**Steam and Gas Power Systems**
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**Module No # 01**
**Lecture No # 01**
**Review of Thermodynamics**

I welcome you all in this course on this team and gas power systems and today we will start with the review of thermodynamics. The topic to be covered in this course are basic term in thermodynamics processes.

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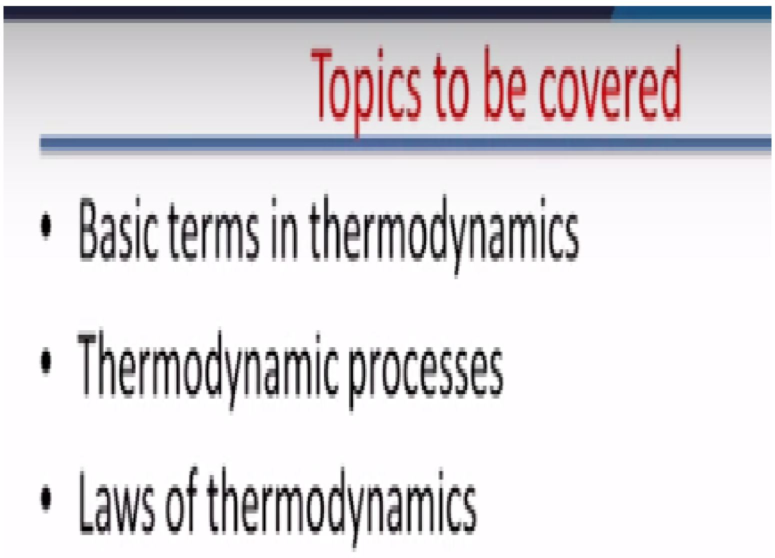


Laws of thermodynamics now there are certain basic terms in the thermodynamics which we are supposed to understand before we start with this course.

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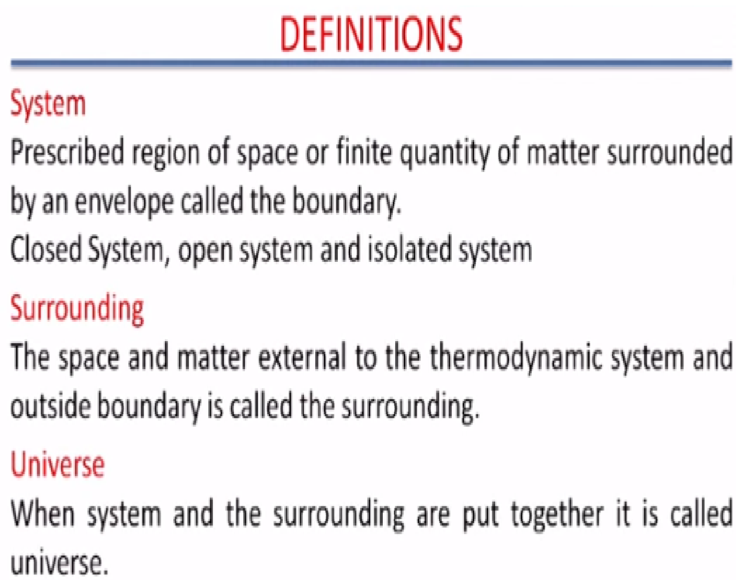


The first system in thermodynamics if prescribed a region of space or finite quantity of matter surrounded by an envelope called that is the boundary. And the system is the three types of systems.

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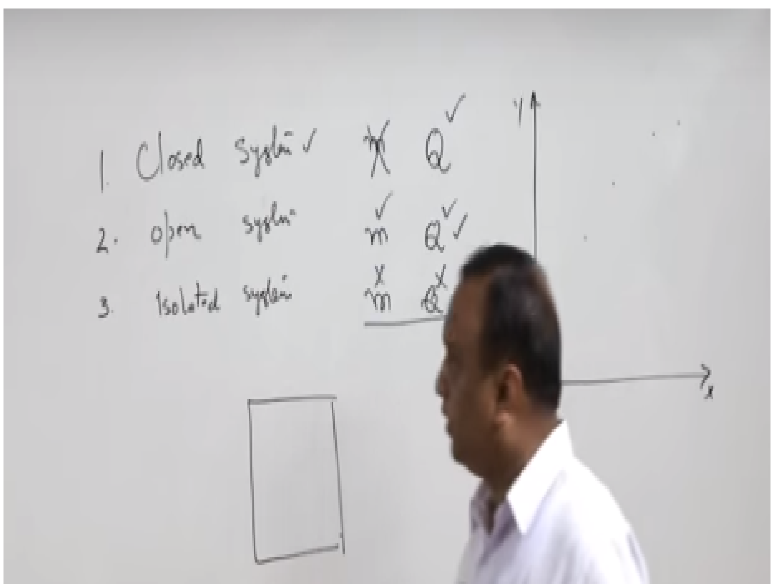


One is closed system second is open system and third one is isolated system. So system is prescribed region of space is it can be a physical entity or it can be an imaginary volume in the space on which the thermodynamics studies are concentrated. In close system for example this room this room can be considered as a closed system if we seal all the doors and windows of this room.

Then in this room heat transmission can take place through the ceiling or the wall or the floor of the room but transfer cannot take place. So in a close system mass transfer is not possible but heat transfer is possible now second type of system is open system in mass system and heat transfer both are allowed. For example if I open the doors and windows of this room then air can come into the room and air can leave the room also and heat transmission through the walls and the ceiling and the floor of room can take place then this room becomes an open system.

Now third type of system is isolated system means there is no mass transfer and there is no heat transfer that is possible if I insolate all walls of this room and floor of this room close all the windows. In that case there will not be any heat transmission from the surroundings and room will become an isolated entity. Now surroundings anything outside the system is surrounding so anything entire universe outside this room is surrounding and system and surrounding together they make universe.

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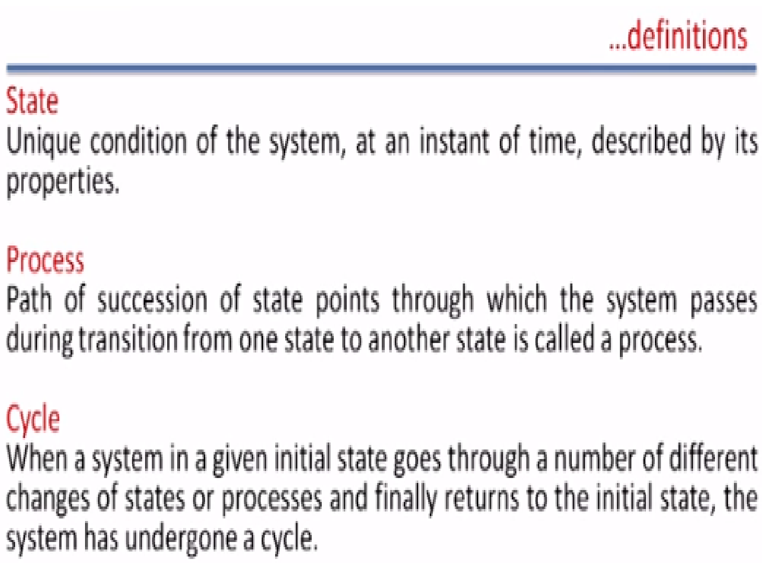


Now state unique condition of the system at an instant of time described by its properties. So state of the system can be described by the properties and minimum two properties are required to describe the system okay and. So state can be defined with the help of two properties.

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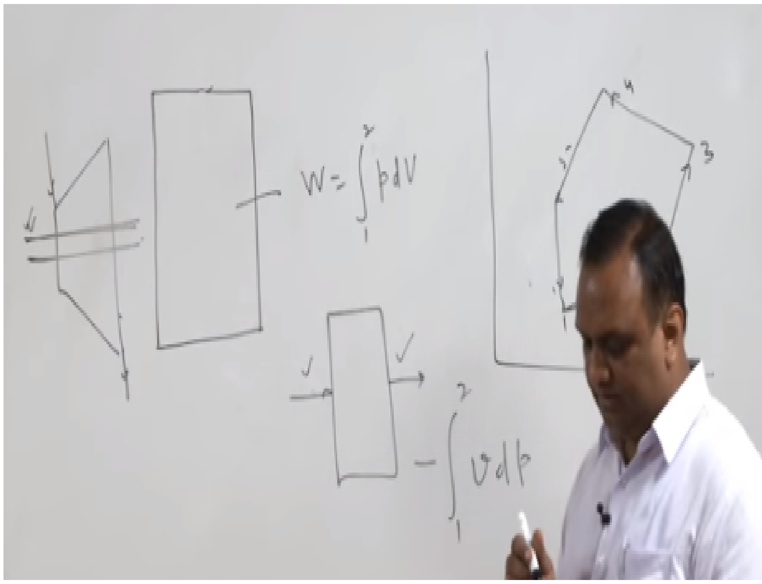


Now process suppose system is moving from state 1 to state 2 right and it moving from state 1 and state 2 it passes through in number of state now combinations of this number of states together will form a process let us say process 1 to 2 + cycle. A cycle thermodynamic cycle can be defined as there is a combination of a cycle is the combination of thermodynamic processes let us say from state 1 to state 2, state 2 to state 3, state 3 to state 4, state 4 to state 5 and state 5 to state 1.

So final state of the last process an initial state of first process if they are same then this is called a thermodynamic cycle in thermodynamics there are two things heat and work.

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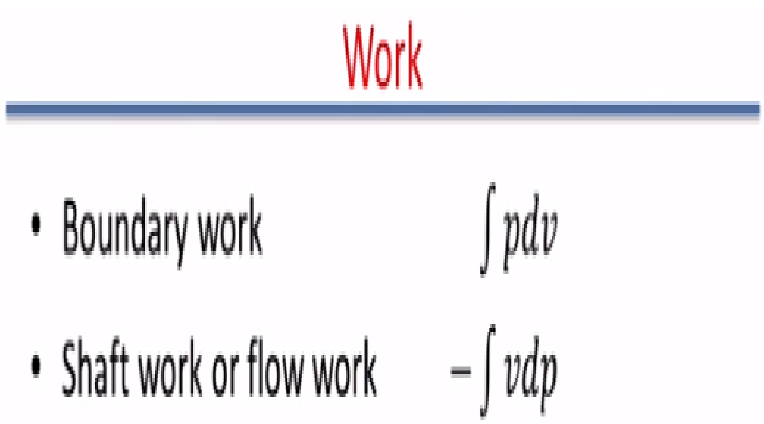

The entire the philosophy of the thermodynamics is based on the interaction between heat and work. So in thermodynamics there are two types of work one is boundary work and his shaft work or flow work. Now in boundary work the work is done by the movement of the boundary suppose there is a system if there is a movement in the boundary of the system movement in the boundary of the system work will be supposed to be done by the system.

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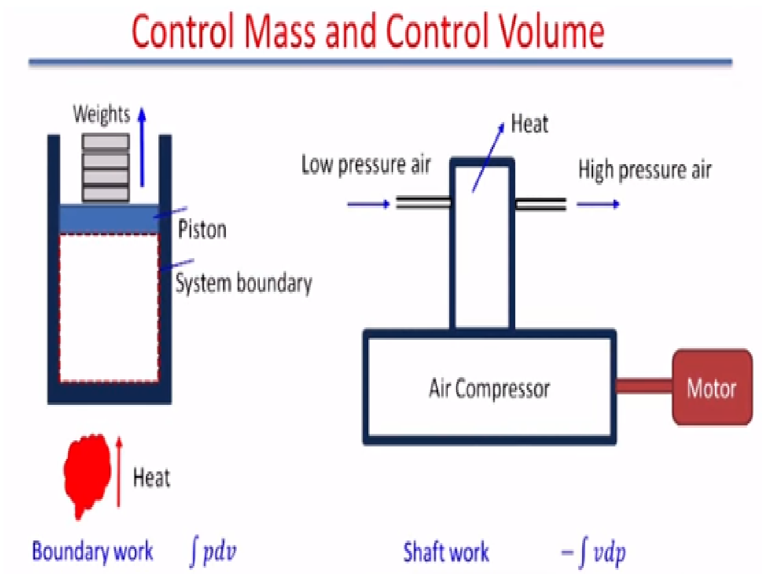


An example is given there is a piston cylinder arrangement and inside this red line this is the system. Now if we are giving heat form the bottom while giving heat of the bottom this gas inside this piston cylinder arrangement will expand. The weight is constant so pressure is remaining constant due to expansion of the gas the volume of the system will increase and work will be suppose to be done and in this case in the boundary work the work is expressed by PDV from state 1 to state 2.

Another type of work is shaft work in shaft work there is no movement of the boundary of the system. Boundary of the system are fixed for example air compressor so the physical boundary of the compressor is fixed. But if you visit pressure at the inlet and outlet you will find compressor outlet pressure is higher than the inlet pressure. And work is done on the gas to increase the pressure vice versa in case of turbines.

In a turbines the expansion of gas takes place and due to expansion of the gas the pressure drop is there and due to this pressure drop we get shaft work from the gas turbines. And this shaft work is expressed by -VDP from state 1 to state 2 where V is the specific value and DP is pressure drop.

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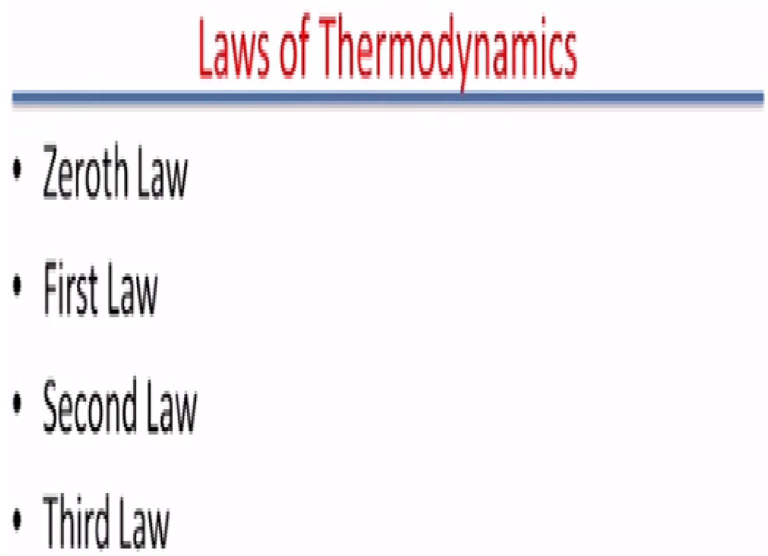


Now after this will discuss the laws of thermodynamics there are four laws of thermodynamics zeroth law, first law, second law and third law of thermodynamics. Zeroth law is the youngest law now zeroth law is the most basic law of thermodynamics which gives the concept of temperature.

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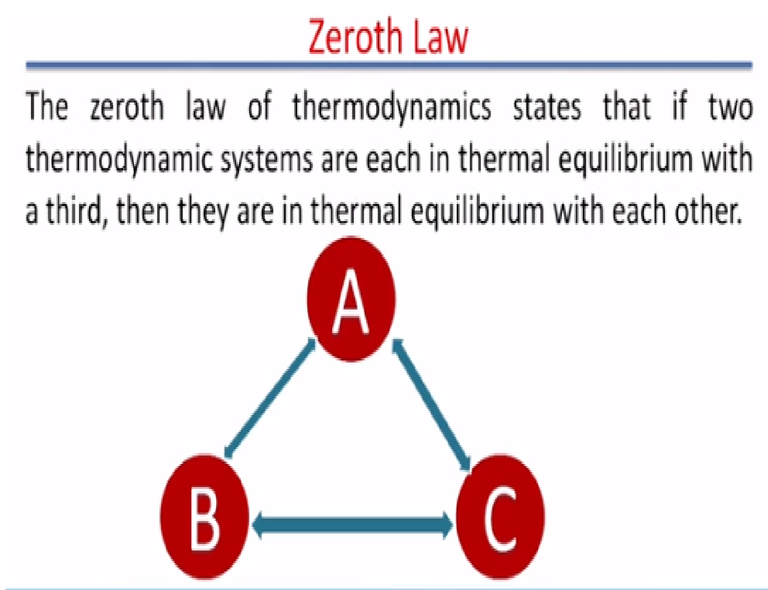

Now this law it states if two thermodynamics systems are in two thermodynamics are in two thermodynamics systems are each in equilibrium with the third then they are in thermal equilibrium with each other it means if they are three bodies suppose A, B and C. Now A and B is they are in thermal equilibrium it means there is no heat transmission between A and B whether from A to B or B to A.

Now B and C also in thermal equilibrium it means there is no heat transmission from B to C or from C to B. So definitely this A and C shall also be in thermal equilibrium this is stated by the zeroth law of thermodynamics and this law gives the concept of temperature in thermodynamic systems.

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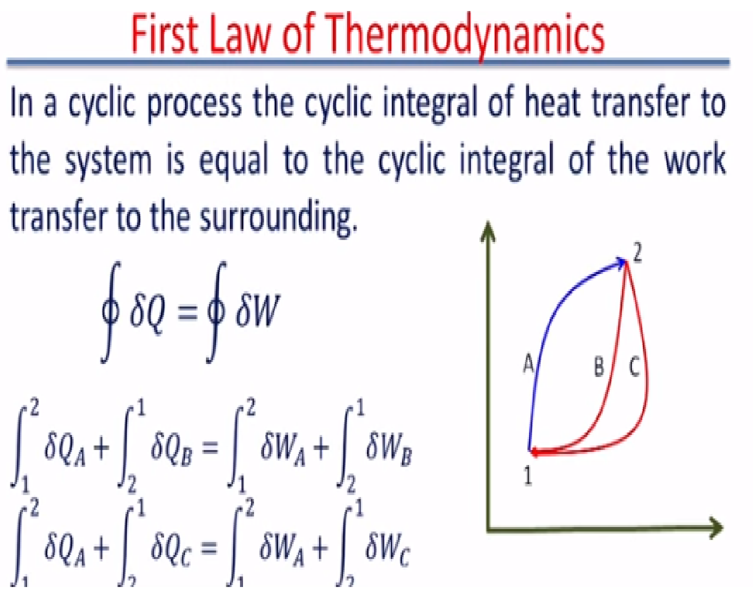


Now the first law of thermodynamics the first law of thermodynamics states that in a cyclic process net heat process given to the system is net work done by the system. First law of thermodynamics does not speaks anything about the internally the concept of internal energy is derivative of the first law of thermodynamics.

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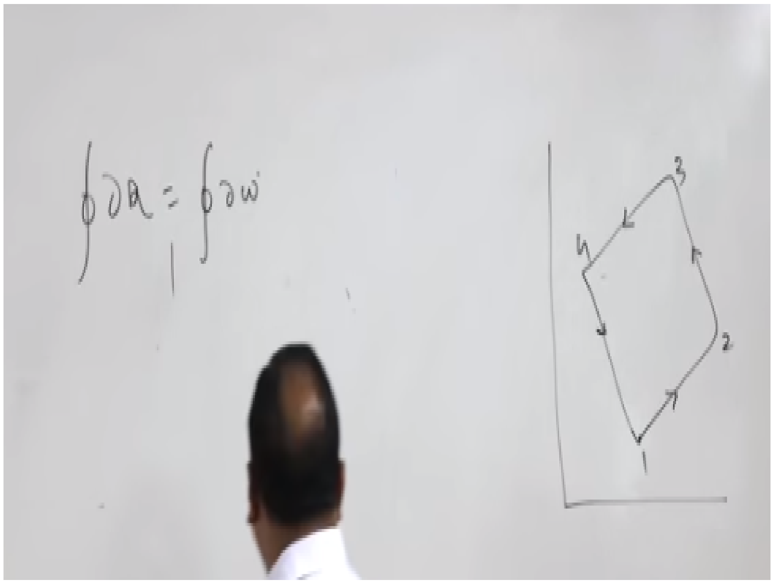


So in a cyclic process as I mentioned earlier cyclic process is a combination of processes where let us say 1, 2, 3, 4. So 1 to 2, 2 to 3, 3 to 4 and 4 to 1 so it is the combination of the processes where initial state of the first processes is the final state of the final processes. So in a cyclic process cyclic integral of heat given to the system is equal to cyclic integral work by the system right.

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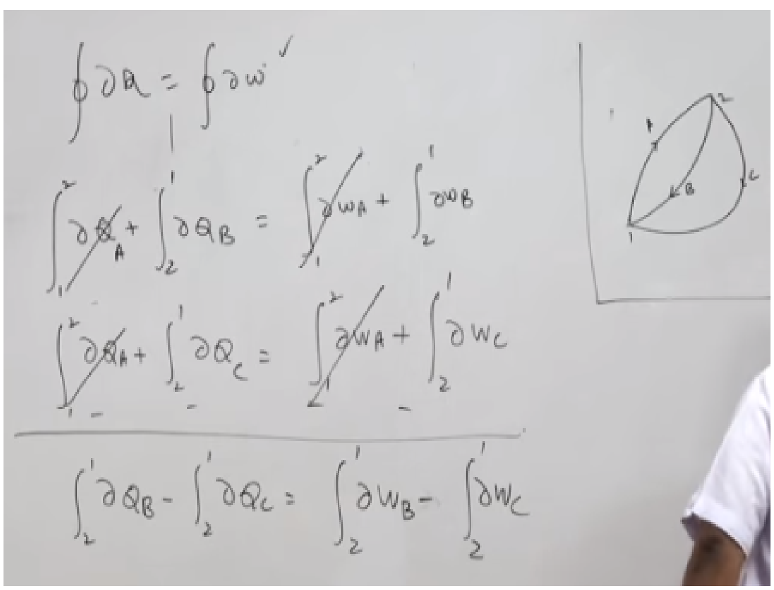


Now let us take a cyclic process A to B this is A sorry going to 2 so from 1 to 2 I am going through path A and coming back by path B. So according to this integral from 1 to 2 delta Q + integral from 2 to 1 delta QB and this is QA = integral of work 1 to 2 delta WA + integral from 2 to 1 Delta WB. So here we have taken cyclic integral to heat interaction in cyclic integral of work interaction.

Heat transfer process from 1 to 2 and heat transfer in process 2 to 1 work done in process 1 to 2 and work done in process 2 to 1. Now instead of coming by B if I come to state 1 by C part C now in this case again we will use this equation 1 to 2 delta QA + 1 to 2 delta QB = 1 to 2 delta WA sorry now this is not A this is C 2 to 1 delta WC ok. Now I subtract this equation from this equation so - QA will be considered out right.

And 2 to 1 delta QB - 2 to 1 delta QC is equal to and this also will be also cancelled out. So 2 to 1 delta WA plus sorry this is - 2 to 1 delta WC right. So we have subtracted this equation from this 1 and finally we are getting this equation now this is WB or WC this is WB right.

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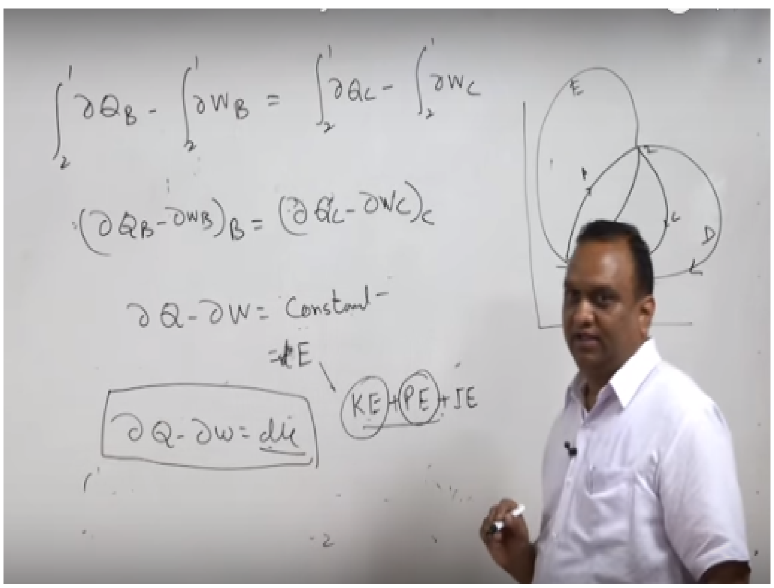

Now we arrange this terms and we will get integral 2 to 1 delta QB minus integral 2 to 1 delta WB = integral 2 to 1 delta QC - integral of 2 to 1 delta WC.

Now delta Q - delta W from 2 to 1 by path CB = delta Q - delta W from 2 to 1 via path C or we can write like this. Then QB - del WB by path B = del QC - del WC by path C right. Now we can choose another path D we come back from 2 to 1 by D as well in that case we will get another term delta Q - delta WD. So it means we choose any path this difference is going to remain constant if you coming from state 2 to state 1 irrespective of path so we take this path also E.

Irrespective of path taken we will getting a constant now this constant is the W is constant because this delta this is also energy this is also energy. So this constant has to be term of energy and it is expressed by E now E involves everything kinetic energy potential energy plus internal energy. But in a close system the change in the kinetic energy or in terms this is delta T this is D change in potential energy is negligible.

So a new term as come into the picture that is del Q - del W = DU and DU is change in the internal energy of the system and this is A derivative of the first law of thermodynamics however the law remains same in a cyclic process net heat given to the system is equal to the net work done by the system. Now after the first law we can take up the thermodynamic processes then you will take the second law.

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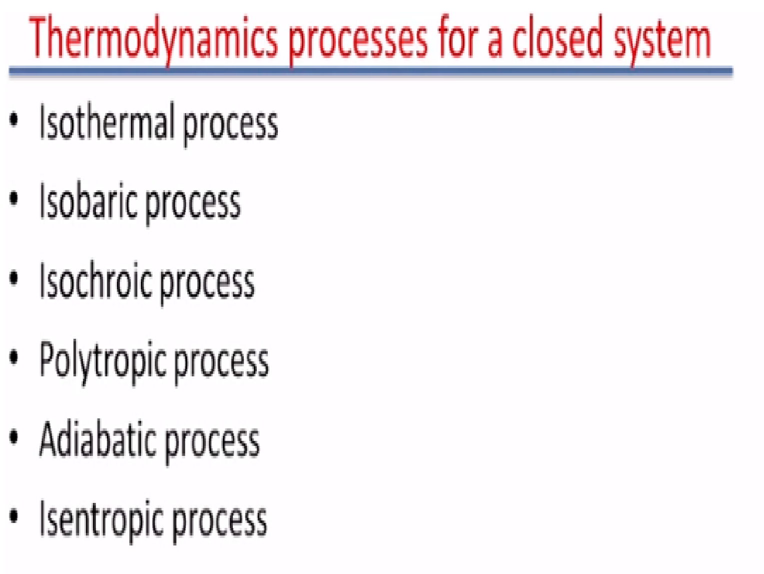


A certain thermodynamic processes standard thermodynamic processes now first is isothermal process isothermal process as it is clear from the name itself if we take on PV diagram pressure volume diagram isothermal process will be depicted by a curve like this in isothermal process the temperature remain constant and the product of pressure and volume is A constant. So at a constant temperature T1 from state 1 to state 2 and isothermal process will follow a like this.

If I change the temperature suppose I change the temperature like T2 another curve parallel to this curve will be formed but these two curves will never cut each other because they are parallel to each other. So this is temperature T2 and temperature T2 is greater than T1 now another process is Isobaric process in isobaric process as it is clear from name itself the pressure is constant. So the pressure is constant means if you are going from state 1 to state 2 then pressure will remain constant this is known as Isobaric process.

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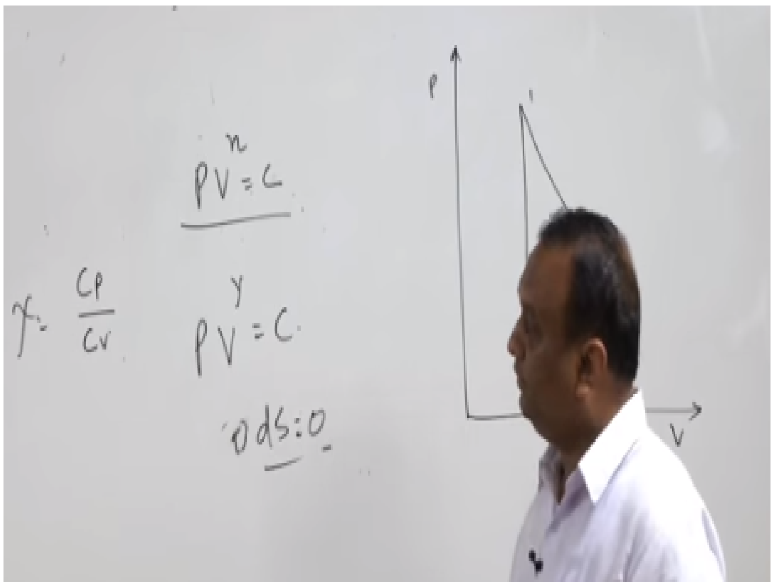


Another process is Isochoric process in Isochoric process if I depict this process on pressure and volume diagram then it is a constant volume process from state 1 to state 2. Now the next process is polytropic process in polytropic process PC raised to power is equal to constant. So if I want to show polytropic process expansion process it is going to be like this 1, 2, 3.

Another process is Adiabatic process an adiabatic process there is no heat interaction in surroundings. So such type of process are known as adiabatic processes and another is Isentropic process in isentropic process the entropy remains constant. So a reversible adiabatic process is known as isentropic process and then it is like this PV raise to power gamma is equal to constant where gamma A is the ratio of specific heat at constant pressure the specific heat at constant volume of this.

Adiabatic process can be isentropic process if it is reversible process but in adiabatic process there is a condition that there should not be heat interaction with the surroundings. But entropy generation due to internal resistance of the system can be take place right. So that is why a reversible adiabatic process can only be isentropic process where change in entropy is 0.

The first law of open system because this first law of open system is very much relevant to his course on steam and gas power.

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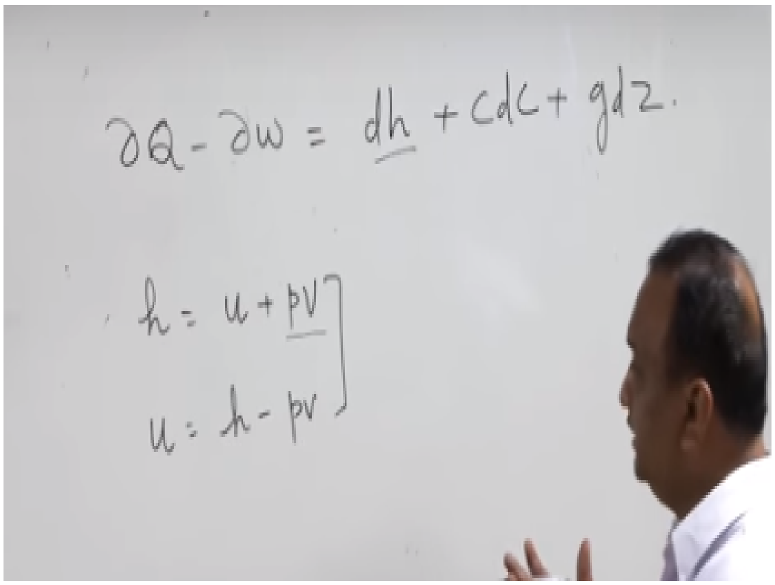


Now first law for open system states that heat interaction, work interaction is equal to change into enthalpy has come into picture CDC change in kinetic energy and change in potential energy. Now this enthalpy H of any gas is internal energy plus PV pressure and product of pressure and volume this product of pressure and volume is also known as flow energy. So internal energy if we have to find internally of the gas then it is H minus PV.

So we will be using frequently using these relations in the subsequent lectures and there we will discuss the application of the first law of thermodynamics for open system in case of turbine compressor nozzles and heat exchangers.

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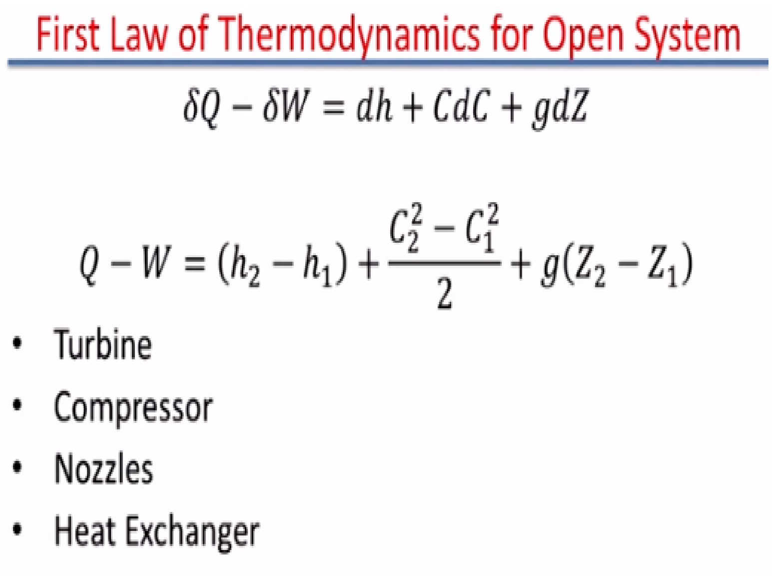


After this we will take up the second law of thermodynamics.

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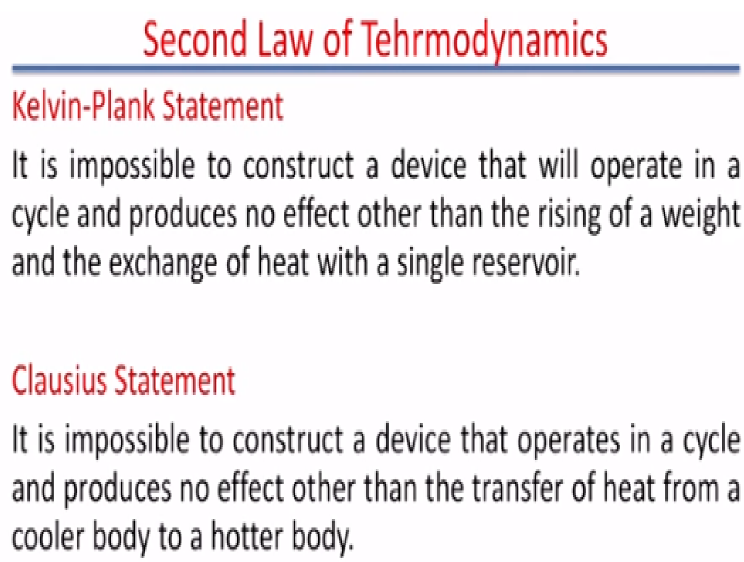


The second law of thermodynamics has a lot of relevance because this law states in a nutshell that if we draw certain amount of heat from a reservoir the equivalent amount heat can be produced.

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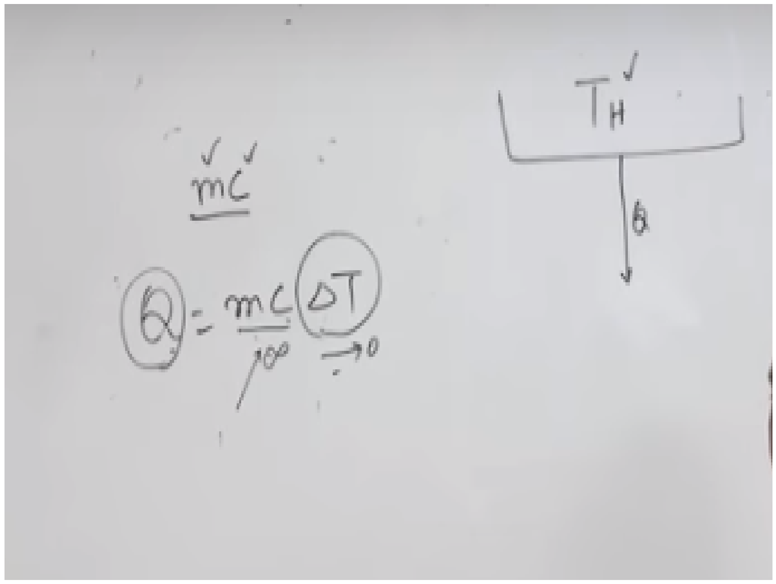


It means there is a thermal reservoir means a body which has very high thermal capacity right. Thermal capacity means the product of M and C mass and specific heat or we can say a body which is having a very high thermal capacity or we can say that you draw any amount of heat from this the temperature of body will not change because Q = MC delta T.

So if this is tending to infinity MC then definitely this delta T will be tending to 0 for a certain amount of heat drawn from the thermal reservoir. So for a thermal reservoir if you draw certain amount of heat you cannot do certain amount of certain amount of equivalent amount of work cannot be done. Now it has two statements Calvin Klein case statement and Clausius has a statement.

No the Calvin Klein statement says then it is impossible construct a device that will operate in a cycle and product no effect other than a rising of weight and the exchange of heat with the single result. That is what I have said earlier so this type of device is not possible which works on a cycle which operates on a cycle and net effect is the transmission of conversion of heat which is drawn from the reservoir in equivalent amount of work.

There is another statement also for the second of thermodynamics and it says that heat by own it is cannot from lower temperature to higher temperature. Now the exact statement of the clausius statement is like this it is impossible construct a device that operates in a cycle produces no effect other than the transfer of heat from a cooler body to hotter body right. So both statements are not different they are same and violation of one statement will automatically lead the violation of another statement.

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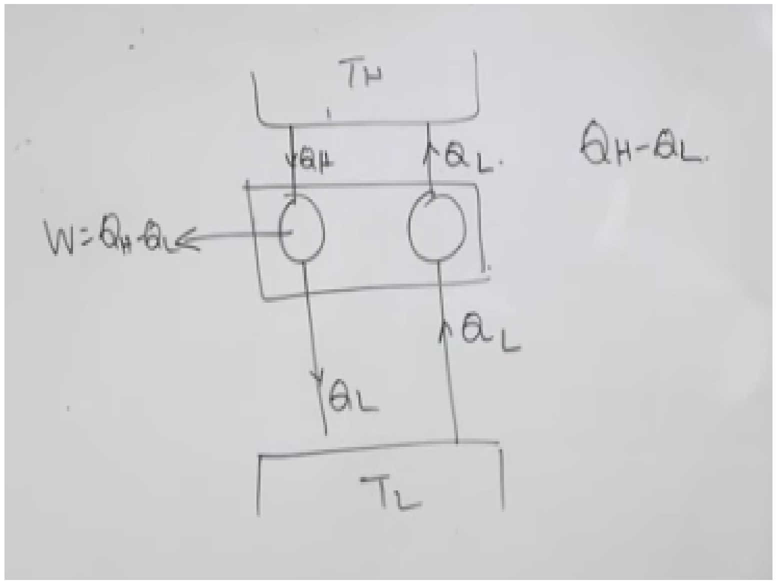


Now we can first of all we can assume there is a violation of this closest statement now if there is a violation of closest statement then heat by its own can flow from lower temperature reservoir or lower temperature body to a higher temperature body.

So heat certain amount of heat can by itself can flow from lower temperature to higher temperature QN this is QN and the heat exchange did not hitting them which is drawing certain amount of heat from high temperature body and rejecting QL to the lower temperature body and net work done by this heat engine which is working from the cycle will be QH - QL right as shown in the slide also.

Now if we club these tow slides these two devices now it is something like QH - QL is drawn from here an equivalent amount of work being done because QL is heat is rejected here and same amount of heat is drawn from the lower temperature reservoir so this can be eliminated.

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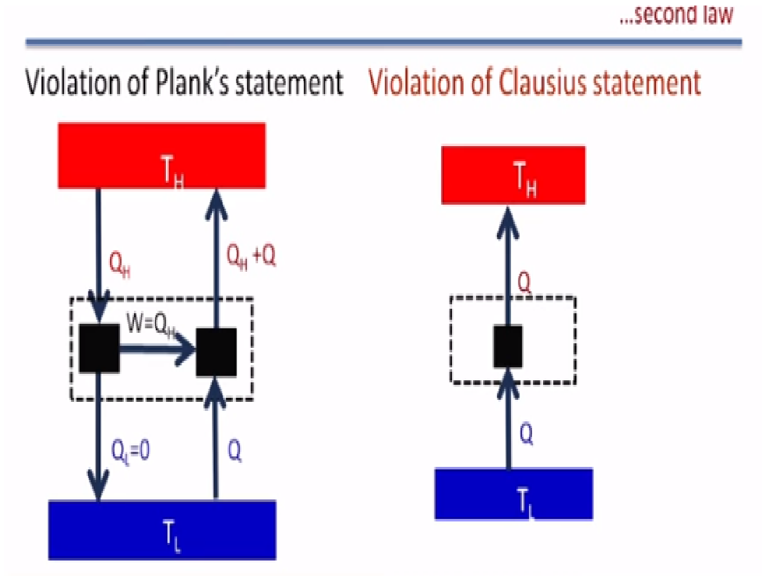


Now again violation of the plank statement now lead to the violation of clauses statement. Suppose we are able to made one device with sole effect is to draw a certain amount of heat from high temperature reservoir that is QH and do equal amount of work W = QH and QL is going to be in that case zero or this thermodynamic device has 100 % efficiency.

Now in this case suppose I want to draw a certain amount of heat from lower temperature reservoir that is TL and this QL will be use to pub the heat to the high temperature reservoir that is Q + QH. Now if I club this two devices right now in this case what is happening we are taking QH amount of heat and it is transmitted from lower temperature and it is being transmitted to higher temperature this Q amount of heat from lower temperature and it is transmitted to higher temperature without any external work.

Because QH which is going here it is moving in this loop only right so this is automatically violation of clauses of statement so both statements are same and the conclusion of both the statement is that we cannot have a device which is working on thermodynamic cycle and sole effect is the conversion of heat from sorry sole effect is withdrawal heat from a reservoir and do equal amount of work

And according to the closet statement the device is not possible which sole effect is transmit of heat from lower temperature to higher temperature without any external work. Now we will discuss the difference between gases and vapors.

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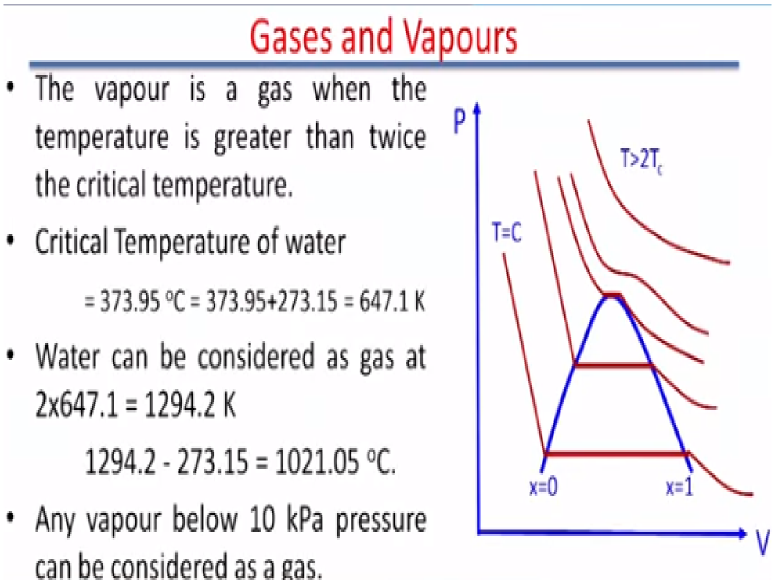


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Now if you draw a PV diagram pressure and volume and this is X = 0, X = 1 the constant this is temperature line constant temperature line is almost vertical it is not vertical then horizontal and then it takes another curve shape state 1, 2, 3 and 4 straight four. Now we keep on increasing the pressure when we keep on increasing the pressure this constant temperature line also keep on shifting.

And at the critical temperature the curve becomes almost horizontal and then we get go like this we move far away from the critical temperature the curve has its nature and when the temperature is greater than is greater than two times the critical temperature it follows the law of PV raised to power C that is product of pressure and volume is constant as in the case of gas. So the vapor can be considered as a gas when critical temperature is greater than two times the critical temperature.

For example for water the critical temperature is 373 degree centigrade critical temperature of water is 373.95 degree centigrade and you convert this into Kelvin it becomes 647.1 kelvin right. Now water can be considered as a gas when the temperature is two time of this absolute temperature and it turns out to be 1000 and 21.05 degree centigrade.

So at this temperature of a steam the steam can be concerned can be considered as a gas that is why we have steam tables because steam does not follow the law ideal gas law PV = RT. Because this law is for ideal gas is at near the temperature is steam can also be we can drive the properties of the steam using this equation. Now if the pressure is very low of this temperature it is irrespective of the pressure but if the pressure is very low let us say pressure is less than 10 kilo pascal.

In that case irrespective of the temperature the vapor will be considered as a gas that is why in air conditioning air conditioning analysis or in refrigeration on air conditioning when we take air consist of water also. So water vapor in present in the air is considered as gas because partial pressure of water vapor in the air is less than ten kilopascal however in the case of steam power plants when the steam had a pressure of 40 bar or 50 bar it is not considered as gas that is why we need is steam table in order to find the properties of this steam.

So that is the end for this lecture on review of thermodynamics in the next class we will take the rankine cycle thank you.