Concepts of chemistry for engineering
Professor Arnab Dutta
Indian Institute of Technology Bombay
Lecture 50
Introduction to Thermodynamics: Work, Heat and Energy

Hello, my name is Arnab Dutta and I am an assistant professor in Chemistry Department. And today we are going to discuss about thermodynamics, its basic concepts, fundamentals and applications. Let us begin with thermodynamics.

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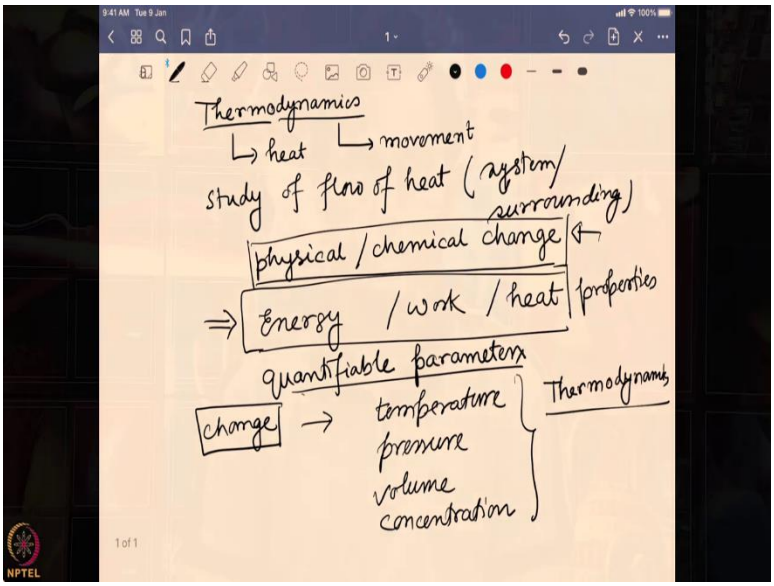

So, when we talk about thermodynamics, and we look into this particular term, we found there are two important terms come together. One is thermal, which means heat and one is dynamics that means movement. So, this thermodynamics basically covers the study of flow of heat around a system and its surrounding and discuss how this system is actually exchanging heat around it and how a physical and chemical change can affect this particular system.

So, all together over here, we are mostly following the physical and chemical change in the form of heat exchange between a system and a surrounding and that is not only the heat, there are two important properties of the system and surroundings, also come into the foray and they are energy and work. So, now we have 3 different properties, energy, heat, work.

They all come together, and these properties are actually going to follow by certain quantifiable parameters that can give us an idea how these 3 parameters, energy, work, and heat are actually exchanging, and those parameters are actually going to change and the change of the system we actually followed that with these quantifiable parameters and those are parameters like temperature, pressure, volume, and even concentration of a system.

So, over here we are going to look into a change happening in a system when it is in a particular surrounding and those change are actually initiated by the physical and chemical change, and those are actually changing the very basic properties of a system in the form of energy, work, and heat, and we can quantify them with this particular parametesr.

And all this study we are doing this that is known as the study of thermodynamics. To give you an example, what kind of system we are actually talking about.

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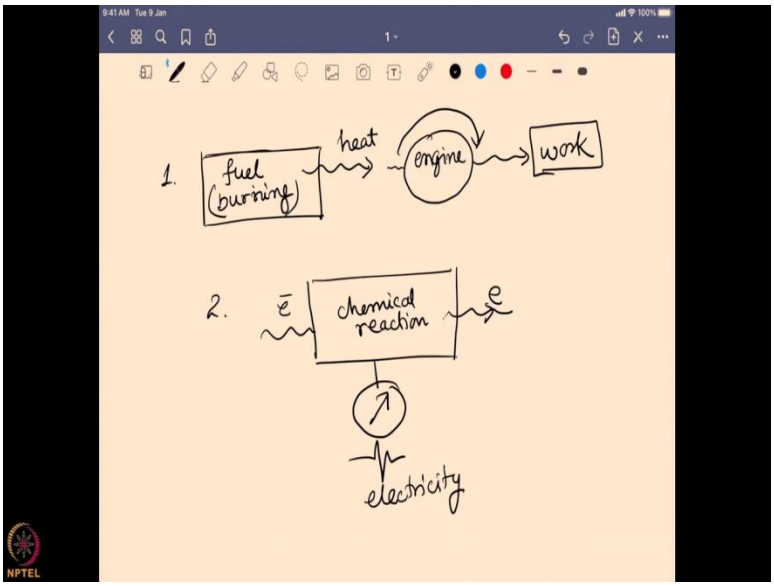

So, how is thermodynamics is actually playing their role? To give you an example, we take the example of a system where the fuel is actually burning. In this system, we put some fuel, we burn it, and we create some heat and that heat is generated by the system. Now, how much heat is generated? How much actually the fuel is burning?

So, all this calculation, we can quantify with the help of thermodynamics. Now say, we have the heat and over there, this heat is actually run through an engine, which can transfer that heat into

the form of work. Now, how much of this heat can get transformed into the work? How much it is getting lost into the mechanical force to run the engine, that again, we can calculate with the help of thermodynamics.

Now, imagine a second example of chemical reaction. During a chemical reaction, it is a redox reaction or reduction-oxidation reaction where electron is actually getting exchange, and this electron exchange can initiate a flow of the electron, which is also known as electricity. Now, how much electricity we are generating through this chemical reaction that also can come under the purview of thermodynamics.

So, thermodynamics can help us understand how a physical or chemical reaction is actually helping us to get in the different form of energy and how we can actually transfer that into the form of work. So, that is the basic background of thermodynamics. Now, to understand thermodynamics, we need to understand some of the basic concepts of thermodynamics.

So, we will go through the basic concepts one by one. Let us start the first thing we actually think about and that is known as the thermodynamic system.

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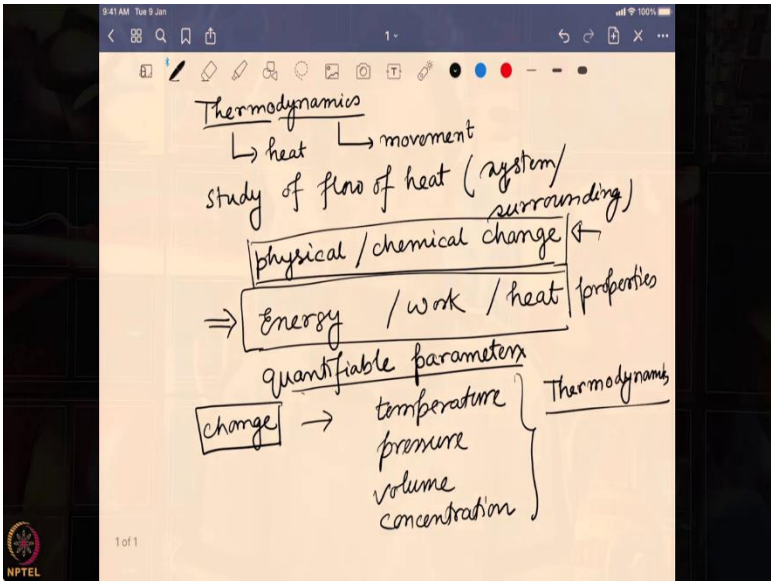

So, when we call about a thermodynamic system, we are actually basically talk about 2 things, a system and its surrounding. Now, imagine that we are actually interested in one of the physical or chemical changes into a particular matter and the region or space that we are interested in is

actually known as the system. So, for an example, in this particular scenario we are actually very much interested what is happening in this particular region.

That will be the system. So, whatever we are calculating, whatever we are measuring all the parameters, all the factors, all the properties, energy, work, or heat, we are measuring with respect to this, particularly confined region and that is known as a system.

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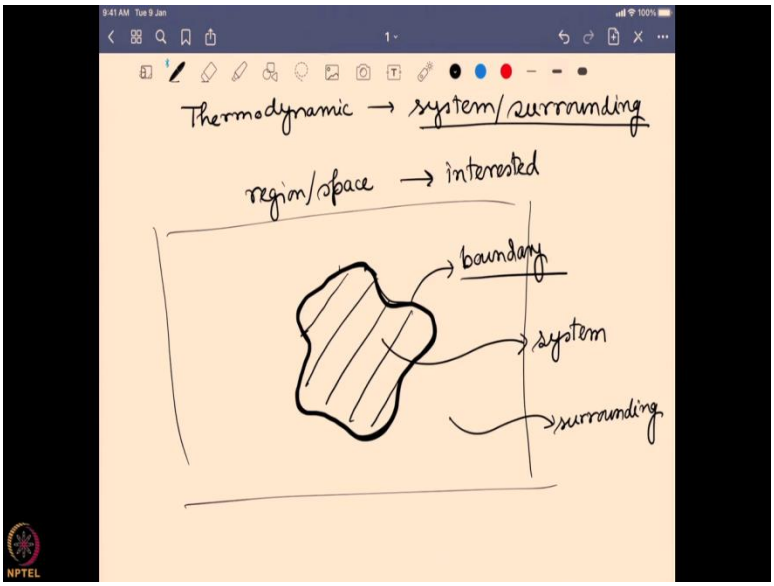

Now, if we look into the system, the rest of it, the rest of the universe around it is known as the surrounding. So, what is the basic difference between system and surrounding? System is this region or confined space that we are interested in where all the changes are happening. Now, the changes are also getting exchanged with the other thing, everything present around that system and that is known as the surrounding, that is nothing but everything other than the system.

Now, how the system and surrounding are separated? They are separated by this particular boundary. This is known as the boundary, which actually separates the system and surrounding. So, again if we want to recap, there are 3 important factors. One is the system, one is the surrounding, and this thing which is separating both system and surrounding it is known as boundary. Now, depending how this system and surrounding are interacting through the boundary, we can define system in 3 different factors. Let us take a look into them.

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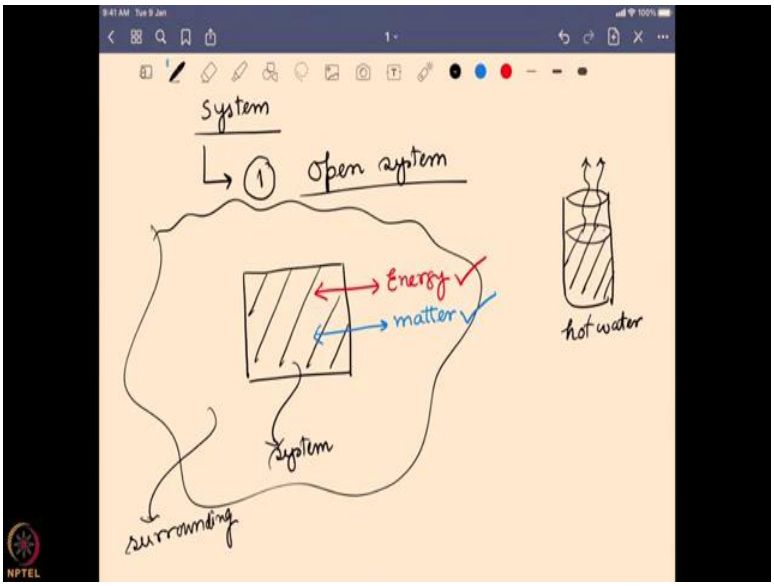

So, we can define system in 3 different ways. The first one is known as an open system. Now, what is na open system. An open system is such that we have a particular system present over here and that is the surrounding around it. So, again this is the system and this is the surrounding. Now, we have such a boundary that allows exchange of energy in between the system and surrounding and not only that, it also allows the exchange of matter in the form of gas, liquid, or solid. If both of them are actually allowed, then we call this particular system an open system.

To give you an example, say I have a glass of water and over there, I put some hot water here. Over here, the glass containing the water is my system, and everything else is my surrounding. And now, what happens, some of the water, because if it is hot, it can vaporized. So, over there, it is not only exchanged energy in the form of heat, but it also exchanging some of the water molecules goes from the liquid state to the vapor state and escapes the glass or system.

Over here, the system is exchanging not only the heat, but it is also exchanging the matter. So, that is an example of an open system.

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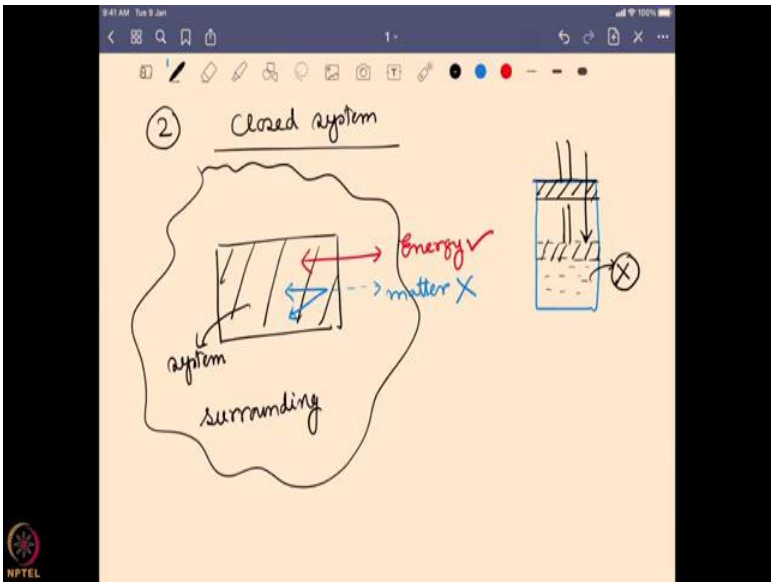

The next one comes into the picture is known as a close system. What is a close system? A close system is again a system we are considering, which is surrounded by , again the surroundings. So, this is my surrounding, and this is my system. So, over here system and surrounding are very much same, as the open system we discussed earlier.

Now, what is the big difference over here? The boundary such that it still is allowing the exchange of energy, it is still allowed; however, the matter exchange is now stopped. So, the matter cannot come out of the system anymore, so that will be defined as a close system where the energy can be exchanged, but not the matter and that is known as a close system.

So, what could be a good example of that? So, example can be given with the help of a piston. So, say this is actually a system where we have some gas, and over there, we put a piston on the top of that. Now, if I decided to bring the piston down. To do that, I am actually doing some work and changing the energy, so there is a change in the energy between the system and surrounding, but the gas present in this system that cannot escape out, that cannot escape.

So over here, there is a direct exchange of energy is possible between the system and the surrounding, but not the matter. So, that is actually known as a close system.

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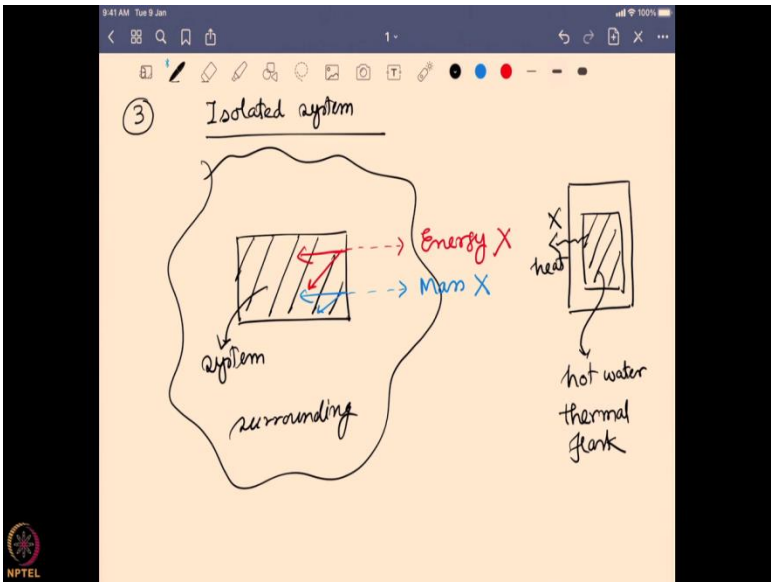

Now, come to the next version, when we talk about an isolated system. What is an isolated system? Again, we have a particular region that we are interested what is happening over there that means the system, and here is the surrounding and over here what is the difference is now, even energy cannot come out of the system anymore, and the mass is also confined in the system. It cannot come out of the system.

There is no direct exchange of neither energy nor mass between the system and surrounding, and that is known as an isolated system. One of the good examples would be again say I have a hot water, but now, I put that in a thermal flask. So, thermal flask is such a way that it is close lid system, which actually not allowing any of the water to escape the system, compared to an open glass where the water can evaporates out. Over here, the water cannot evaporate.

So, this particular system is not allowing any mass transfer, and also it has such a boundary that it is not even allowing the heat to pass out of the system. So, there is no exchange of energy either. So, a thermal flask can be considered as an example of an isolated system, which not allowing any transfer of energy or it is not allowing any transfer of the mass. So, these are the 3 different systems we can think about again to just put it together.

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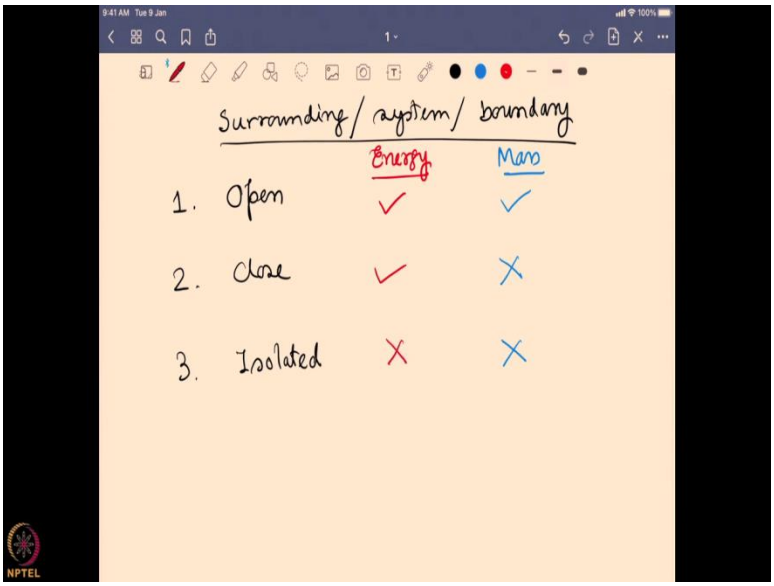

So, we have surrounding, we have system, we have boundary, which is separating them and depending on the nature of them, we can define, there are 3 different system possible, open system, close system, and isolated system. And what is actually happening, we define it whether it can exchange mass, whether it can exchange energy are not.

In an open system, both of them are actually allowed. In a close system, energy exchange is allowed, mass is not. And in an isolated system, neither mass, nor energy is allowed to exchange. So, that is the 3 different variants of system we can think about with the help of different qualities of the boundaries.

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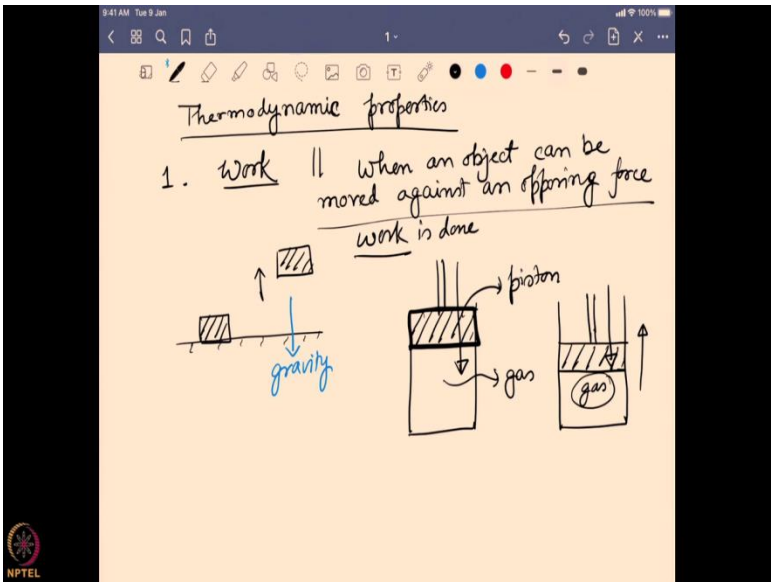

Now we will go to the next section, and we will discuss about 3 important thermodynamic properties, those properties, which will help us to understand the system properly. So, what are those properties we are actually thinking about? So, there are 3 different thermodynamic properties it comes to our mind. First is work. So, what is the definition of a work?

So, if we go to the basic physics, the definition of a work is the following, when an object can be moved against an opposing force, we say that work is actually done. So, that is the definition of a work. When we actually doing or moving some object, such a way that it is going against an opposing force. For an example, very simple system is that we have a particular mass present on the ground floor, and then we are lifting the mass up.

Over here, we are doing a work, because over here we are working against the gravity, because gravity wants to make sure that it stays on the ground level, but when we are working it and moving it up, we are working against the gravity, that is the opposing force over here and we can say a work has been done. Now, to understand the thermodynamics, we will take an example of a gas cylinder, which is actually connected with a piston.

So, this gas cylinder is actually bound with a piston over here, and here I have some gas. Now, say I want to push this piston down. I am pushing this piston down, and I am going to this particular

state where I actually bringing it down. So, I am working against the force because the gas molecules, they are actually at a particular density.

Now, I am pushing them to bring it closer. So, to do that, I am acting as the natural force where the gas molecule wants to be as far as possible. Doing that, I am doing an actually work. Over here I am doing this work on the system. So, this is a definition of a work and we can explain that with the help of a gas cylinder bound with a piston.

If we are moving it down, I am actually doing a work. Now, if I move that up, then I am actually making a work done by the system, because the system wants to release it back. The gas is actually going to, again going back to the older condition where they are actually well separated, and for that, that will push the piston against. So, now the gas molecules are actually doing a work against the force of the piston. So, that is we can also define as a work actually been done.

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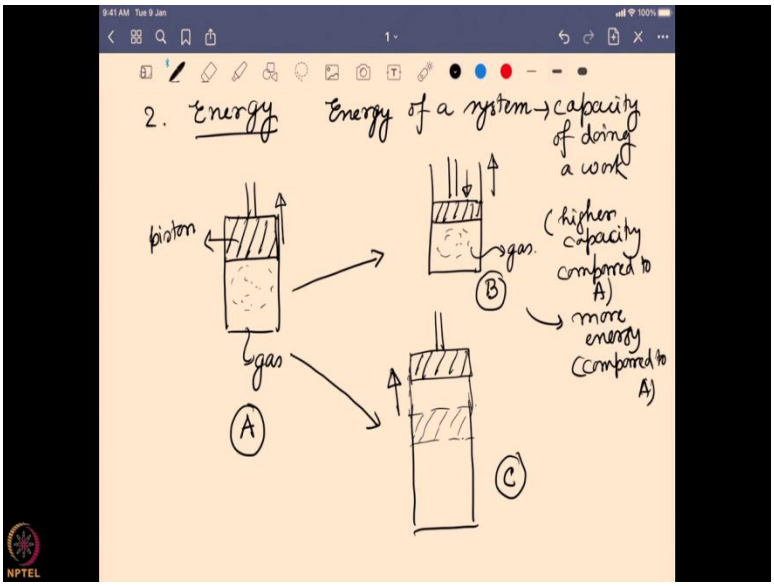

Now going to the next part, the second parameter we are going to discuss is going to be known as energy. Now what is energy? Energy of a system is defined by the capacity of doing a work. That means, if we just imagine that, we say that there is some energy present in a system, what we mean that energy can be utilized to do some work by that particular system. How to explain it properly? So, let us come to this particular picture again.

Say I have, again this particular gas cylinder. We have some gas, and here is the piston present there and that is in situation A. Now from there, I am going to a different situation where I am actually pushing the piston down. So, I am actually doing some work against that gas. But what happens over there. Previously, in the system A, the gas molecules are present over here; they can push the piston up.

But if I compared that system with the new system, say it is system B, which has more tendency to push the piston back. Previously it was A, now it is B. So, which one has more propensity to push the piston back? It will be B because now the gas molecules are much closer, and they want to relax back where they can easily move the piston out.

So, over there, if we compare A and B, because of the molecular properties of the gas molecules, it has more tendency to push the piston out, and that we can explain in the following way that B has more tendency or more capacity to do a work. We can say B has higher capacity now, compared to A, and that we define that B has now more energy, again compared to A.

Now say different scenario, right with the same gas cylinder we are still playing with, but now we are moving this piston up and go to a system C. So, over here, previously, the piston was somewhere around here, and now we have moved that up. With respect to B, we actually move it down in the beginning, the piston. Now we are moving the piston up. So now in the case of C, the gas has more volume to play with.

Now, if we compare A and C where we have more tendency to move the piston out because C already is getting more space that has less tendency to move the piston out, so we can say it has less capacity to do work compared to A. So, we can say it has, again, less energetic system, again in comparison to A. So, over here, you can see that work and energy actually correlated.

One system can do more work; we can say it has more energy. And if we say, a system which has less capacity to do a work, we can say it has less energy. That is the definition of an energy, which can define in the form of a work.

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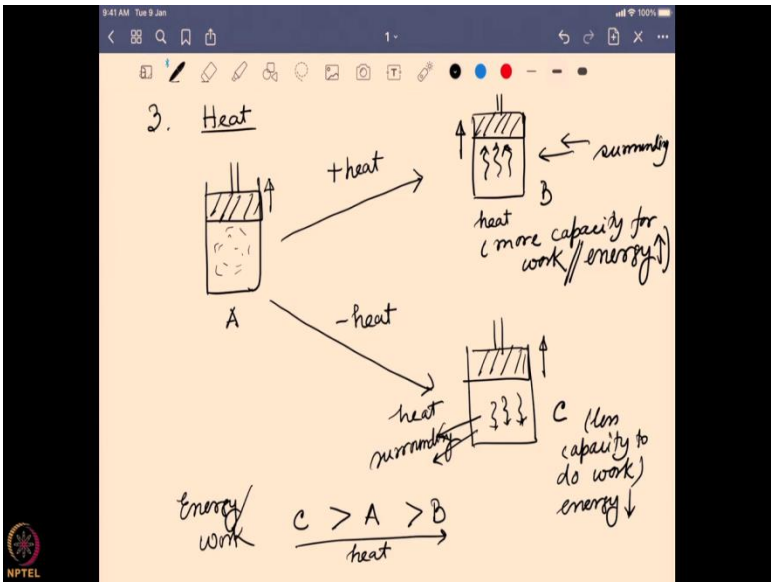

Now, we go to the third important property of a system and that is known as heat. If we look into a heat, heat is such an energetic system, which can also, not only change the energy, but also affect the capacity of doing your work in a system. So, how we can explain? Heat we can also explain with the same gas cylinder system, which is connected to a piston.

So, now see, this is actually the system A, I am talking about. And over here, I am not doing any work or not moving the piston at this moment. But what I am actually doing over here, I am adding some heat to the system. So, I am heating the molecules together. So, over here, what happens the same piston is in the same place, I m going to a condition B where I have now heated the system. And the heat, where it is going from?

It is going from the surrounding to the system. So, there is a direct heat exchange from the surrounding, and it is going towards the system, and this particular system how it is affected? So, now imagine over here, in system A, the gas molecules have a tendency to move the piston out. What happens now if I added some heat over there?

Now gas molecules are more energetic, because with the heat, it directly affects its movement. Now, it is moving away too faster than it is doing compared to its position in A. So, over there, in step B, the molecules are going to have more energy and that will reflect with respect to their propensity or capacity to move the piston out.

So, over here, they will have more capacity for work and that can be reflected, we can say, it has more energy compared to A. Now say I am doing that in a different way, and I am moving the heat out of the system. What happens if I move the heat out of the system? So, where I am taking the heat out, I am taking the heat out from the system to the surrounding.

Now, the surrounding is accepting heat from the system. And by that it is cooling down, say in this system C. So, when it cools down, what happens? The gas molecules, the movement is going to slow down, because I am extracting the energy out of it in the form of heat. And if that is happening, what will be the propensity of it to move the piston up? It will be comparatively be very low with respect to A.

So, we can say, when the heat is actually moved out of the system to surrounding, it is have less capacity to do a work, and that means the overall energy of it, it goes down in compared from C with respect to A. Now you can see the heat is also connected directly in work and energy. And if we want to put all these things together with respect to energy system or propensity to do a work, we can say C has the highest propensity or energy to do work.

Then it is the A, then it is the B, and you can see it is directly correlated with respect to how much heat it has. So, altogether so far, in this first segment, we discussed about the 3 important properties, the heat, work and the energy. And at the same time, we also talked about how a system can be defined, how it is interacting with the surrounding with respect to the boundary, and they are the open system, the close system and the isolated system.

Over here, we will conclude the first segment where we actually now got to know about the heat, energy, and work, how they are correlated, and how it brings up to the first law of thermodynamics. We will look into that in the next segment. Thank you.