Engineering Thermodynamics
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Lecture 29
Perpetual motion machines, reversible and irreversible processes, Carnot cycle

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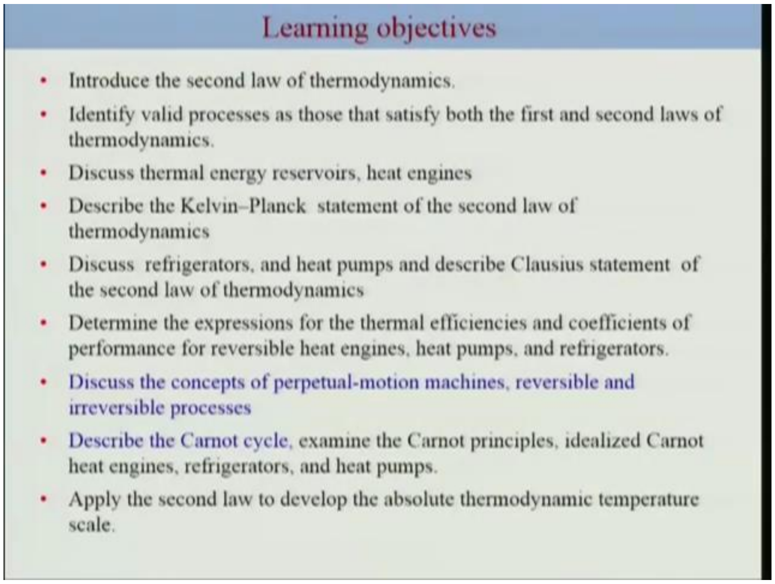

Welcome back, now discuss about the perpetual motion machine as well as Carnot cycle.

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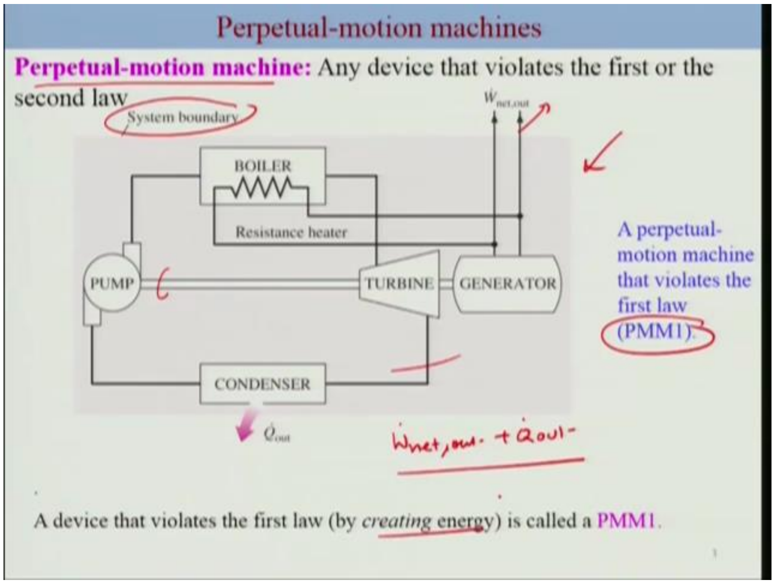

So let me consider device, what is described here. This particular device has a boiler, turbine, condenser, and pump operates on the cycle. It is supposed that the energy needed or required to heat water in this case for example can be formed internally rather than form the outside. Such as let us say, Furness.

What the inventor does here in this case that the electricity which is being generated, some part of the electricity is used to power the heater which is here, and some part is used to power the pump. And rest of the electricity is generated out, okay in terms of power. So what we see here is a specific device which works for the cycle.

Now if you consider this system which is (())(1:14) then the net effect of the system is to produce this energy weight without considering any energy input. Thus whole output is just a generation of energy, and we know that energy cannot generate continuously like this. So because this violates the first law of thermodynamics.

And thus perpetual motion machines are such machines which essentially violates the first law and second law. So this would be perpetual machine that violates the first law. So this was the case where violation was the creation of energy. Now we will consider another device. The previous invention was a bit modified now.

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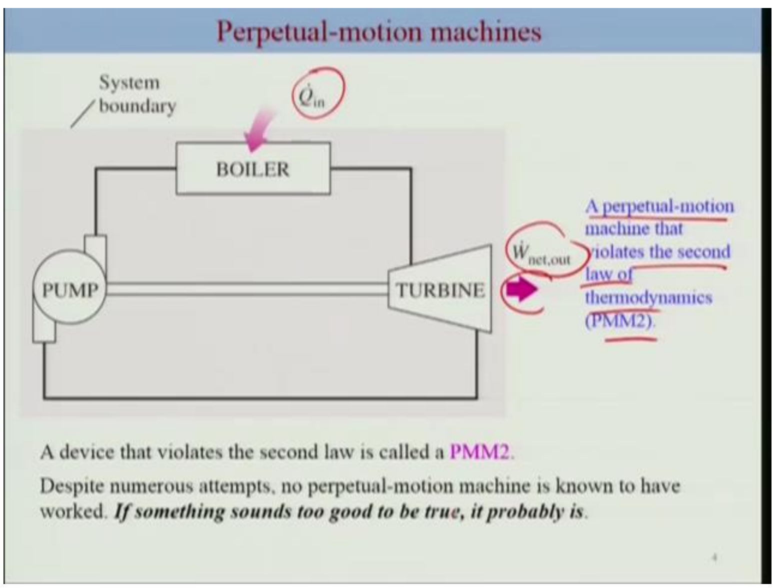

So here what is been done is that instead of resistant heater, we have used heat from outside, that is from Furness, and to boil the fluid or the water. So overall effect is that you have one specific boiler, however the condenser which was the part of this earlier was removed in order to remove the losses of the heater.

So the net effect here is that you have one specific heat input, and net output is here which essentially means that this is the complete conversion of heat input, this would be the violation of second law which says that the cyclic device you need to have more than one or in other word they say it is impossible to have a device which operates on the cycle which is this where only one reservoir is used, okay, and produces a net output.

So this is exactly the condition which violates a second law. So this is our example perpetual-motion which violates the second law or thermodynamics, okay. So numerous items are made in order to come up with such devices, but till date no such device been developed. In other words, if something sounds too good to be true probably is, this is the example of that.

Let us ask more practical questions, considering that we cannot have 100 percent efficient engine. So what is the maximum possible efficiency of heating. In order to address that question, let us first understand processes which are reversible processes. So let us first look at that, and then we can understand a bit more of higher possible efficiency.

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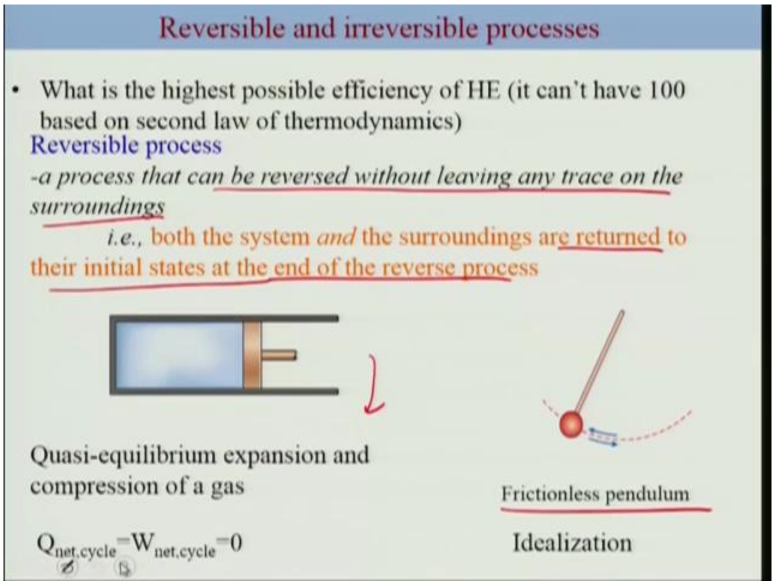

So what is reversible process, reversible process is a process that can be reversed without leaving any trace on the surroundings. Now if you recall our earlier discussion of Quasi Static Reversible process, it was something which was within the system, okay. It never bothered about the surrounding.

So here the reversible process is that you also have to consider the surrounding along with the system, and this is the process which can be reversed without leaving any trace on the surroundings, which means both the system and surroundings are returned to their initial states at the end of the reverse process, okay. So the examples are Quasi- static equilibrium expansion, and a compression of a gas, frictionless pendulum.

Now in this particular case we are bothered by the fact that the surrounding has to be brought back to this original state. So in this if you are considering Quasi-equilibrium expansion and compression and of course for a cycle then Q net should 0, and W net should be 0. So this suddenly reversible process idolization, and typically all the process nature is irreversible process.

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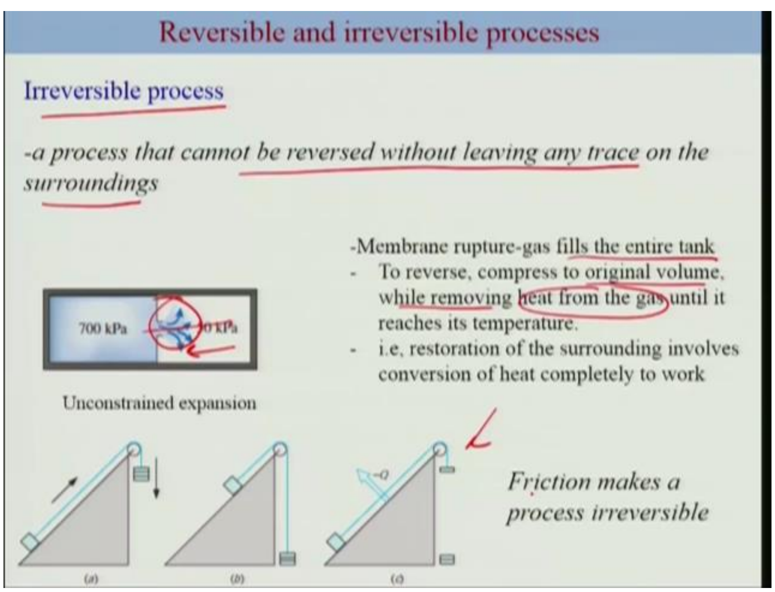

Or the process which cannot be reversed without leaving any trace on the surrounding are irreversible process which of course would be realistic process, okay. So the examples of such process would be Membrane rupture of the gas which fills the entire tank. In order to reverse completely to the original volume we need to also remove heat from the gas.

So essentially once it fills, if you want to bring it back to the original volume you need to compress, compressing the heat will be generated in a sense heat has to be removed. Heat has to be removed in such a way that heat gets converted to the work completely in order to reach its temperature, okay.

This conversion of heat to work completely is violation of second law of thermodynamics. Thus this cannot be reversed without leaving any trace on the surroundings. Other example would be your friction based processes, because friction makes the process irreversible because of the heat losses.

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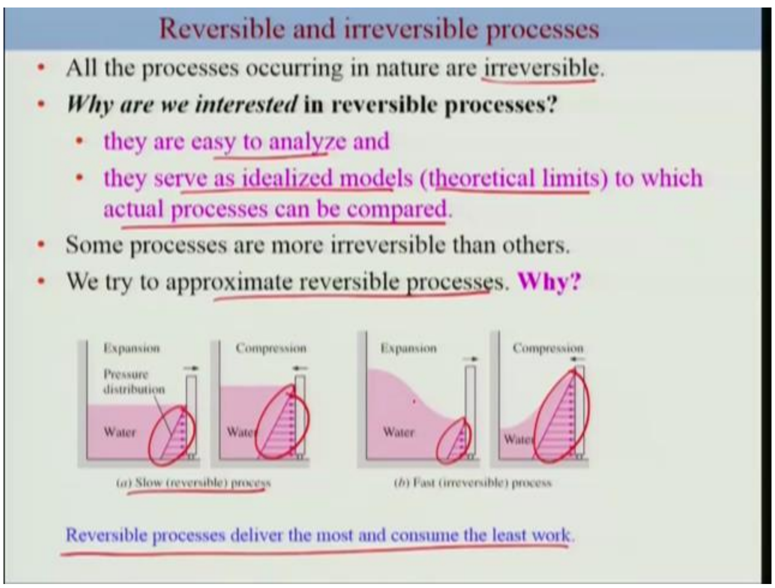

As I mentioned already that all the process in nature are irreversible. So in that case why we are interested in reversible processes when the natural process are irreversible because of the fact that reversible process are easy to analyze. They serve as idealized models, act like an aim to achieving such process, closed to that possible process. So this becomes a theoretical limit to which any actual process can be compared.

Some processes are more irreversible than others so why do we approximate reversible processes. Why we try to mimic such process, because reversible processes deliver the most, and consumes the least process. So it makes typical heat engine the most efficient if we consider all the parts of heat engine processes as reversible process.

So this is an example of slow reversible process, where the expansion and suspension have same pressure distribution. On the other hand the fast process, then the pressure distribution or the properties during the expansion and compression are going to be different. Thus they are irreversible.

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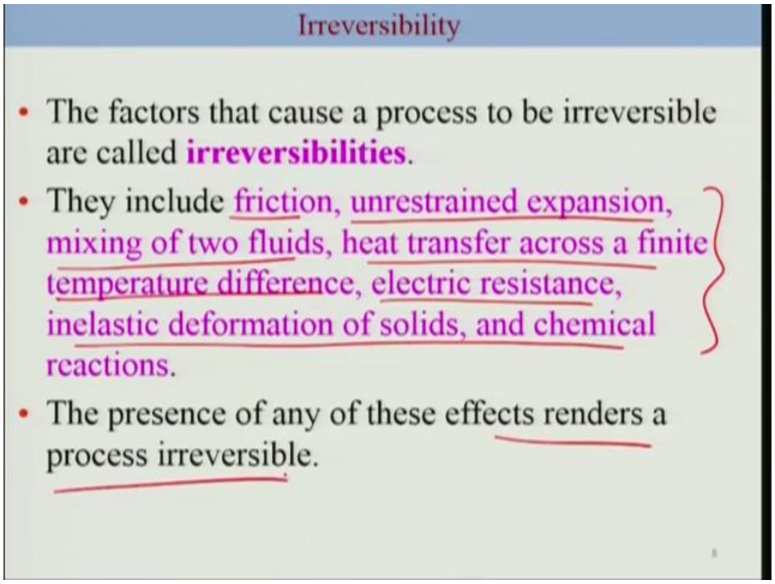

What are the factors that cause a particular process to be irreversible? They are friction, unrestrained expansion for example, mixing of two fluids, heat transfer across a finite temperature difference, electrical resistance, inelastic deformation of solids, and any specific chemical reaction, okay. The presence of any of these particular effects will render process irreversible.

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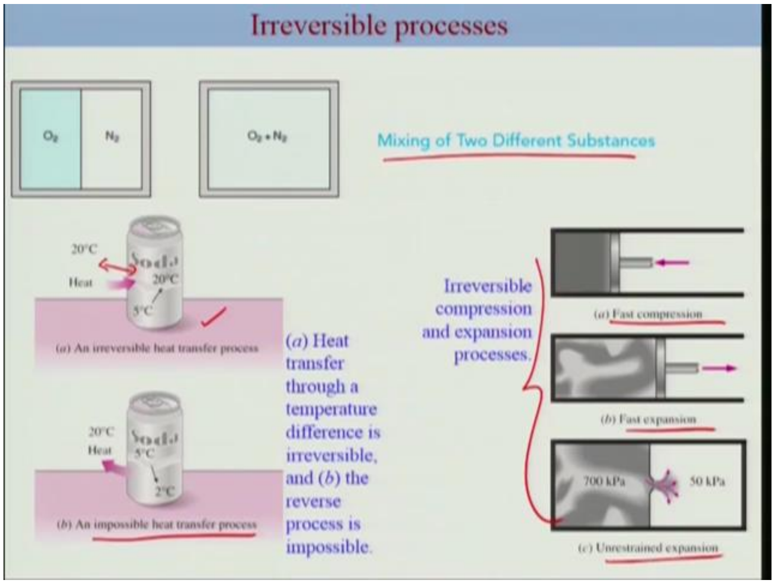

So this is the example of that, this is the mixing of two different substances specific heat transfer where temperature, discrete temperature difference, okay. So this is irreversible heat transfer process, this is impossible heat transfer process, and as I already mentioned the irreversible compression and expansion processes which are fast compression, fast expansion, or unrestrained expansion. These are all irreversible process, okay.

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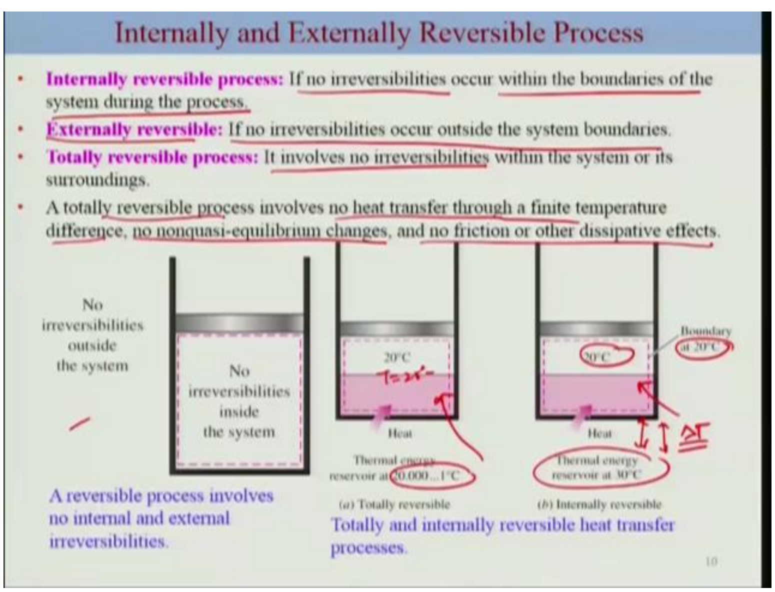

There are processes which we would be considering internally reversible, externally reversible, and totally reversible. Let me just describe a bit, and then you can connect to our earlier discussion of Quasi equilibrium process where we considered all the boundary working those consideration.

So internally reversible processes are if there is no irreversibilities occur within the boundaries of the system during the process, okay. So the example would be your such a case. Your system is a twenty degree Celsius, and boundary is also twenty degree Celsius. This process is slow, and there is a heat transfer and externally there is a specific temperature difference. So internally the process is reversible, but it is not externally reversible, and is not totally reversible.

In the case of external reversible if no irreversibility occur outside the system boundary then it will be external reversible. If totally reversible process would be, it involves no irreversibility within the system or its surroundings. Take an example of this. You have temperature is twenty degree here, right, and outside temperature is slightly higher than inside.

Or rather I should say it is infinitesimally higher than that of the system. And hence, there is a heat transfer, but process is extremely slow. This is the case of totally reversible process. So in a word a totally reversible process involves no heat transfer through a finite difference. So this will not be considered as finite difference in the temperature is extremely small.

For example this one there is a finite difference, and hence this is not totally reversible, okay. So if you have no heat transfer through a finite temperature difference, no non Quasi equilibrium changes, and no fraction or other dissipative effects then the process would be totally reversible process.

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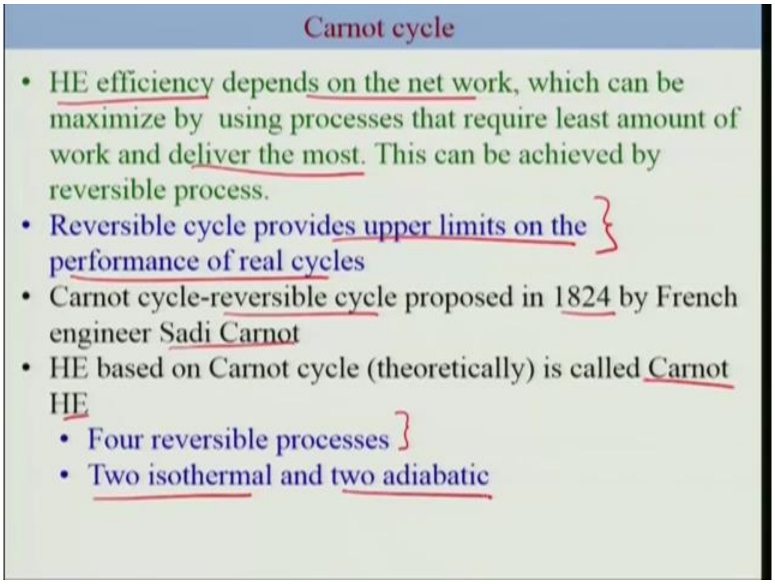

Okay, so now we will realize the fact that in order to have high efficiency you need to have reversible process. And reversible process is there temperature difference between the surrounding and system is almost negligible. And there is no (())(09:37) fact, or any other kind of a fact. So what we are going to consider is where fictitious kind of a cycle which we call Carnot cycle which will have maximum heat engines efficiency.

So we will discuss this Carnot cycle. So let us consider this heat engine efficiency which depends on the network, and which can be maximize by using processes that require least amount of work, and deliver the most which essentially mean you can increase heat efficiency by considering reversible cycle.

Reversible cycle provides upper limits to the performance of real cycles. Now Carnot cycle which is reversible cycle was proposed in Eighteen Twenty Four by Sadi Carnot, and this heat engine based on Carnot Cycle is called Carnot Heat Engine.

In Carnot Heat Engine we have four reversible process, because we recall in heat typical engine there are four devices which we are using. All these four devices particularly operates, particular execute specific process, okay whether it is isothermal expansion, compression, or adiabatic expansion or compression.

So we are going to make use of four reversible process for the case of Carnot heat engine, in which two would be isothermal, and two would be adiabatic.

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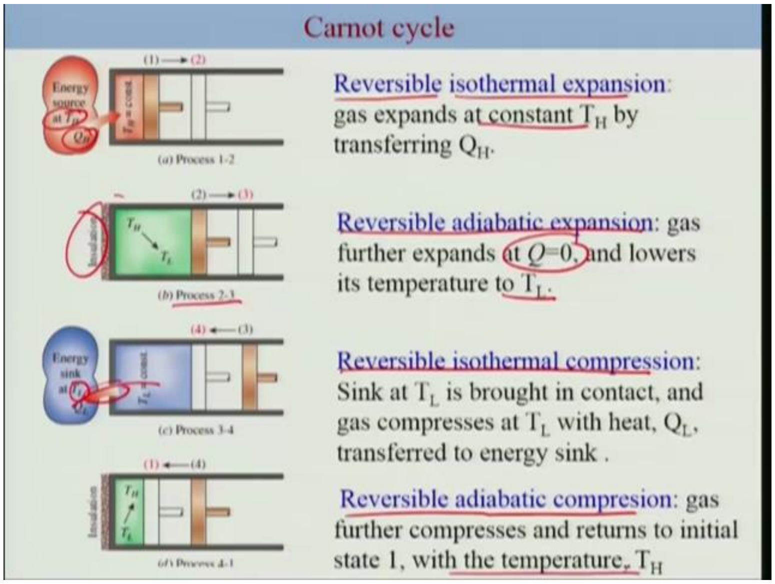

So let us consider our complete cycle, okay, for the Carnot case. So here we start with the system at one and it takes energy source at temperature Th. Remember that this Th is same as the system that means a very small difference, okay. There is no finite difference here. So heat supplied is Qh, and then it expands, this will call Reversible isothermal expansion at a constant Th by transferring Qh.

Then we insulate this, so this is insulation for the second process, process two to three. This is a Reversible adiabatic expansion, and here the gas further expand at Q is equal to zero, since it expands temperature lowers to Tl. Now we would like to bring this system to its original state.

So the first thing which we do is we reversibly compress it by transferring heat to a sink at constant temperature. So that will be Reversible isothermal compression. Here transfer is occurring at Tl, and then we again insulate it. So this would be, and then there is a further compression, but now this will be a compression at adiabatic condition, so it will be reversible adiabatic compression.

Gas further compresses and returns to initial state with temperature Th. So that will be complete four cycles and then this cycle will make a complete process. You can describe these particular four processes on PV diagram.

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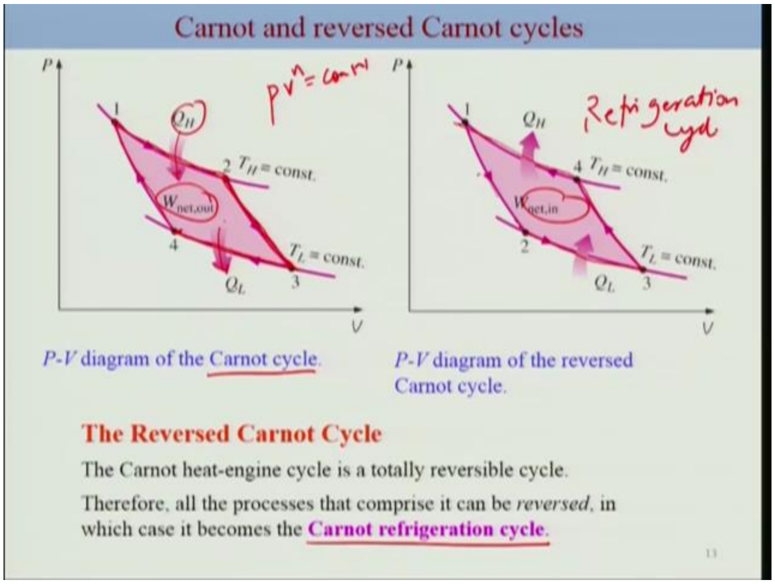

So this is PV diagram. If we go back to polytrophic process, then gava or PVn constant. So recall that slope N, if you take log P by log V, you can write in terms of slope. Typically you will see that for isothermal slope is lower than adiabatic. So this starts from isothermal expansion, then we have adiabatic expansion, then the system is compressed at isothermal condition followed by adiabatic compression, bringing back to the original condition.

And this area under this is Q net. So this arrow indicates that there is a heat transfer here from the surrounding to the system, and there is a heat transfer here from the system to the surrounding at isothermal conditions. This is simple Carnot cycle. You can reverse Carnot Cycle because this is all reversible process, and if you reverse the process then you get Carnot Refrigeration Cycle.

Here there is a change in the arrow, so this would be your first from one to two which is adiabatic expansion followed by adiabatic compression followed by isothermal compression. So this would be your Wnet.in, this was Wnet.out. So this is the example of Refrigeration Cycle and this would be your Carnot heat engine.

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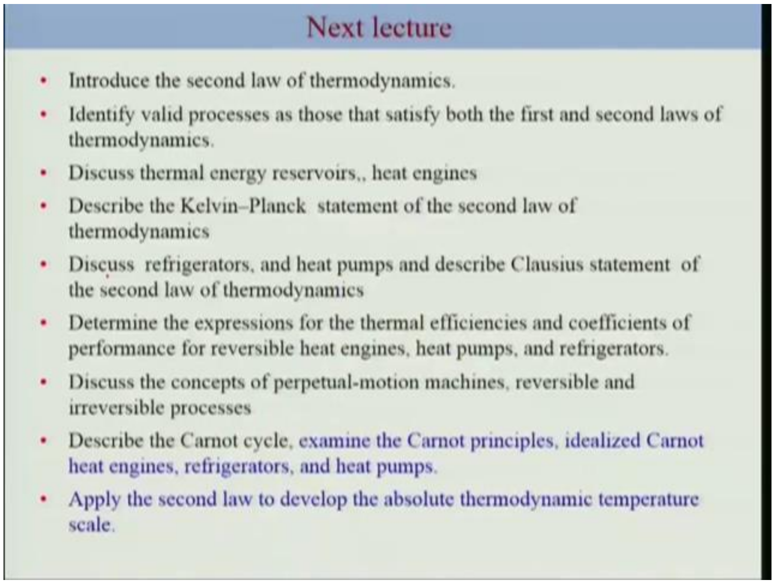

So I will end this particular lecture, okay. In the next lecture we are going to understand the Carnot principles, a bit more thermodynamic temperature scale. We will discuss more in details subsequent lectures about second law of thermodynamic particularly entropy. So I will see you in the next lecture.