Welcome to your entropy class. In the last class, we talked about Clauses Inequality. How to use it to know if there will be any process or not. So, it is directly connected to the second law. So, Clauses Inequality is very important. We will know more about the term del Q by T. and how it is connected to entropy, how the classes have invented a new term, a new property. We will learn about that. So, let's start. entropy introduce the process diagram. PV diagram. and states 1 and 2 are two states. Process can come between 1 and 2 through A. This is the process path. And can go back through B. Similarly, we can go from A 1 to 2 through C and back through B. So, we will consider this as an assumption. which we are assuming is reversible. And we consider this cycle as A or B. We assume that this is totally reversible. Yeah, internally. I mean, inside the system. soon. now if you take reversible, then in this whole cycle, you take this particular term which we had read last time, del Q by T. Since it is a cycle and reversible, it should be 0.
For reversible cycle A-B

$$\oint \frac{\delta Q}{T} = 0 = \int_1^2 (\frac{\delta Q}{T})_A + \int_2^1 (\frac{\delta Q}{T})_B$$

reversible cycle B-C

$$\oint \frac{\delta Q}{T} = 0 = \int_1^2 (\frac{\delta Q}{T})_C + \int_2^1 (\frac{\delta Q}{T})_B$$

Substrct above both equations

$$\int_1^2 (\frac{\delta Q}{T})_A - \int_1^2 \left(\frac{\delta Q}{T}\right)_C = 0$$

$$\int_1^2 (\frac{\delta Q}{T})_A = \int_1^2 \left(\frac{\delta Q}{T}\right)_C$$

Now, this means that this term is independent from path. Because you will integrate 1 to 2 or any process through A or B or C is independent. So, this part, when it comes to independent, means it is not path dependent. It does not depend on the path. And it is only dependent on a state point. So, this is very important that it is an independent path, and this term is dependent on the state. 1 or 2. It is between 1 and 2. So only this can be called a final point. The 1 or 2 point is a state point. Because it is only dependent on P or V. It is not dependent on the path. So, this state function or depends on the end state and this term This is very interesting because if you take a piston cylinder Now, you compress it to here and bring it back. This way your state point is fixed. When you do the integral dv, it comes out to be zero. Similarly, you bring this state point

back from anywhere. whether it is enthalpy or internal energy these properties will be integrated, and it will be zero this term del Q by T when we integrate after cycle in the cyclic process it will be zero so its connection is directly connected to the properties it is a state point heat or work and you do it on the cyclic process, then it is not zero. So, if you do the same in the cyclic process, then it is not zero. Similarly, if you look at heat, you see that we used 4 heat engines, but if you integrate del Q, then this is also not zero. Because it is not a property. when it is. So, this is the same. Point that classes saw and said that this property behaves completely. And that's why this thing is defined as a differential element. A property which is S. And this differential element is defined in the differential term and in the differential form ds is defined as del Q by T So, this is what the Calusius which is in 1865, this term is called as entropy. Now this definition, del S is equal to del Q by T, this will happen only when you consider it as internally reversible. Because the definition we have just defined, when this definition is connected to dS del Q by T, that is only when it is internally reversible. But S, the defined we have done, the property comes out, which depends on the state.

$$ds = \frac{\delta Q}{T}$$

$$S_2 - S_1 = \int_1^2 (\frac{\delta Q}{T})_{int,rev}$$

So, we can take out the change in entropy. So, notice that the change we can take out is delta S, change in entropy. Like we said in the case of energy, we can take out the change in energy with some initial reference. Similarly, entropy also needs reference. So, we can extract change in entropy. To extract absolute entropy, you have to add something related to the third law. We will read about the third law later. We can extract change in entropy by taking that reference. because in that case we can take S as 0, in reference state, so there you can take chain in reference state. This term, as we said, is equal to the internal reversible. But the left-hand term is a property that depends on state. So, if you consider, let us say, in the TS diagram, that your process is state point 1 and this is 2, and the first process is reversible, which you are doing with this. And you come back to this process. Or you can say that you have processed it from 1 to 2 reversible and the dashed line 1 to 2 is now irreversible. So, the question is, will your delta S be the same as the deltaS A and deltaS B? So, It will definitely be same because this is your state point. So, delta S A will be same as delta S B. Change in entropy will be same because it is state point or property. It depends on the state directly. State points are the same so delta S will be same. But We cannot write del Q by del t because it is irreversible. We can definitely write delta S A as del Q by del t because it is internal reversible. And if you want to extract entropy properties, then you will always need a delQ, heat information, or you should know the relation between heat and temperature. But sometimes you won't know the relation between heat and temperature, that's why you won't be able to integrate. That's why some people use fluid, which we use for working fluid in engines. For that, we have taken out the entropy and you will get it in the form of a table. So, for steam engine, or for water, refrigerant system, refrigerant flutes that we will use, these tables are made for that. And these tables are normally found in reference books. So, you can directly take them out from that table. So, there will always be a reference in that table, taking some reference because entropy. We can't directly calculate the reference. So, delta will be like this but S will be a reference. Usually, the reference state is S is equal to 0 when we take D equal to 0. It is important to look at the table because the table has its own reference. So, it is not necessary that it should always be there. So, this reference state is important. So, if you put any

information in the table, an element reference state is important that through that your energy will be taken out whether it is internal energy or enthalpy or entropy.

Generally, as we said that this is internal but in such cases where it is not reversible in such cases we would delta S2-S1 that greater than equal to del Q by T. Why does this happen? Because you can see its definition carefully again. When we said that the clauses inequality is this. If you have considered the same thing in the first two parts A and B. Okay, this is definitely internal reversible. B let's assume that it can be reversible. If I draw it again here, like the diagram made by TSM, let's take a point. From here, we are doing 1 to 2. 1, 2, these are straight points. And this dotted line, I don't know this process. Let's assume A, in which we say that it can be reversible or reversible. I don't know this. So, it can be irreversible or reversible. But when we are returning, we are returning from an internally reversible process. Now we connect this cycle to Clausius Inequality. We know that in any cycle, if we consider the cyclic process, less than or equal to zero so in this case we will expand it that you're this will be del Q by T 1 to 2 which is your A plus del Q by T let's consider it B 2 to 1 internally reversible. So, this is less than equal to zero. And we know this part because this 1 to 2 is S1 minus S2 delta S which you just mentioned. The definition we just gave is this. So, we will rearrange If we write it in differential form, then we will get ds greater than or equal to del q by. So, this is a general statement that differential form, we had said that dS form is here, this was the definition. Now what we have done is that we have defined this thing using the cyclic process. So, this is a general definition. of any process will be greater than or equal to del Q by T. Equal to will be only when the internal reversible process is done. Ok? So, we will move forward with the same thing that if we do equal to, then what will be your term? So, we said that this is the definition. Now, the same thing that we wrote in the differential form. If we write this in the form of equal to, then this term plus the additional term is equal to. Because in the irreversible case, it will be more than delta Q plus T, delta S, then this additional term comes, which is called S generation. Here, entropy is generated and produced. We will call this term S generation. and it will be 0 when internal reversible process is done, and S generation will be greater than 0 when it is irreversible process so if we apply this condition then this condition will be applied on S generation Because delta S is greater than or equal to integral del Q by T. And if you write delta S in this form, then this condition will be given on S generation. And S generation will be 0 when there is a reversible process. And greater than 0 when there is an irreversible process. So, this is our basic definition. Now we call this thing the same way in the betterway. The change in the close system in the irreversible process of entropy will always be greater than the heat transferred between the system and the surrounding. That means if delta S is the irreversible process of the system, always the heat that is transferred del Q by T will be more than this. We will remove equal to and simply add greater than. Because in this, the irreversible process will always be more than this. It means that in the irreversible process, entropy is generated. And since this is connected to irreversibility, in which you have many ways, your temperature difference is too high or you have friction, this type of thing generates your reversibility, so S generation is greater than zero.

So, the third statement is that S generation will always be positive or zero. Zero will be when your answer is reversible. And it only depends on the process. This part depends on the process of S generation. As you can see, this is the same thing. You can bring the same two state points from irreversible process to reversible process. In irreversible process, your generation will be more, your S generation will be positive and in reversible process, your generation will be zero. So, this affects the process, the efficiency of the process, the way you process it. And of course, Try to keep the minimum as much as possible because you will see later how much loss is

generated. The more it is generated, the more inefficient the system becomes. Its capabilities will decrease. There is a statement on this matter which we call the Increase of entropy principle. This is what shows you that if you suppose that any the system is isolated. The whole thing is isolated from the outside. In which neither mass nor heat is being transferred. In such a case, if there is a process happening, because there are no changes from outside, but there is a process happening, in such cases, delta S in the isolated system will always be greater than or equal to. So, the meaning of the isolated system is that your adiabatic is done. So, in such cases, delta S will always be greater than or equal to 0. So, this is isolated. How did this come out? Because you had made the same statement here. Delta S is greater than or equal to delta Q by T. If it is isolated, delta Q is 0. So, this means that delta S will always be greater than or equal to 0 in isolated cases. So, this is called Increase of entropy principle. Entropy will be constant for any isolated process, which is reversible, or it will always increase. Now you can connect it to the universe. That your universe is isolated, but the process is going on internally. And that's why its entropy is always increasing. Let's move this topic forward. An important statement that we have not discussed yet is that is entropy extensive or intensive. From here you can see that the terms del Q by T, you can assume that it is summation of subsystems. So, this is an extensive property. If you understand it through an isolated system, then any other system. So, you can divide it into subsystems 1, 2, 3, 4. So for the sum of all the changes that have come in this process, let's say between 1 and 2, for that you can calculate the change in entropy of the individual subsystems, and we will sum it. So, you will get the total entropy, change in entropy delta S. And this is because it is an extensive property. We are already summing the entropy of the subsystem. So, we are removing the entropy of the subsystem. We are removing the entropy of the subsystem. As you can understand, the heat engine devices are also a subsystem. So, we can add the corresponding entropy of the subsystem. So, this is an extensive property. Because it is isolated, this delta S will be greater than or equal to zero. Like, I tried to understand this with the help of another example. If this system is here, then if we isolate its surroundings with the help of boundary, then if the temperature differences are very less, then effectively, if no mass is exchanged here, heat is not exchanged, no additional boundary work is happening, then you can call it isolate in a way. There is a system in which both system and surrounding are isolated. If you talk about such a system, then the question arises that of course you can separate both system and surrounding and say that delta S total is delta S system plus delta S surrounding. And in isolated system, delta S total is S generation. Now you will ask how is it possible? If you look at the isolated system again, what we did was that delta S Delta S change in the system is we said that in general if you move this definition forward then in general it is your del Q by T plus S generation. If it is isolated, then if it is isolated then it is zero. So, what is delta S system? S generation. And this is your greater than or equal to zero. So, if you understand this, then this is your S generation, delta S total, system plus round, this will be greater than or equal to zero. Now the question is, should the entropy of the system be greater than or equal to zero? Or one can be less, one can be more. So, can the entropy of the system be less? The answer is yes, because it depends on the heat transfer. If you remove the heat from the system, the entropy will decrease. If you put heat, the entropy will increase. So, the entropy of the system can decrease. But the total entropy, system plus surrounding, will always increase or remain the same. It will depend on whether your process is reversible internally or not. For example, let's understand from the example of a medium. This is your isolated system plus surrounding. in which the system is losing the heat to the surrounding and the surrounding is gaining heat So, delta S surrounding is the value and delta S system is negative. And when you add both, then S

generation will be positive. And you can also remove this. If you consider it as isothermal, then you can also remove direct information from the heat. You can also remove delta S from the amount of heat. So, we will give some examples of that. And we will try to understand more through this example. So, we will continue this discussion further. So, we will move ahead with this topic in the next lecture. We will try to understand more through examples of how entropy is used in engineering applications. See you in the next lecture.