When we are concerned about the conversion from heat to work or work to heat this is basically the way the first law of thermodynamics originated. However, first law of thermodynamics in a broad sense is the conservation of energy, but this will be defined the same conservation of energy principle in terms of the processes which converts heat to work or work to heat. We will be concentrating the discussion on first law in relation to conversion of heat to work and work to heat.

Before giving you a formal statement of the conservation of energy, in this regard, as the first law of thermodynamics, let us see that how it was first discovered or originated by the great scientist Joule.

Let us go through Joules experiment which is again a recapitulation of what you have read at school level, what Joule did.

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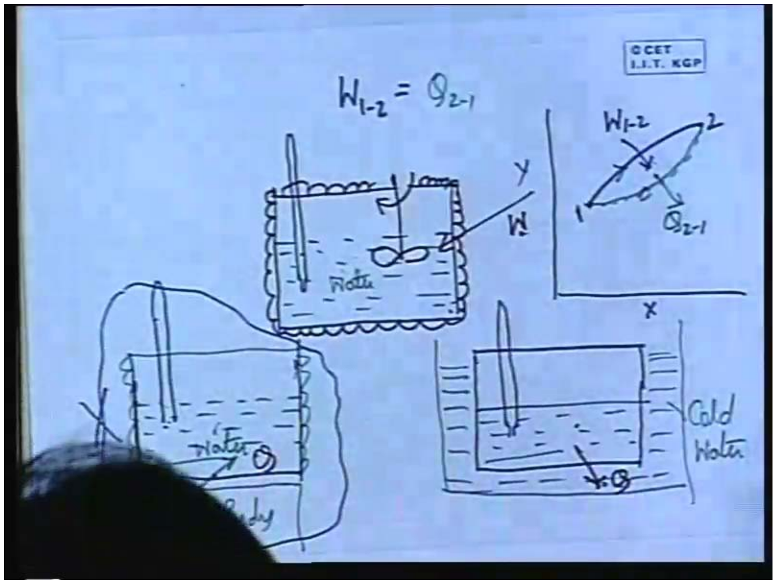

Let us consider the Joules experiment. First take two k container where there is water for example, let water and the well. Let a paddle wheel or a stirrer be rotated and the entire system is insulated; no heat is being allowed; let this be also closed and insulated.

Let a thermometer be dipped into it, the way Joule did the experiment. He rotated the stirrer for some time and then stopped. What happened, tell me? Some amount of work cross the system boundary that means it has come from the surrounding to the system for which the temperature has raised; the system state has changed. Then Joule observed that because of this work transfer into the system there is a change of state which is manifested by the raising temperature; did he also measure the pressure? He found the pressure remains all most the same. What he did after that? He took this same container well, same container with the water and made it insulated for example by the sides. Let it be closed and in one side of it, it made a contact with a hot body

We simply mean that the added heat to the system and he found that the same temperature rise can be observed by giving a calculated amount of heat and the same change of the state. What concluded into thing that moment probably today you will laugh at him because this was some hundred fifty years back that people use to think before that the heat and work are the two things at entirely different quantity.

They may be the energy transfer but they do not have any link with each other. It was Joule first to point it out from this simple experiment that work and heat can produce the same effect on a system and they two cannot be different type of energy transfer though may be different afterwards the difference will be proved in second law but they are all most same type of energy transfer by producing the effect in a system. Both these things can produce the same effect in a system.

Then little farther what he did there. Now come back to this diagram that means some work transfer took place and the system temperature increase. Now, we remove this insulation, what it did? When we recognize this one that giving heat temperature can be increased what he did, we took a bigger bath water containing cold water that means this is cold water.

What happen heat comes out from the system to this cold water and he restored the initial state by reading the thermometer that means the initial state of the water from where the stirrer where the transfer the work to resist temperature, then he found the amount of heat which was coming out because of this which is the exactly the same which was giving to resist temperature and at the same time this becomes exactly equal to the work and he took different fluid and a different container different time and he always found is heat and work is same by doing this experiment.

Now, if I draw this in a cycle here, how can I show it in a thermodynamic cycle Y,X. For example, the first one is a process it goes from state 1 to 2, while one minute let me explain. so work is being given work and if it comes back again to the state 1 then he has found out that some heat the work is being given heat is coming out 2 to 1 and he has found out that this w_{1-2} is exactly equal to Q_{2-1} and this is a cyclic process, what is a cyclic process? If a system performs number of processes so that it comes back again to the initial state then the number of processes forms a closed loop in thermodynamic diagram which is called a thermodynamic cycle.

So, it is a thermodynamic cycle or cyclic process where system starts from 1 goes to 2 and then system comes back again to two. But if it is not a reversible process, then we can show it by a dotted line, you can ask me a question that, how do you specify the process.

This will be shown by a dotted line, that means now I tell you that, when I specify a natural process in a thermodynamic diagram it is always advisable you show it by a because this is a irreversible process not a quasi equilibrium process by a w_{1-2} by a dotted line it you cannot specify it by a form line and this is the process where heat is this is coming out to coming back to the initial state.

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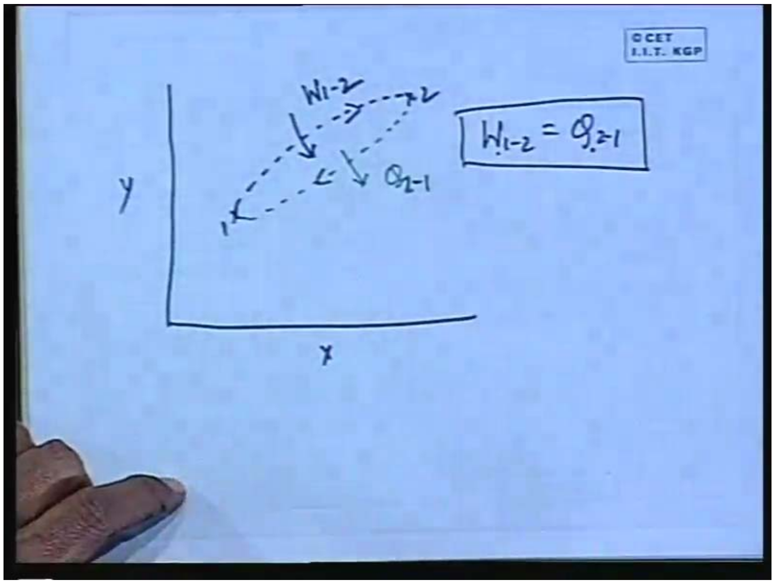

So we get the work w_{2-1} and w_{1-2} is Q_{2-1} simply this was the observation of Joule. While we did the experiment that time the unit switch were expressing the mechanical work and the heat quantity were entirely different.

Therefore, because of these difference in unit, the work quantity evaluated in that unit and heat quantity evaluated in the unit of heat that was previously existing calorie, these two are not equal and there was proportional to each other which is known as mechanical equivalent of it, but that is absolute by this time, because now work and heat are expressed in the same unit, because they are the same type of energy transfer which can cause similar effects in a system and in a cyclic process if you see then the work becomes equal to heat.

Now I describe this process, let this statement in a more formal way. Now, before doing that I must do there are sign conventions.

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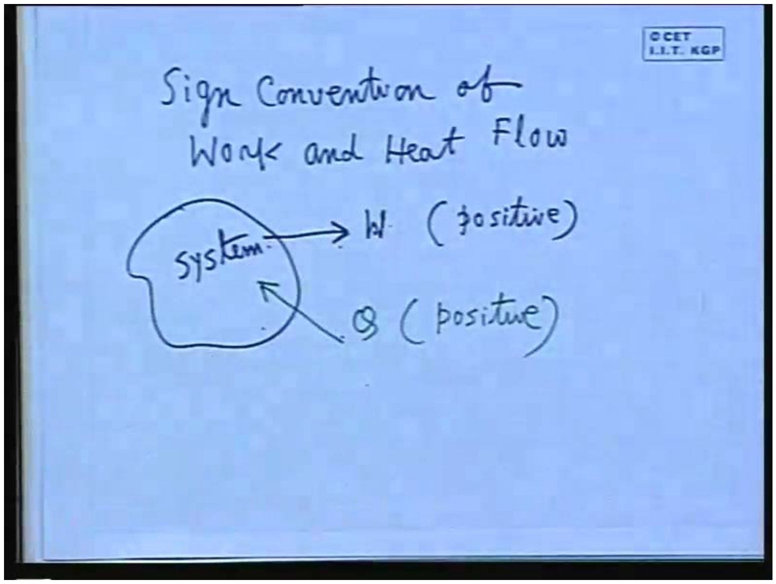

Sign conventions implies write that sign convention of work and heat transfer of work and heat flow now let us consider a system with respect to a closed system I am drawing it is same for open system and work is coming out, it is considered positive. So positive direction of the work is consist a convention you can do it in other way also but this is the convention most of the books most of the literature follow this when work is coming out of the system to surrounding we call it as positive.

when work is given to the system from a surrounding it is negative just delivers this the heat that means when heat is giving to the system then heat is positive while heat is coming out of the system it is negative so common convention which is going on since the birth of thermodynamics is this that the two different directions are considered the positive for this two cases.

When work quantity is concerned work coming out of the system to the surrounding is considered, positive work going into the system from the surrounding is negative, while it is the reverse. When heat is given into the system is positive coming out is the negative, but you can do other way also that means, positive for both the quantities in the same direction, the work out is positive heat out is positive, work in is negative heat in is negative, but this way you will be confused because most of the literature and the follows this terminology.

So, therefore the equations will be little different we get plus minus sign but ultimately the results are same that you will see afterwards. Better we should follow this convention the work coming out is positive coming out of a system and the reverse is the negative. Similarly, heat given into the system is positive coming out is negative, so with this as the sign convention and choose experiments in mind, now we can tell the thermodynamics first law in a formal form like this.

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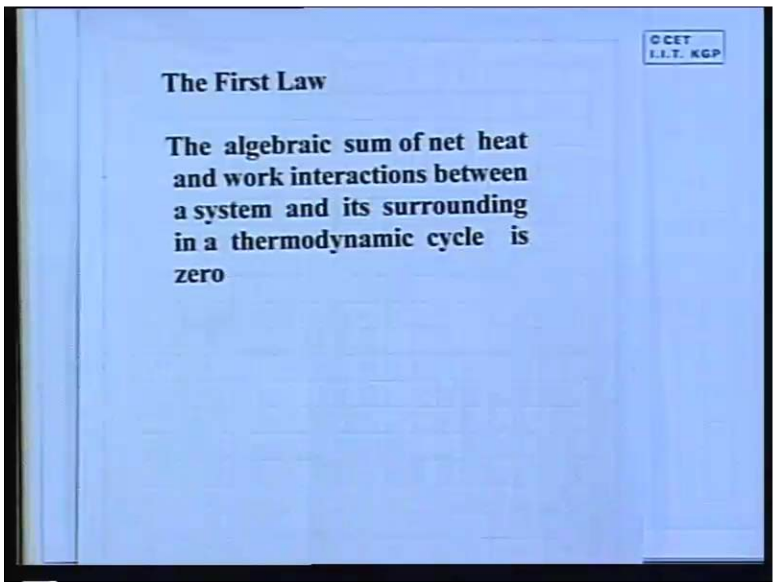

The first law is the algebraic sum of work and heat interactions, net work and heat interactions in a cyclic process by a system with its surroundings in a cyclic process is zero. Today it appears to be a common sense, because in a cyclic process when a system come backs to its initial state all the energy interactions have to be zero, it gains something, it loose something and ultimately it is net zero.

So, that it can come back to its initial state, this is the formal statement of the first law of thermodynamics the algebraic sum of net heat and work interactions between a system and its surrounding in a thermodynamic cycle is zero, that means, with this definition we can write that algebraic sum of heat in a cycle is equal to algebraic sum of with this sign convention positive to positive, that means if there is a net heat added to the cycle then there will be a net work out of the cycle has to be whose magnitude will be same as the net it added, that means net interactions of heat and work will be zero.

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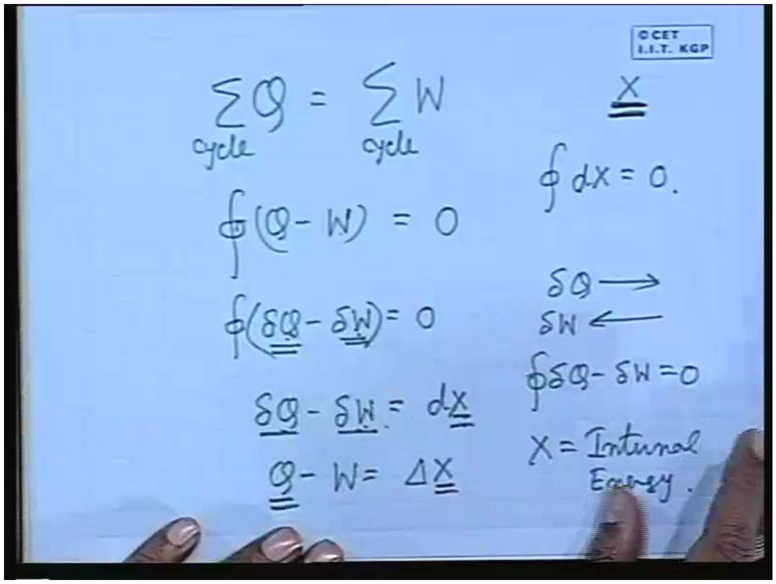

so this is basically the first step of the analytical expressions of the first law of thermodynamics This can be written like this, in an integral fashion and taking this into this side Q minus w this means in a cycle with a sign like that the direction is equal to zero, that means difference of heat and work interactions in a cyclic process must be zero, Q minus w is zero.

This can be interpreted in a different way like this, if I write this for a small infinite small process in state of Q and W, let us write this deltaQ minus deltaw the same expression I am writing what is this that means, we consider an infinite small process executed by a system where deltaQ is the heat added and deltaW is the work done by the system. That means, we consider a system which performs an infinite small process, try to understand and a differential amount of heat differential means not in calculus sense of differential because Q and W are the path function they cannot be differentiated, that means infinite small amount of deltaQ is given and infinite small amount of deltaW is coming out. If you integrate this in a thermodynamic cycle, then we can write cyclic integral delQ minus delW is 0, why I am writing this way.

Now you know from mathematics elementary mathematics that cyclic integral of any point function is zero, which means I can write cyclic integral of any point function x in this fashion dx is zero x is any point function which is a property of a system

So, for any property of a system already in my knowledge I can write differential of that property in a cyclic integral resident physical sense also tells like that in a cyclic integral property change has to be zero because it comes back to its initial state, so all properties will be regain back to its initial values, so property changes as zero, therefore for all properties and all point functions x this is zero and if this is so then obviously one can tell that this becomes is equal to dx, that means this difference can be expressed by a point functions which he may not load so far .

But now we know that the difference between the heat and work is a point function, note in a cyclic process that means, in an infinite small process deltaQ minus deltaW is dx. That means we have recognized deltaQ is the heat given to a system in a infinite small process and we get the work done as deltaW, but their difference we don't know what it is,it will be something, but its cyclic integral is zero, but now at least to you know that their difference is a point function that means if you convert the statement to a finite process then you can write Q minus W is delta of x, x is the property.

That means for any finite process the heat given to the system in executing the process minus the work delivered by the system in executing the process is equals to the change of a point function that means heat is a path function, work is a path function; but their difference is a change in a point function. We go to the earlier one which we discussed that there are number of paths connecting the two state points work and heats are different, but their differences are same that means they are different but following a constant in equations that difference between this two Q and W though Q and W are varying from process to process, but their difference is the same that means this is the change of a point function between the two states and this point function is defined as internal energy s. So, therefore now we can write, for an infinite small process deltaQ minus deltaW is dE, now E as the internal energy well so this can be written this way sometimes deltaQ taking this here deltaW plus dE now for a finite process what will be Q minus W is equal to deltaE and this will be Q is equal to W plus deltaE.

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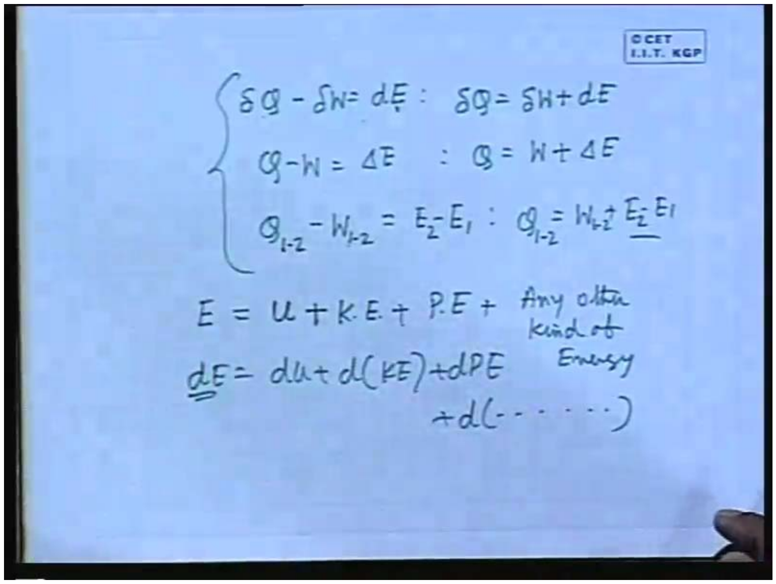

Now, if we denote this state points then it will be much better, that means process connecting one to two terms that means from state 1 to state 2 work obtained for the process from state 1 to state 2, then delE from state 1 to state 2 will be simply E_2 minus E_1 that means this version will be $Q_{1\text{-}2}$ is equal to $W_{1\text{-}2}$ plus E_2 minus $E_{1.}$ Now, mathematically this is arrived physically also it is true that in a system executing a finite process if I give some amount of heat and if I take some amount of work their balance has to be stored in the system.

They are not necessarily make equal they not necessarily to be equal they may be equal in that case dE will be zero but if they are not equal then they are balance has to be stored in that, that means if heat added is more than the work coming out then this is positive that means the difference will be stored as an energy within the system. If it is other way some stored energy has to be released so that there will be a decrease in the internal energy. So therefore this gives the point function status of energy by thermodynamics which is defined as internal energy and physically which we mean as energy stored in a system.

Now what is this internal energy? Now, I think that internal energy E composed of several paths. The very first is that in any system what is the very primary form of internal energy or fine primary component of internal energy which is stored in a system, intermolecular energy because of temperature if in a based system does not move there is no kinetic energy nothing that there is intermolecular energy.

So, first part is the u which is inter molecular energy, plus there may the other forms of energy stored any form of energy stored within the system will be consider internal energy. I give you one example, that there is a gas or there is a motion with in it that means the kinetic energy contained within the system there may be kinetic energy plus there may be potential energy of the system because of its position or placement in a conservative force filled that you place the system in a conservative force filled the work done on it non dissipative work that is stored within the system as the stored energy that is potential energy or any other kind of energy. So, therefore the internal energy comprises of this, that means change of internal energy all are point functions du plus d of KE plus d of PE plus d of any other form of stored energy.

All these together comprise the internal energy E, so this is the form that internal energy is defined. So, therefore we see that internal energy is a point function and we can define now internal energy like that.

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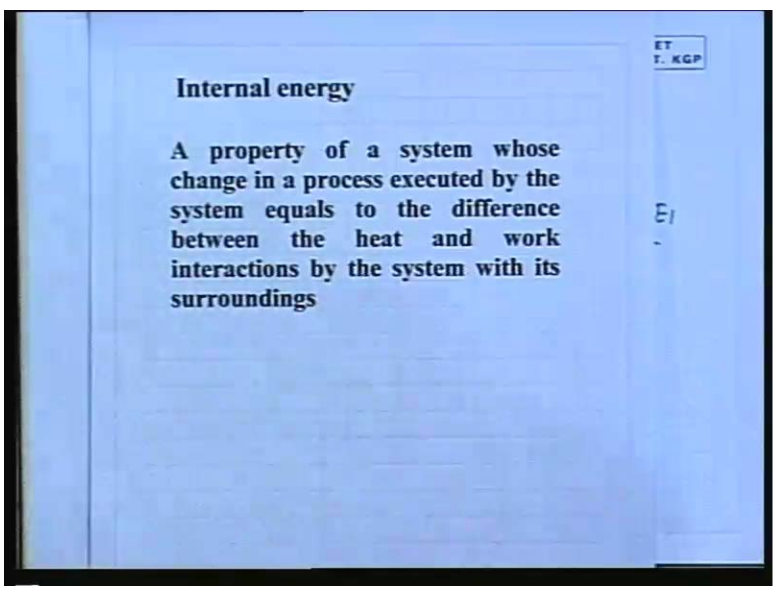

A property of a system whose change in a process executed by the system equals to the difference between the heat and work interactions by the system with its surrounding, this is another form of first law, the beauty of first law is that though work and heat are path functions but the difference is a point function two are path functions but their difference is a point functions and that point function is the internal energy that is the energy stored within the system.

So, internal energy is therefore a property of the system state variable which equals to the difference between work and heat and another important point you must know the birth of internal energy or the definition of the internal energy in classical thermodynamics is given through its difference, I am not going to define internal energy on the absolute value, but it is initially defined in terms of this difference, that means heat minus work is the difference in internal energy not equals to the internal energy. Today I think I will end here. We have just started the first law internal energy how the first law is written. About the sign convention now you see the sign convention is that cyclic integral dQ minus dw is zero.

Some modern books you will see the cyclic integral dQ plus dw is 0, just all on a suddenly open the book are we what professor. Stomads Tolds cyclic integral dQ minus dw is 0 and dQ plus dw is 0, that means the sign convention is that there in same directions both are positive very simple, but if you follow the classical sign convention that work coming out is positive then heat given in the positive then cyclic integral dQ minus dw is 0 or delQ minus delW this del and d are infinite small amount of work and heat interactions not their differential, because they are path functions, but their difference is a point function which is the differential of internal energy that is an exact differential because internal energy the state variable and point function.

When it is suddenly removed, this is a irreversible works that has to be found out from the experiment that cannot given by these expression, but one thing when I define the first law of thermodynamics, there is no restriction on friction because it is the conservation of energy there is no restriction on friction

Now, if somebody once to substitute W by pdV then the question of friction comes in to be there is a constant that it is a frictionless system reversible work you understand, so in a irreversible work that means you suddenly reduce the load and the piston the cylinder comes first and work is deliver to the surrounding that is an irreversible one that is to be measured only given by the measured value that cannot be substituted by pdV work.

Now, Q is equal to W plus G it is for both frictional and frictionless systems so that there is reversible work or irreversible work but when you substitute the work by some term then you have to be causes what you are doing if you substitute it by pdV then you are doing it for irreversible process that means non dissipative frictionless system, Otherwise you are not permitted to do that that I will come afterwards all right any question

Paddle wheel work and shaft work is different, paddle wheel work is the work which is done in a closed system by virtue of the friction if you rotate a stirrer rotate a paddle wheel that is the work transfer and shaft work is different that is the rotation of a shaft against the resistance against a torque that is also a non reversible work, but that is a different kind of work which pertains to a control volume system continuous flow of matter which gives rise to so we gives ah some amount of work transfer to the surrounding through the rotation of the shaft that is the only difference.

We cannot make these two things in a same shape and try to find out a microscopic difference between that these two things are entirely different, one part into a closed system and the work done by rotating a paddle wheel by the agency friction another is an open system where the work is developed by the rotation of a shaft against a resisting torque, that is the difference just the difference as it is by the physics of the thing as you describe it mechanically. There is no more thermodynamics in between this .Thank you.