INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

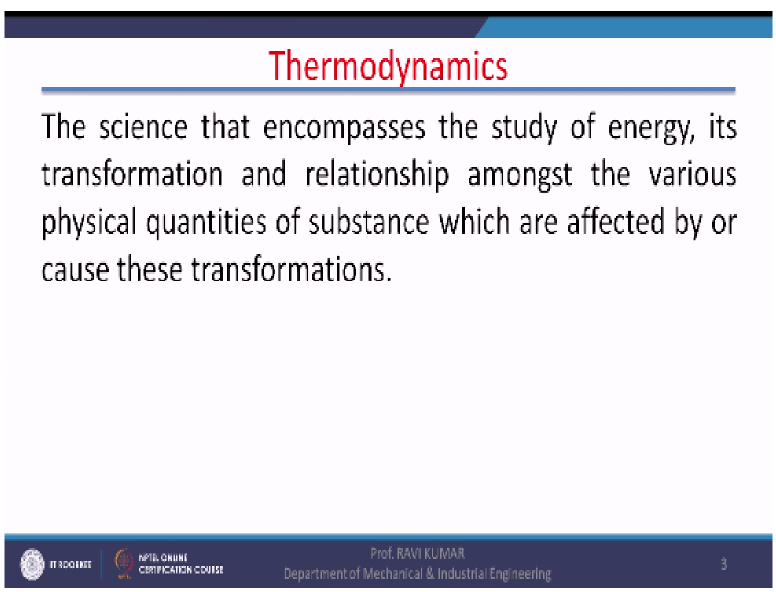
Refrigeration and Air-conditioning

Lecture-01
Recapitulation of Thermodynamics

with
Prof. Ravi Kumar
Department of Mechanical and Industrial Engineering
Indian Initiation of technology, Rookee

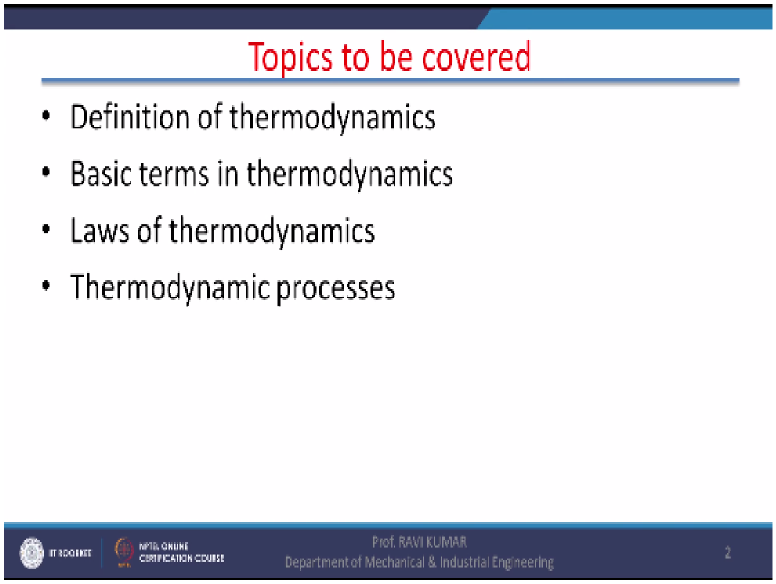
Hello I am Ravi Kumar I will be taking this course on refrigeration and air conditioning but before we start this course I would like to review the concepts of thermodynamics.

(Refer Slide Time: 00:37)



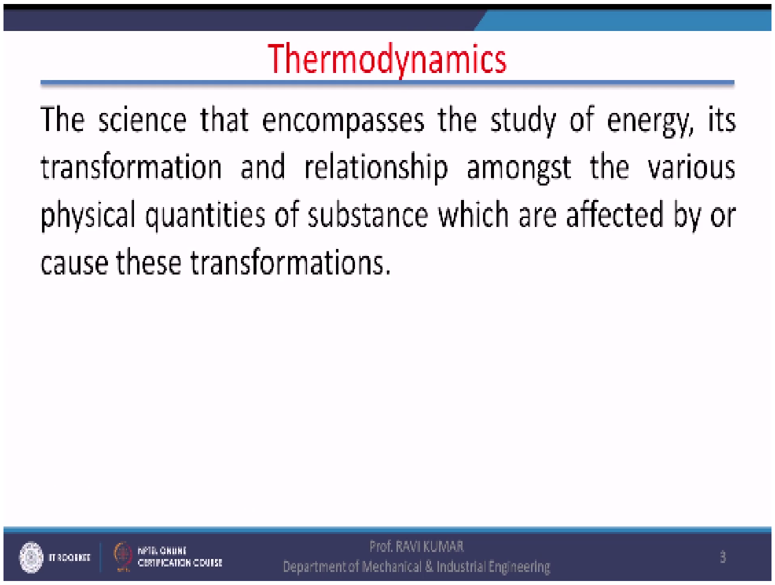
Because thermodynamics is a very wide area and it cannot be covered in one lecture I will cover only those parts of the thermodynamics which are relevant with this course so topic to be covered in this lecture our definition of thermodynamics.

(Refer Slide Time: 00:52)



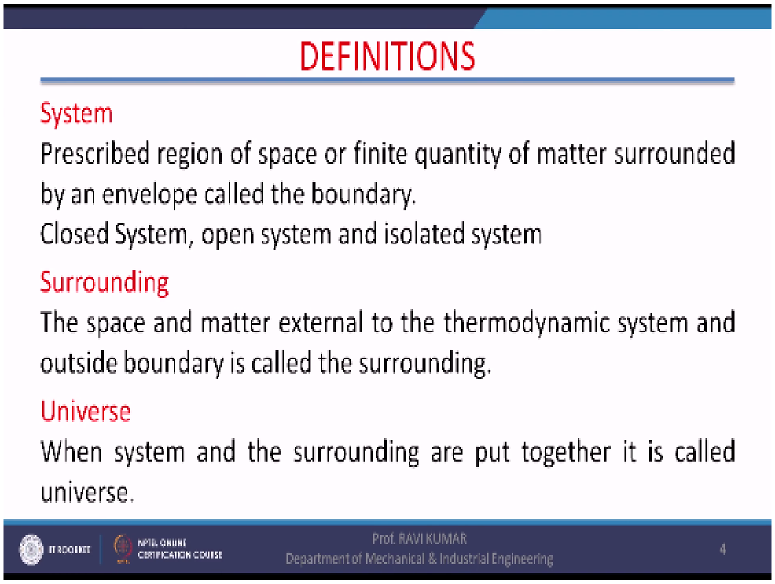
Basic terms in thermodynamics laws of thermodynamics and thermodynamic processes.

(Refer Slide Time: 00:59)



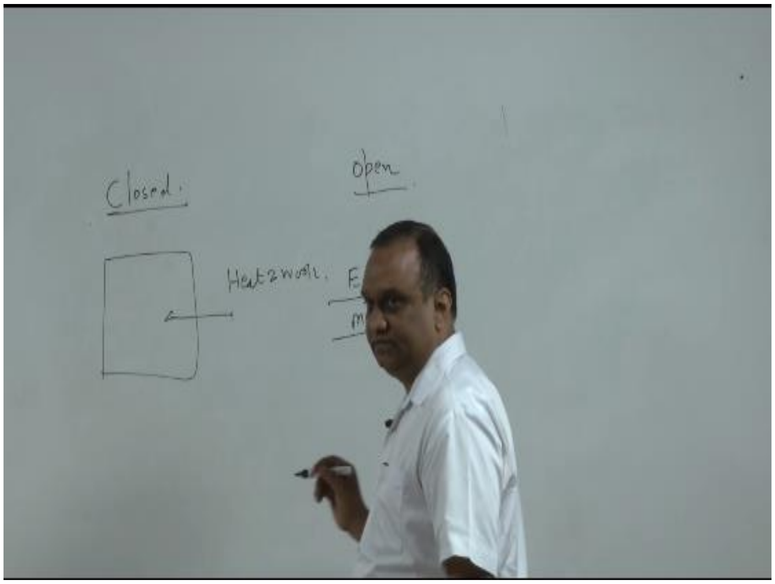
Now we will start with the definition of thermodynamics the thermodynamics is the science encompasses the study of energy it is transformation and the relationship amongst the various physical quantities of substance which are affected by or cause these transformation basically thermodynamics is the study of energy basically it deals with the heat and work interactions and their effect on different physical quantities like pressure temperature or volume of the system. They are certain terms in the thermodynamics which need to be defined here first is the system.

(Refer Slide Time: 01:38)



Is the prescribed region of space or finite quantity of matter surrounded by an annual apart of the boundary so any region in the space on which the thermodynamics studies are focused is called system now the system there are three types of system one is closed system.

(Refer Slide Time: 01:58)

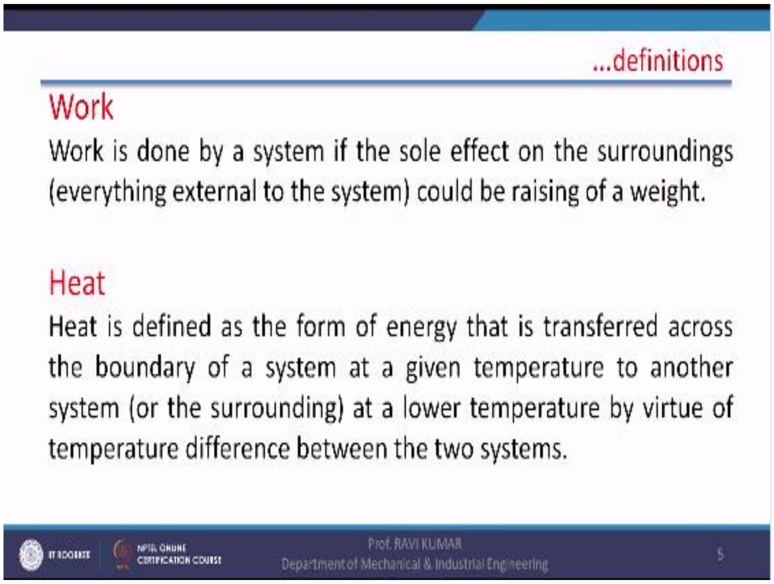


In closed system there is only energy interaction with the surroundings in the form of heat and work there is no mass transfer across the system boundary in closed system in open system in open system there is a energy and mass interaction with the surroundings the open system is like a wire mesh box suppose there is a wire mesh box kept in this space so in a wire mesh box the energy transfer and mass transfer both can take place.

Now third type of system is isolated system in isolated system there is no energy transfer there is no mass transfer for example this room so if I close all doors and windows of this room this room will become a closed system okay, so if the outside temperature is high the heat can be transmitted to this room through the walls of this room so energy interaction is possible but mass interaction mass transfer across the room wall is not possible at the same time if I open the doors and windows of this room there will be flow of air across the room through the windows and room becomes an open system.

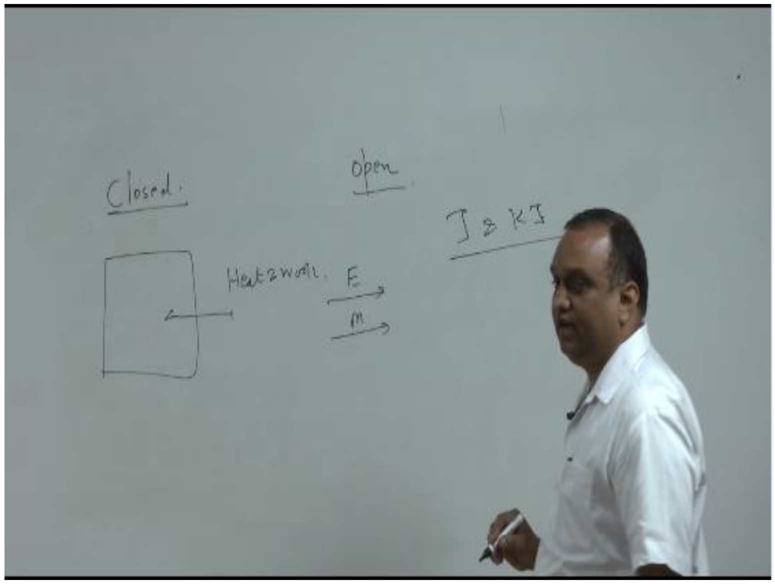
Now in the third case that is a isolated system in isolated system if I close all doors and windows of this room if I insulate the roof walls in the roof in that case there will not be any heat transfer across the room wall there will not be any mass transfer across the room wall and room becomes an isolated system anything outside the system is surrounding anything existing outside system is surrounding and system in surrounding together they make universe now work in thermodynamics.

(Refer Slide Time: 03:58)



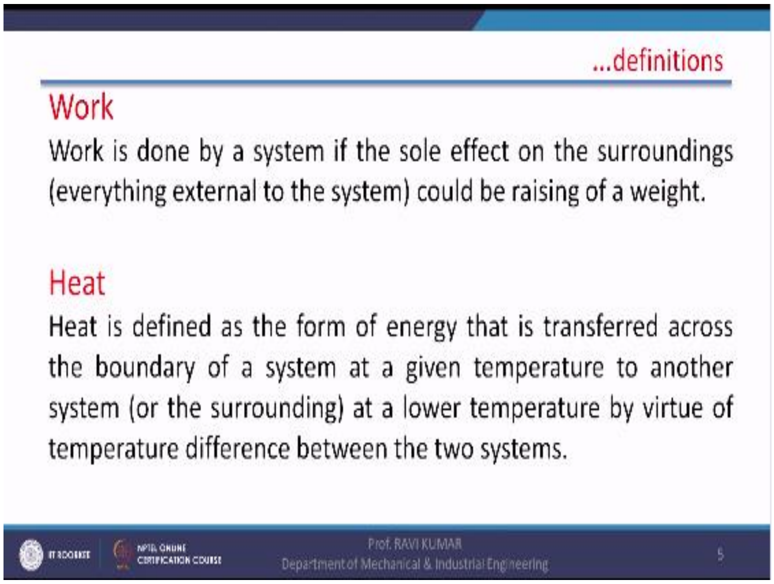
The work is defined as the work is done by a system if the sole effect on the surrounding could be raising of weight so in the thermodynamics if any process the sole effect of the process is raising of the weight it means the work is being done now heat is sort of energy so heat is the energy in transition by virtue of temperature difference so through temperature difference any transfer of energy is called heat transfer and in engineering practice we deal with the engineering heat transfer because in engineering practice we do not deal with Joules and kilojoules.

(Refer Slide Time: 04:38)



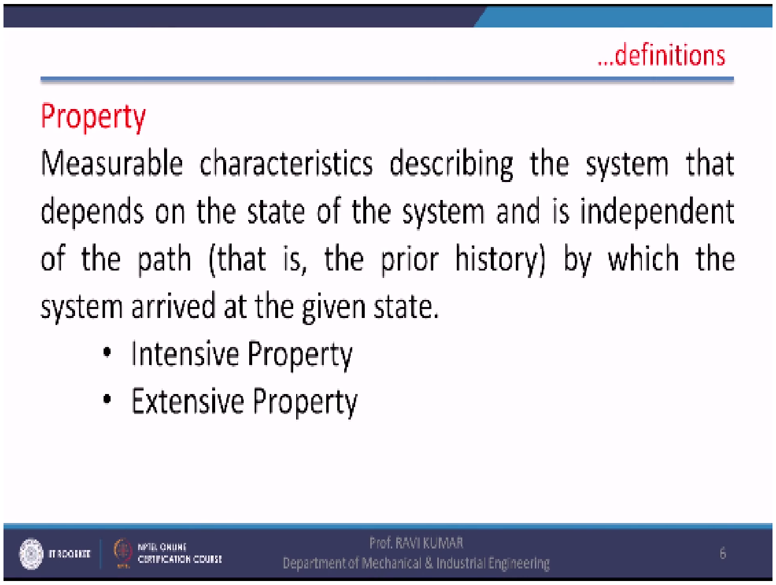
When we say heat transfer is there heat transfer means it is in terms of watts and kilowatts so we are more concerned with the heat transfer rate in engineering practices.

(Refer Slide Time: 04:48)



Rather than the heat itself so whenever we say there is a heat transfer it means there is a heat transfer rate or transfer of heat in the form of joules in kilojoules/sec.

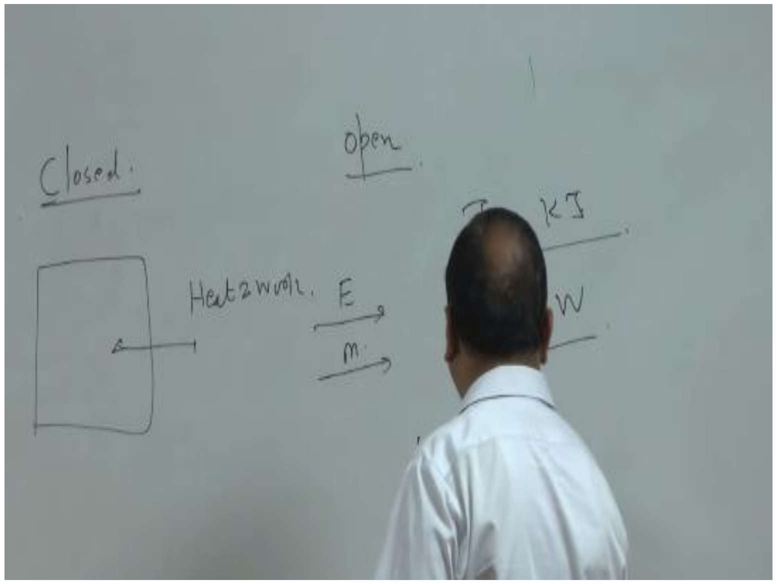
(Refer Slide Time: 05:00)



No property miserable characteristics describing the system that depends on the state of the system and is independent of the path by which the system arrived at the given state the property of the system can also be driven from the miserable characteristics of the system for example enthalpy and entropy and in order to describe a state of the system we require minimum of two properties of the system.

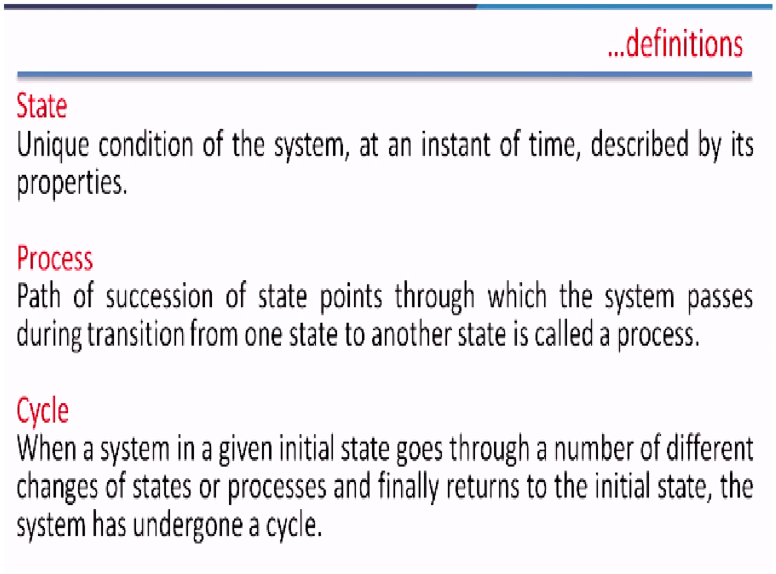
Now the properties are classified as intensive property and extensive property, now intensive properties are those properties of the system which are independent of the mass of the system for example temperature, in the room whether the mass of the air is 5 kg or 6 kg or 7 kg the temperature is not going to change with mass so the temperature is going to remain constant so there are certain properties like temperature.

(Refer Slide Time: 05:55)



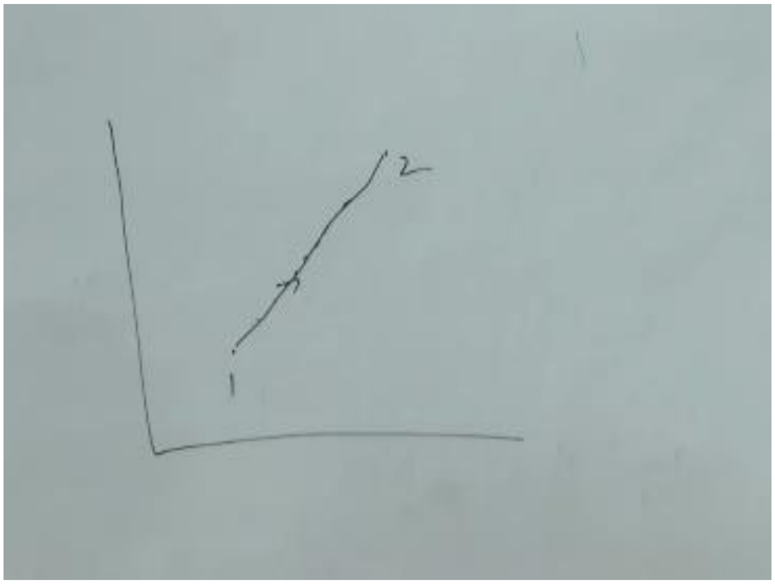
Pressure, so these properties are or entropy specific entropy not entropy specific entropy so these properties are intensive properties and there are certain properties which are extensive properties, now extensive properties are those properties which are dependent upon the mass of the system for example kinetic energy, potential energy so these type of properties are extensive properties not state.

(Refer Slide Time: 06:21)



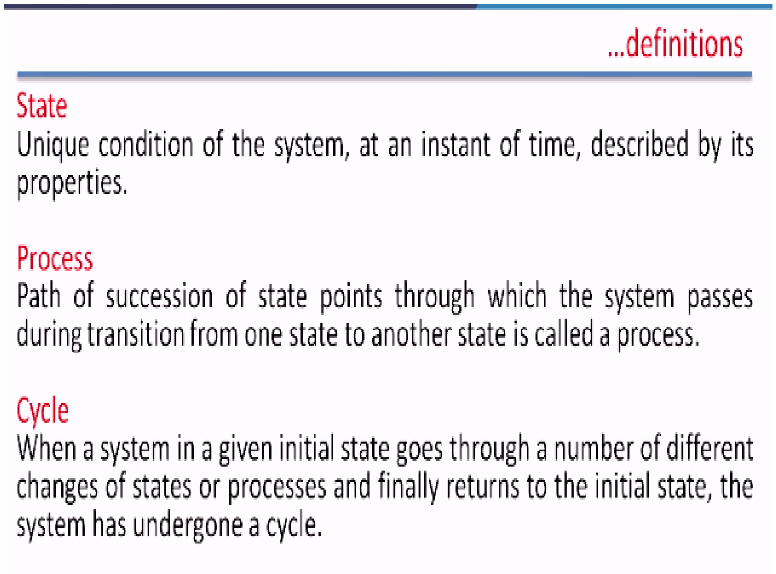
The state of the system is the unique condition of system at a state of time described by its properties so state of the system is described by a properties and in order to describe state of the system minimum two properties are required. Now another one other term is the process the path of successive States, state points through which the system passes during transition from one state to another state called a process.

(Refer Slide Time: 06:52)



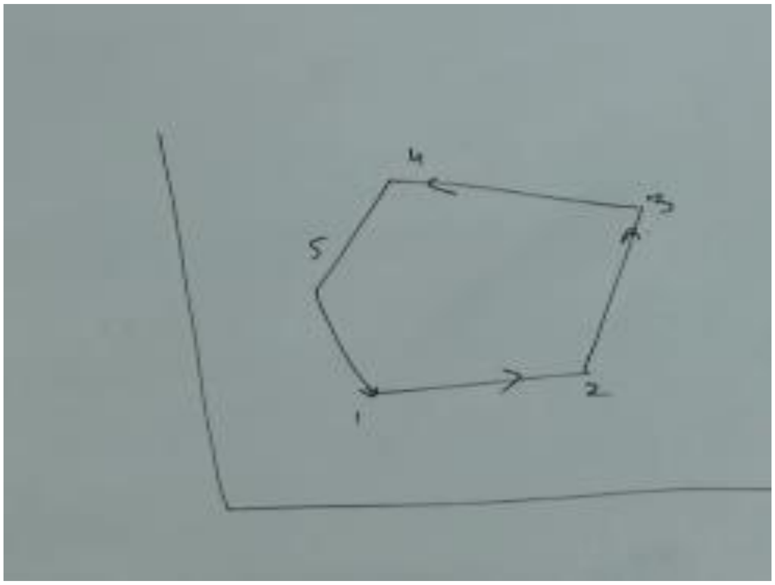
Suppose a system passes from state 1 to state 2 through different successive states so these different successive states together they form a process per cycle or cyclic processes.

(Refer Slide Time: 07:08)



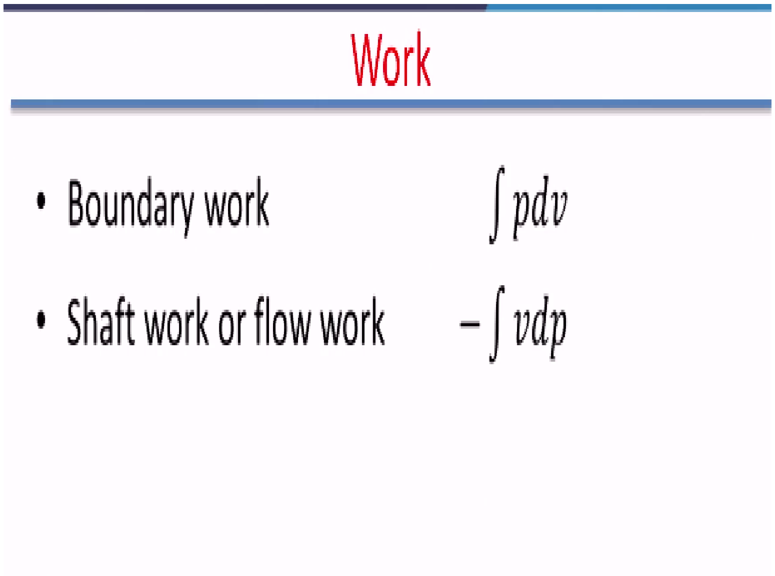
Cycle is a combination of number of processes suppose there are number of processes.

(Refer Slide Time: 07:17)



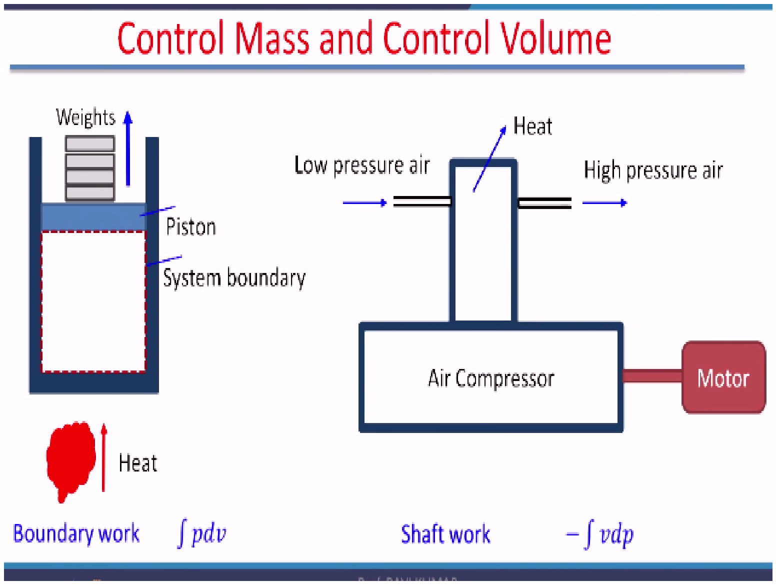
Starting from 1 to 2, 2 to 3, 3 to 4, 4 to5 & 5 to 1. So initially state of the process 1 and the final state of process last process are same then this is known as cyclic process or this is known as a cycle thermodynamic cycle, now work in thermodynamics the two type of work.

(Refer Slide Time: 07:48)



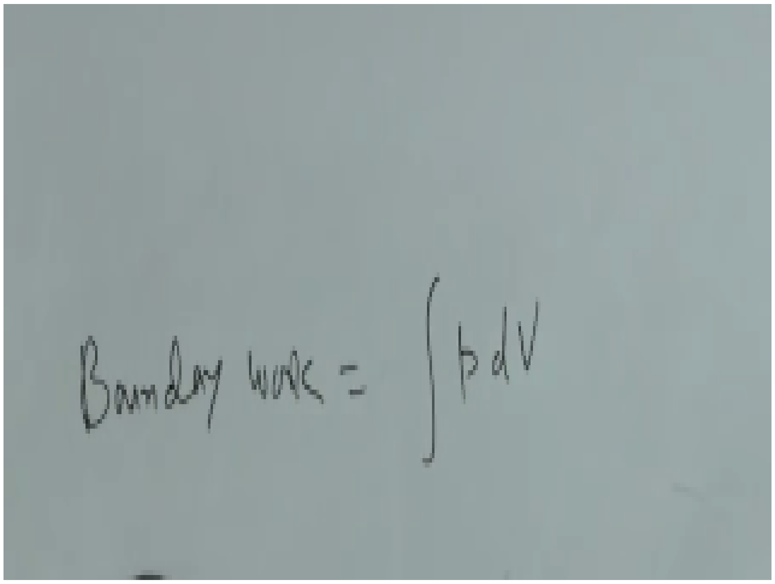
One is boundary work another is shaft work.

(Refer Slide Time: 07:51)



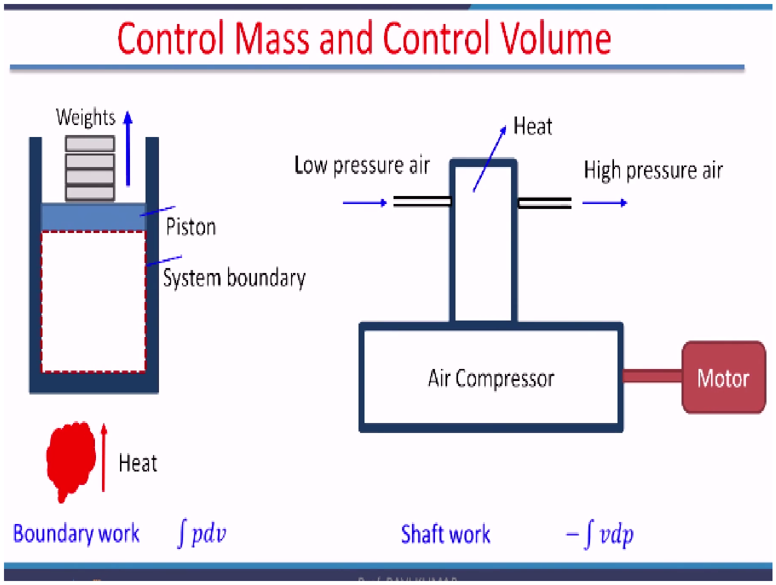
Now boundary work comes in the picture when there is a closed system as shown in the figure in this figure a piston cylinder arrangement is shown in this piston cylinder arrangement the boundary is shown by the dotted red lines but if I give heat to the system the piston will move upward direction and piston carries weights also and piston will move it upward direction but there is no mass interaction with the surroundings. So this heat transfer the system because there is a movement in the system boundary so in this case work is done by the system so the boundary work.

(Refer Slide Time: 08:31)



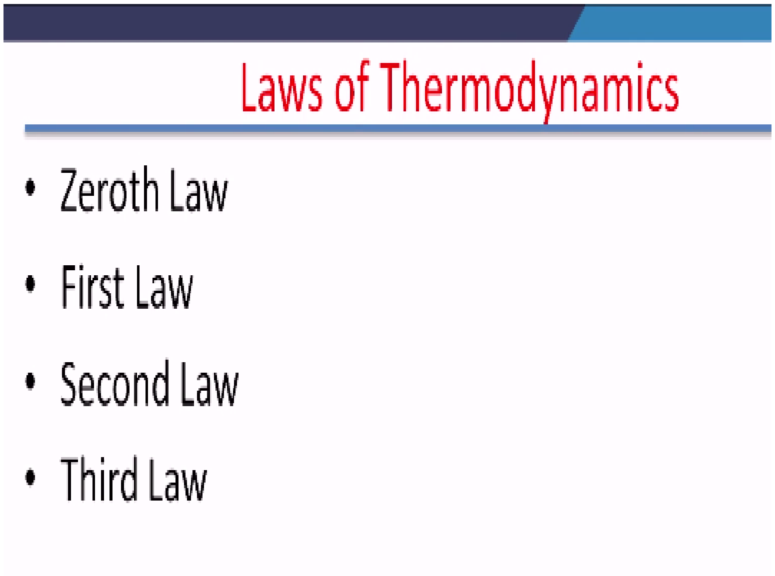
Boundary work is always integral of P dv. So in order to have boundary work there has to be change in the volume if there is no change in the volume there shall not be any boundary work, now another type of work is shaft work with the example of the short work is.

(Refer Slide Time: 08:53)



Air compressor air compressor there is no movement of the boundary and low pressure air enters from the one side and high pressure air leaves from the other side and this pressurization of air is done with the help of a motor and because work is done on the system here the shaft work is equal to –vdv work is done on the system and if there is no pressure change if there is no patch change in the shaft work in that case if there is no pressure change in the open system shaft work is zero so in order to have shaft work there has to be in change in the pressure same is the case with the boundary work if we want to have boundary work in that case there has to be change in the volume of the system.

(Refer Slide Time: 09:44)

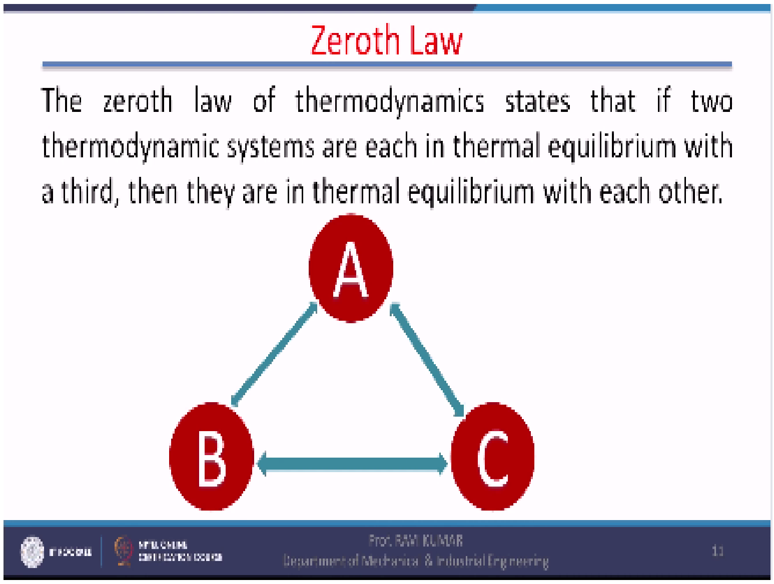


Laws of thermodynamics so there are four laws of thermodynamics starting from the zeroth law first law second law and third law they are not numbered as first second and third and fourth law of thermodynamics the reason being that it is started with the fact that when we learned that heat can be converted to the useful work but is it possible to convert entire you ever they will heat into the useful work but is it possible to convert entire you ever they will heat into the useful work.

Suppose we have 100 Jules of heat is it possible to convert 100 joules of heat into the hundred joules of work that is not possible and it is stated by the second law of thermodynamics now the first law of thermodynamics speaks about the conversion of heat into the work because when we say can we convert hundred joules of heat into the 100 joules of work first of all we have to ensure can we convert heat into the work so first law of thermodynamics says that we can convert heat into the work or work into the heat.

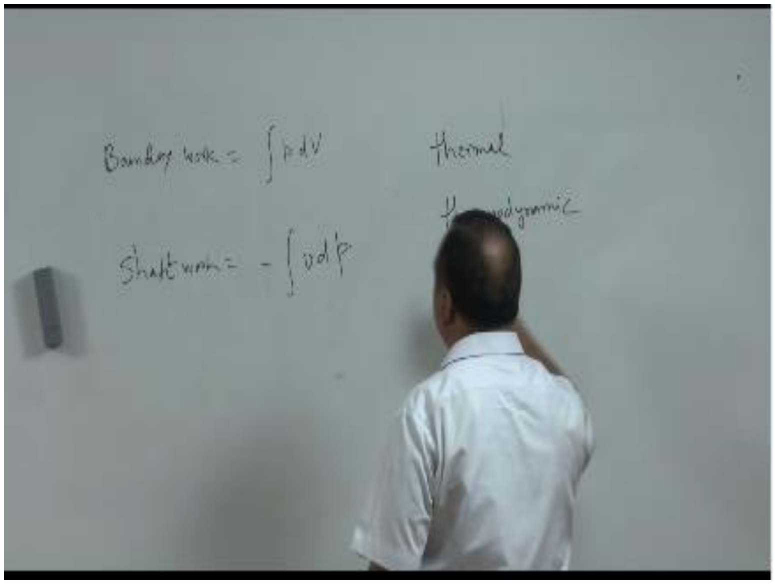
And zeroth law zeroth laws is the most fundamental law and it came after the around 50 to 60 years after the introduction of the first law and second law of thermodynamics and zeroth law of thermodynamics it speaks about the it gives the concept of temperature it is the most fundamental law and it gives the concept of temperature now zeroth law we'll start with the 0^{th} law of thermodynamics now zeroth law of thermodynamics states.

(Refer Slide Time: 11:11)



If two thermodynamic systems are each in thermal equilibrium with the third then they are in thermal equilibrium with each other now here I would like to distinguish thermal equilibrium with thermodynamic equilibrium there is one thermal equilibrium.

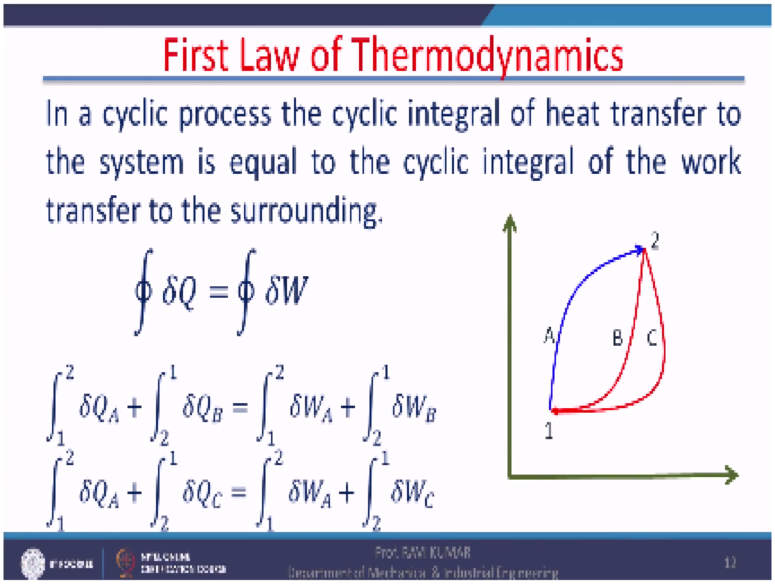
(Refer Slide Time: 11:28)



Another is thermodynamic equilibrium now these two equilibriums are different now in thermal equilibrium means there is no transfer of heat between two bodies then if there are two bodies are in contact with each other and there is no heat transfer between these two or there is no energy interaction between these two bodies they are called to be in thermal equilibrium but when we talk about thermodynamic equilibrium it includes the mechanical equilibrium and the chemical equilibrium it means the system should not have any unbalanced force at the same time system should not have any unfinished chemical reaction.

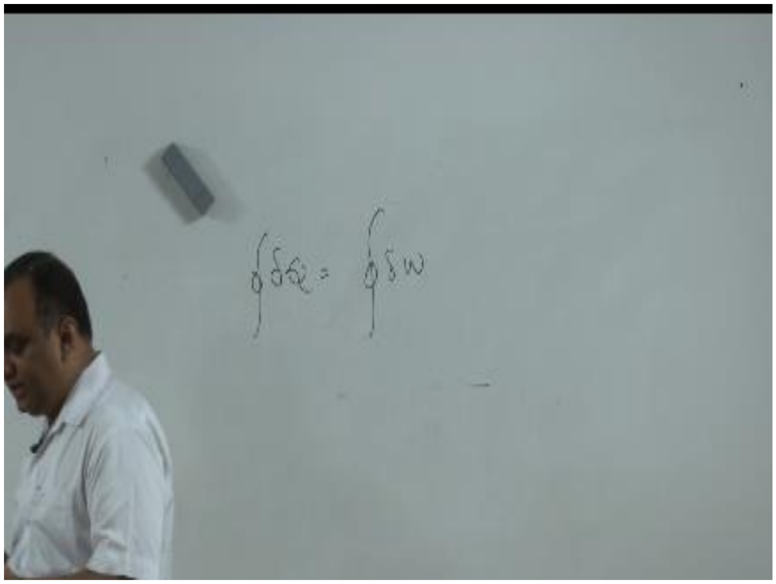
So now we will go back to the zeroth law of thermodynamics so when system A is in thermal equilibrium system B is also in thermal equilibrium with system C then B and C are also in thermal equilibrium it means if the temperature of a it is derivative of the zeroth law that temperature of A is equal to temperature of B and temperature of A is equal to temperature of C then temperature of B is also equal to the temperature of C now we will come to the first law of thermodynamics the first law of thermodynamics states that in a cyclic process the cyclic integral of heat transfer to the system is equal to the cyclic integral.

(Refer Slide Time: 12:55)



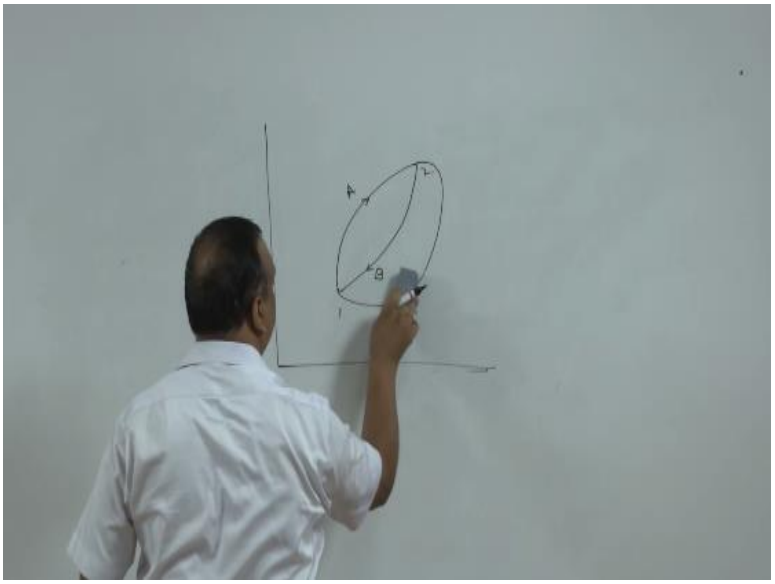
Work transfer to the surroundings so the first law says cyclic integral of heat transfer to the system is equal to.

(Refer Slide Time: 13:03)



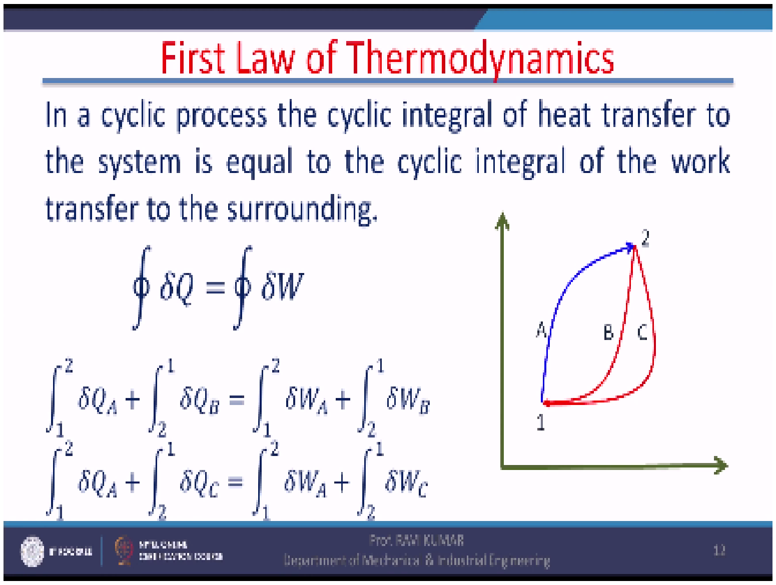
Cyclic integral of work transfer to the surrounding now in thermodynamics when heat is given to the system it is taken as a positive heat transfer when heat is extracted from the system it is taken as a negative heat transfer similarly when the work is done by the system work is done by the system it is considered as positive and when work is consumed by the system or work is done on the system the sign is negative now in this case now the statement of the first law of thermodynamics does not say anything about the internal energy the concept of interval energy is derivative of the first law of thermodynamics and this is how it is done suppose there are two states one and two.

(Refer Slide Time: 13:52)



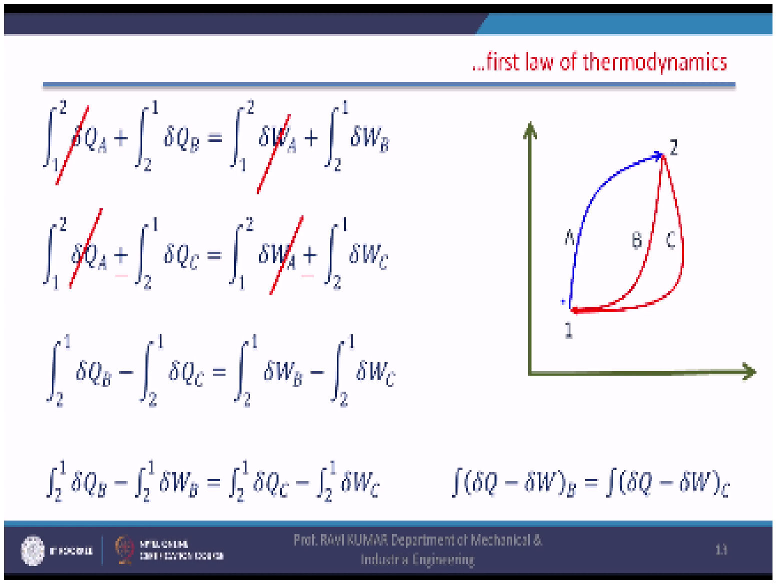
From state one to state two you are going by path A and from state two to state one you are coming by path P as shown here in the presentation also and there is an alternative path through which also you can compose state 1 that is path C that is path C now here in this case if we do the cyclic integral of this process 1A 2B1.

(Refer Slide Time: 14:31)



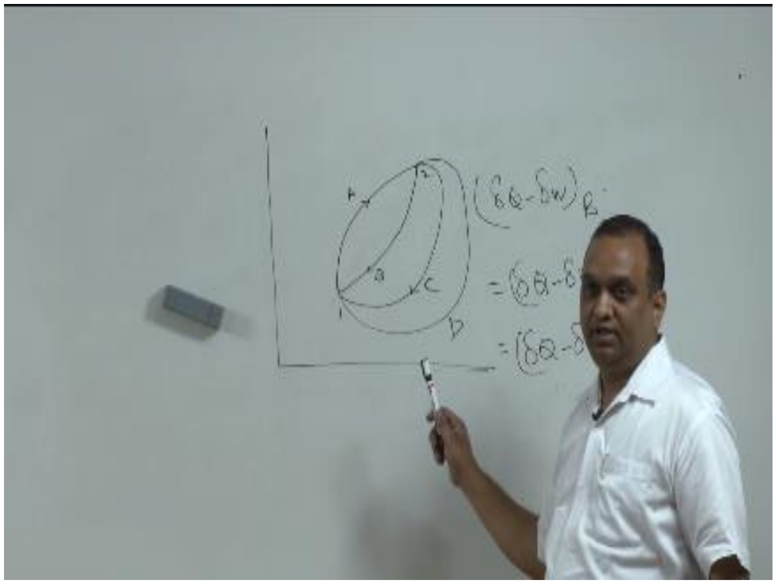
Then integral of ΔQ from 1 to 2 and 2 to 1 ΔQB is equal to integral of 1 to 2 ΔWA and two 1ΔWB so work and heat interaction in this closed loop or a cyclic process is taken into account in this equation now we will take another path that is 1A2C1. In this path again we will take the cyclic integral of heat transfer that is 1 to 2 δQ_A plus 2 to 1 δQ_C= 1 to2 δW_A+ 2 to 1 δW_C now we have these two equations, these two equations have been driven from the concept of the first law of thermodynamics. Now if you take difference of these two equations we will be getting this equation.

(Refer Slide Time: 15:19)



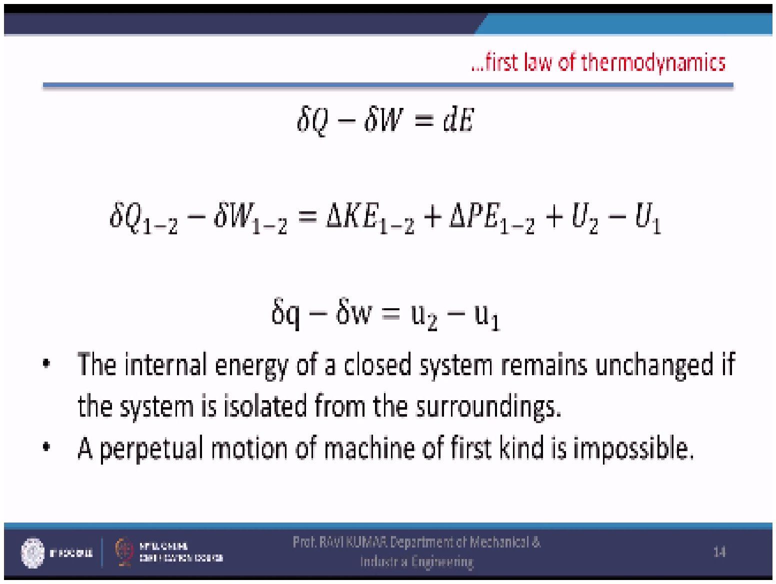
And now if you look at this equation if you again manipulate it then you can have δQ_B $\int$2 to 1 - $\int$2 to 1 δW_B= is 2 to 1 integral of δQ_C- 2 to 1 integral δW_C or δQ- δW.

(Refer Slide Time: 15:39)



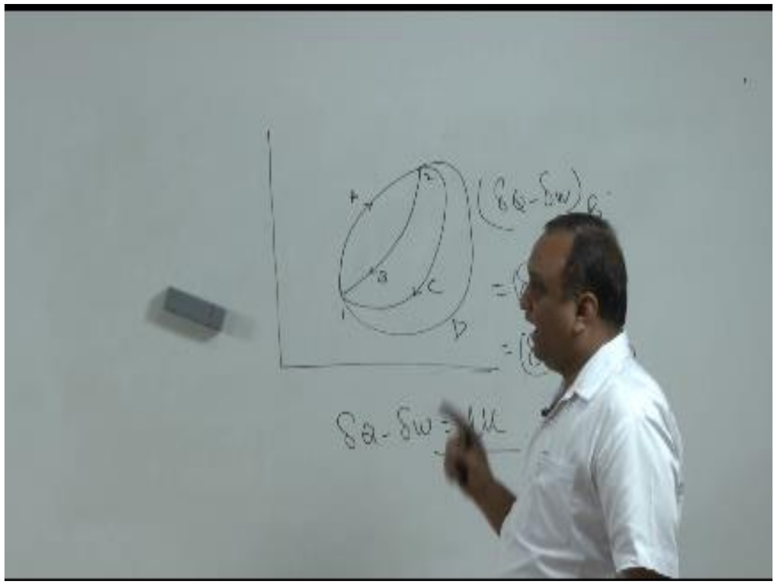
Through B is equal to δ is equal to δQ-δW through C in similar fashion we can prove that if there is another path D in that case δQ- δW_D so all these three are equal it means you choose any path you choose B, C or D the difference of δQ-δW is going to be the same this indicates there exist where exist a property in the system and this property is later known as internal energy of the system it is total energy of the system it involves everything.

(Refer Slide Time: 16:30)



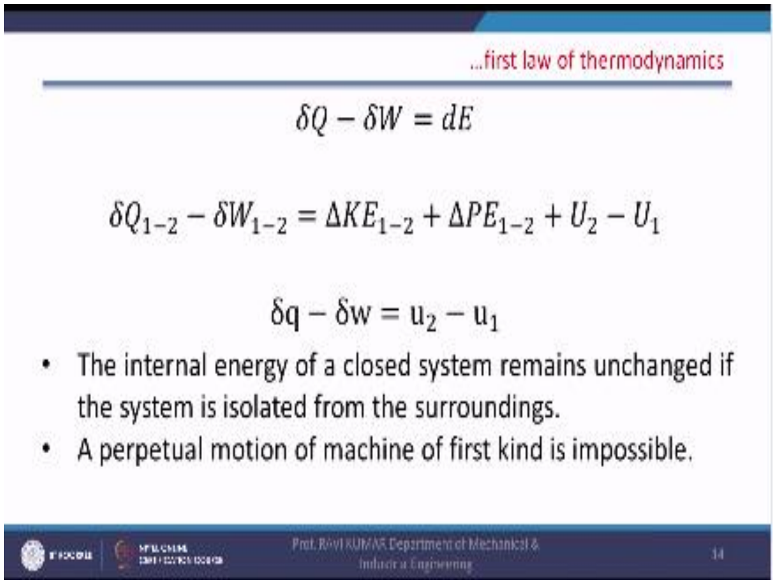
The difference in kinetic energy potential energy, rotational energy of the atoms everything it involves and normally in the system because we are dealing in the macroscopic level in the thermodynamics, so the finally for a closed system the for the first law of thermodynamics it turns out to be.

(Refer Slide Time: 16:46)



δQ-δW= du okay because these three expressions are equal it means irrespective of the fact we choose path B, path C, and path D you will be getting the same value it means this value this change in value is independent of the path you have chosen to arrive state 2 to state 1 and this value is nothing but the property of the system and this property is internal energy of the system.

(Refer Slide Time: 17:16)



So the internal energy of a closed system remains unchanged if the system is isolated from the surroundings, it also says that the, a perpetual motion of machine of first kind is impossible. now a perpetual motion machine is an imaginary machine and the first kind of perpetual motion machine means a machine which give constant output without any input and it works for an infinite time, it gives perpetual output without having any input and this machine is not possible.

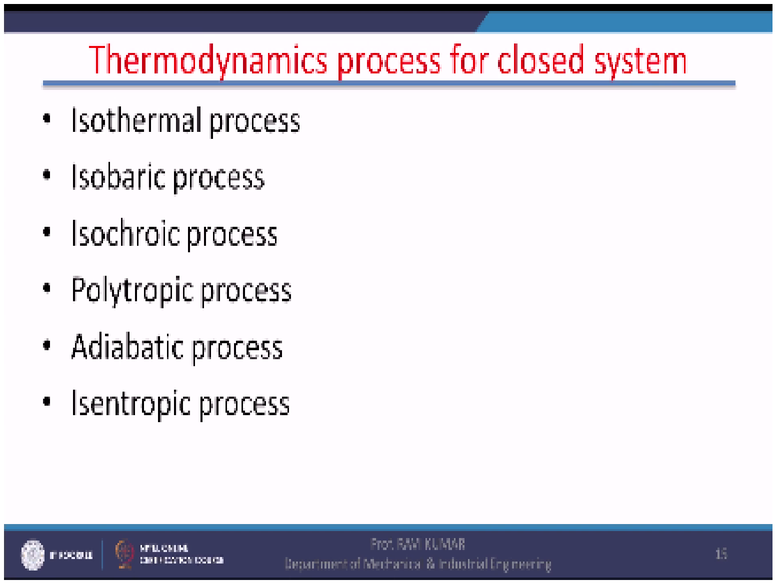
(Refer Slide Time: 17:49)

Because when we say δQ-δW=du perpetual bush output you will be getting but without any input so this is 0 at the cost of internal energy you will be getting output but this cannot be done for infinitely long time for a short period it is okay, for infinitely long time you cannot run a perpetual motion machine. So the perpetual motion machine of the first kind the machine which give perpetual output without any having any input is not possible.

Now there in fact I will explain you there are three types of perpetual motion machines first kind, second kind and third , now the second kind of machine is that machine which has 100% efficiency so that is violation of the second law of thermodynamics. So any machine cannot have 100% efficiency it means a machine cannot draw certain amount of energy from the source and do equal amount of work that we will discuss say in the during the second law of thermodynamics.

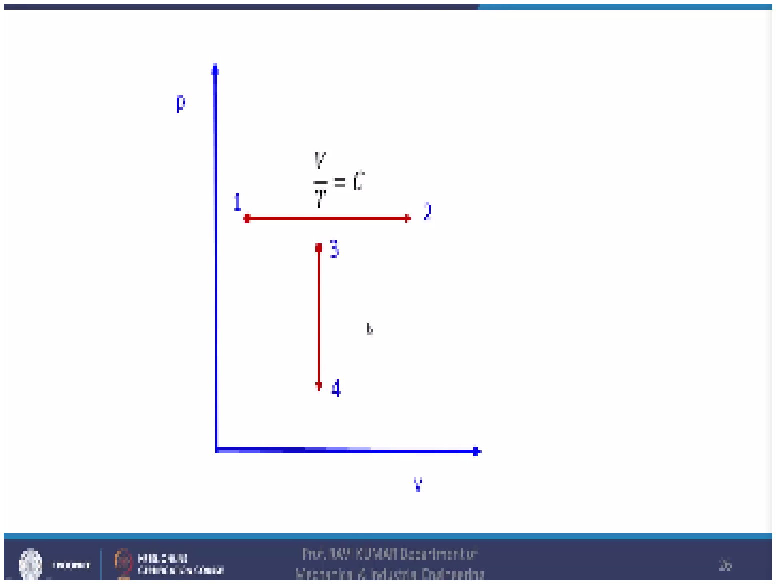
And there is a perpetual motion machine of third kind also, it means the machine which does not have any friction losses and it have, it has perpetual motion by the inertia itself, so the machine so all the machines are having friction losses and other damping effects. So no machine is possible which has no friction and no other damping effect and it runs by its own inertia so these are the three perpetual machines they are affect the imaginary machines.

(Refer Slide Time: 19:19)



And for the first law of thermodynamics we can draw that the first kind of perpetual machine is not possible. Now for the closed systems there are certain thermodynamic processes when this isothermal process.

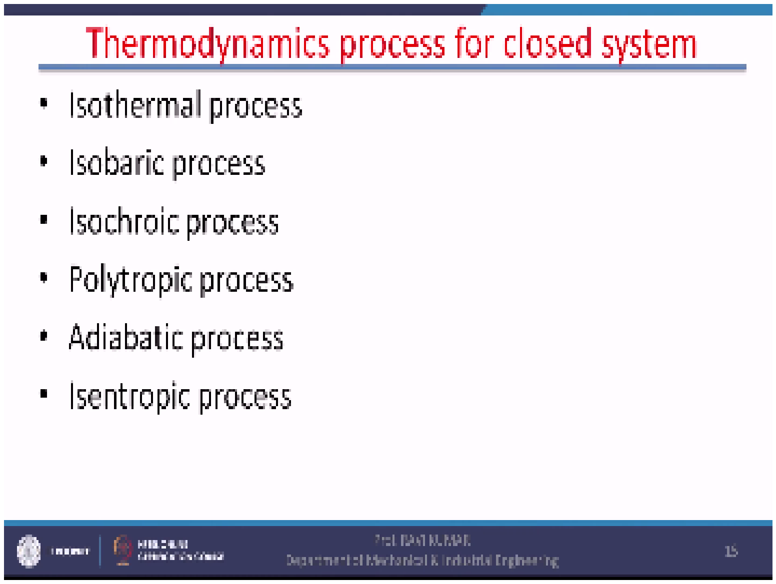
(Refer Slide Time: 19:30)



Now if you take isothermal process the temperature remains constant if you draw a PV diagram of an isothermal process it is going to be like this into the hyperbola, temperature is constant. Now if we increase the temperature we will be getting another curve and this curve will be parallel to this curve these two lines will not cut each other, and for isothermal process the relation the ideal gas relation is PV is equal to constant.

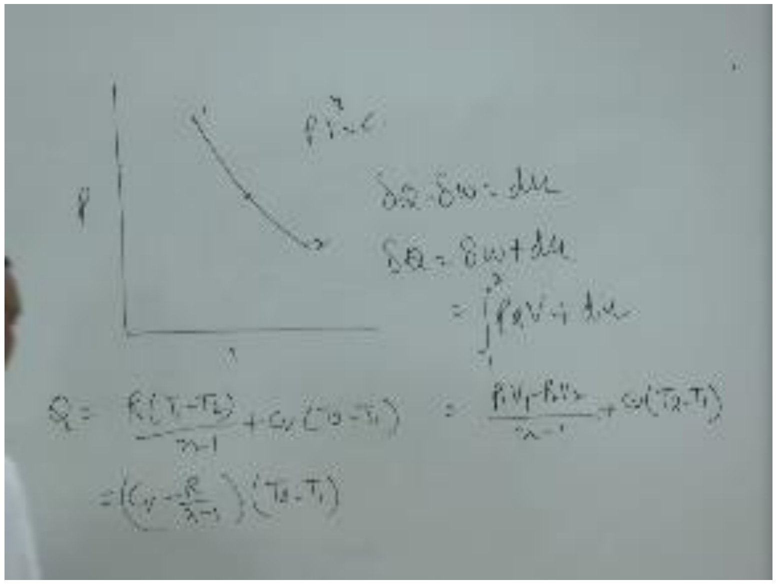
Now the second process is isobaric process isobaric, isobaric process means constant pressure process so the pressure is maintained constant throughout the process that is known as isobaric process similarly the third kind of process is isochoric process in isochoric process the volume remains constant so isobaric process the pressure remains constant and isobaric process the volume remains constant.

(Refer Slide Time: 20:29)



Now the third process is poly tropic process the poly tropic process because these processes will be frequently come across when we will work on reflection in air-conditioning so state one to state two poly tropic process follows the law PV^n = constant now adiabatic process and isentropic process they are also part type of poly tropic process but adiabatic process is special type of poly tropic process where there is no heat transfer across the system boundary. So if you look at the poly tropic process if you apply the first law $\delta Q - \delta W = D u$.

(Refer Slide Time: 21:10)

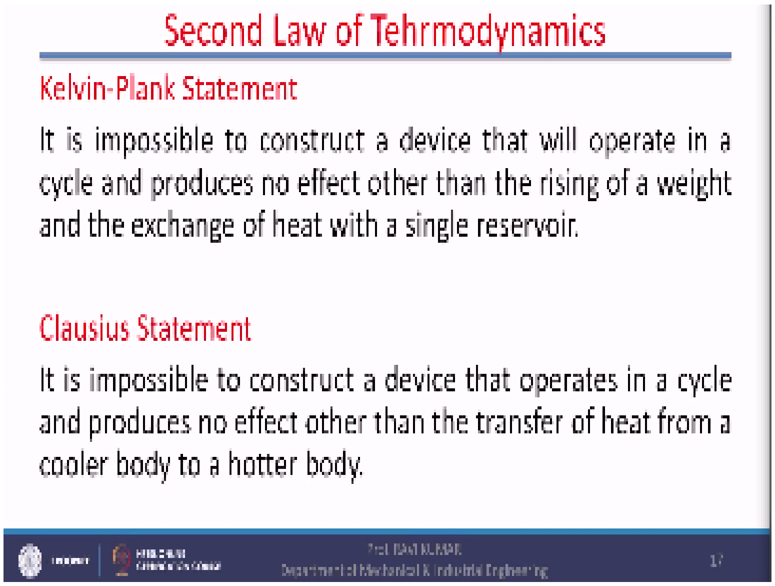


So $\delta Q = \delta W + D u$ and here we will say that it is integral of P DV system 1 to 2 plus D U and if we integrate using this if we integrate we will be getting p1 v1 minusp2 v2 divided by n - 1 +CV T_2- T_1or if you want if you write in a differential form Q =r $t_1 - t_2$ /n-1+CV t_2-t_1 or we can write CV - R / n-1 x t_2 - t_1 now in this case this is the heat transfer in poly tropic process now in this case suppose if I take n = γ when I take n = γ R / γ -1 becomes CV and when this becomes CV the heat transfer is 0.

So in a poly tropic process so in a adiabatic process where gamma is equal to for example here γ =1.4, so when it is a ratio of CP n CP specific heat at constant pressure and specific heat at constant volume the poly tropic process becomes adiabatic process there is no heat transfer in isentropic process it is clear from itself isentropic process entropy remains constant but they are different in adiabatic process though there is no heat transfer across the boundary of the system but internal friction losses may take place and entropy may change.

So adiabatic process is not necessarily a an isentropic process only a reversible adiabatic process reversible adiabatic process their process in which there are is no friction loss so a reversible adiabatic process is an isentropic process and in isotropic process also there is no heat transfer as it is clear from the name itself the entropy remains constant so heat transfer is zero.

(Refer Slide Time: 23:39)

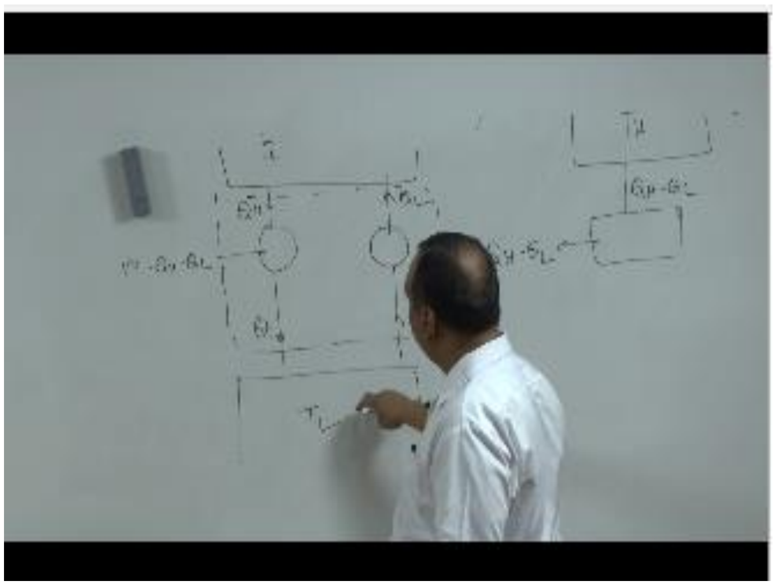


We will discuss about the second law of thermo dynamics second law of thermodynamics has two statements one is Kelvin-Plank statement this statement says it is impossible to construct a device that will operate in a cycle and produce no effect other than the rising of a weight and the exchange of heat with the signal reservoir it means it is not possible to draw certain amount of heat that is let us say hundred joules of heat from reservoir, and do equal amount of work it is not possible that is a statement by Kelvin – Planck. Another statement is back Claudius the clauses statement says that it is impossible to construct a device that operates in a cycle and produces no effect, other than the transfer of heat from a cold body to the hotter body.

It means heat by itself cannot flow from lower temperature to higher temperature, or cooler body to hotter body, so if you want to make heat flow from low temperature to high temperature external work is required, these two statements Kelvin - Planck statement and clauses statement, both these statements are addressing the second law of thermodynamics.

It means violation of one statement should automatically lead to the violation of another statement, let us assume that there is a violation of clauses a statement, so in that case suppose there is a reservoir of temperature T_H.

(Refer Slide Time: 25:08)



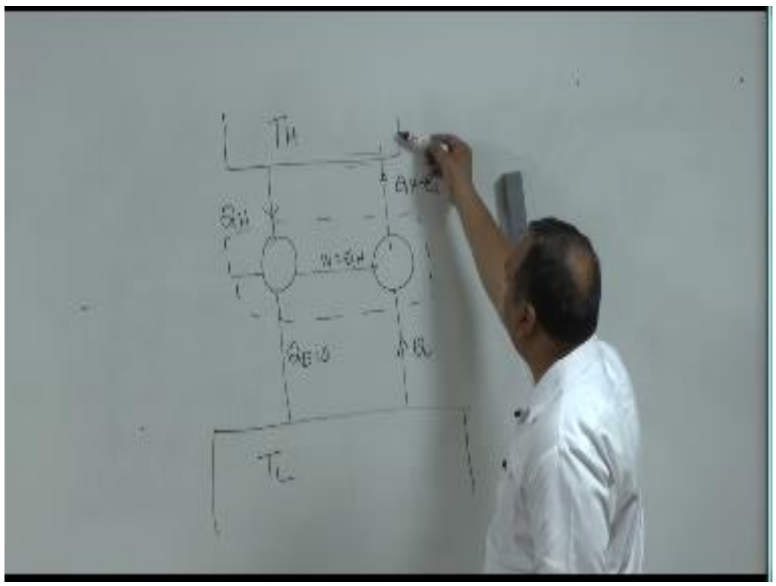
Thermal reservoirs are the bodies, of infinite thermal capacity so that if you draw a certain amount of energy from these bodies, the temperature of these bodies does not change, so there is a device which is extracting certain amount of heat, that is Q_H from here, and rejecting Q_L, here in the lower temperature and this device is doing work is equal to Q_H - Q_L right.

Now another device which is violating the Clauses statement, it means Q_L from lower temperature is flowing to higher temperature, without any external assistance, now if we Club these two devices, if you close these two devices, then we will be getting a scenario like this T_H, there is a device giving the output, Q_H - Q_L which is drawing heat Q_H – Q_L.

So Q_H- Q_L because Q_H is coming from the reservoir, and Q_L is going back to the reservoir, so net heat coming through from the reservoir is Q_H - Q_L however in this case Q_L heat is coming to the reservoir, and Q_L heat is leaving the reservoir, so net heat transfer to the reservoir is zero.

So if you are trying Q_H - Q_L from high temperature reservoir, then we can produce Q_H - Q_L amount of work that is violation of, Kelvin - Planck statement, so violation of clauses statement will automatically lead to the violation of Kelvin –Planck statement. Now we will assume that there is a violation of Kelvin –Planck statement. So when there is a violation of Kelvin -Planck statement at high temperature reservoir.

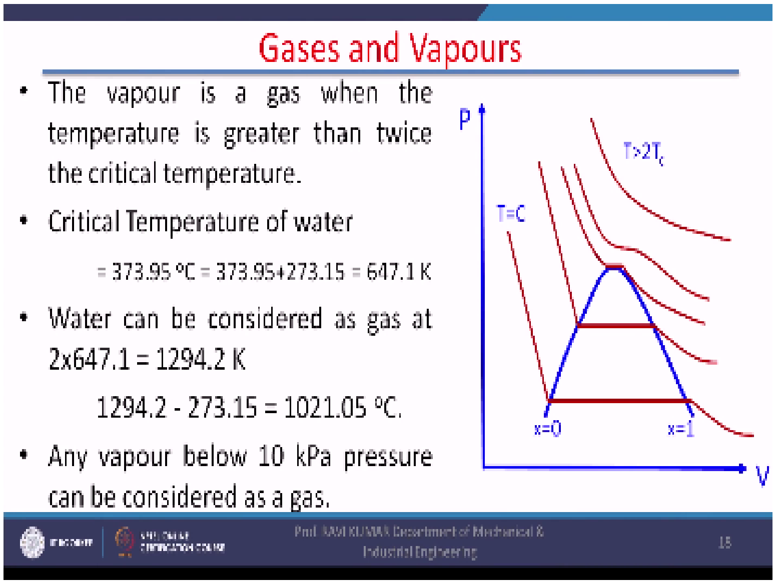
(Refer Slide Time: 27:11)



Q_H amount of heat is taken, and work is done by in the Q_H amount, and zero heat is rejected to the reservoir, this is violation of the Kelvin –Planck statement, now we have a device which is pumping q amount of heat, and if we connect this with this device instead of having output on this side, if we couple them then this is going to be $W = Q_H$, and heat transmitted to the high temperature reservoir will be $Q_H + Q$.

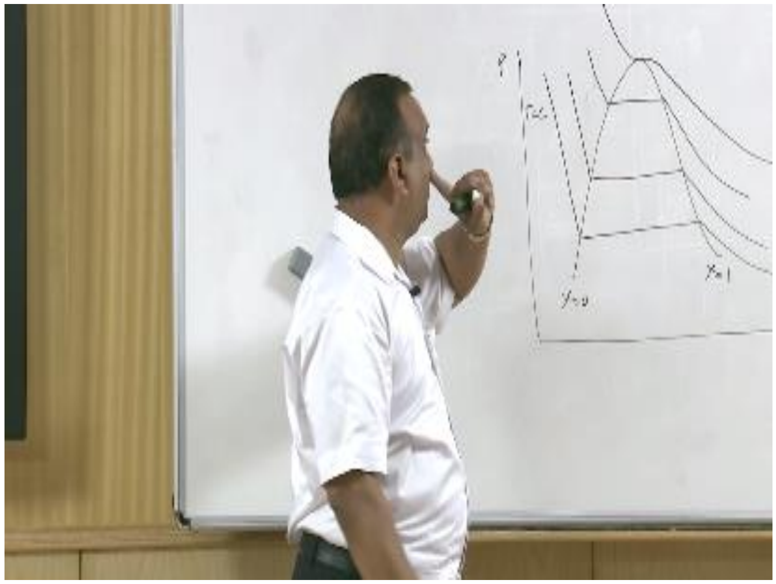
Now we are coupling these devices so Q amount of heat is getting transmitted from lower temperature to higher temperature without any external work, this is leading to the violation of clauses statement. So it is proved that if you violate one statement it will automatically lead to the violation of another statement. Now there is often confusion about the gases in the vapor and their behavior.

(Refer Slide Time: 28:37)



If vapor does not follow the ideal gas equation, if you look at the PV diagram of a typical PV diagram here quality is 0, this is pressure and this is volume and this is quality is 1. If you look at the typical PV diagram at constant temperature characteristic line will be like this, this is temperature is equal to constant, now if you increase the temperature the line will also shift. You keep on increasing the temperature the line will keep on shifting and during this region the vapor does not follow the ideal gas equation PV = RT and the maximum deviation is single-phase is here.

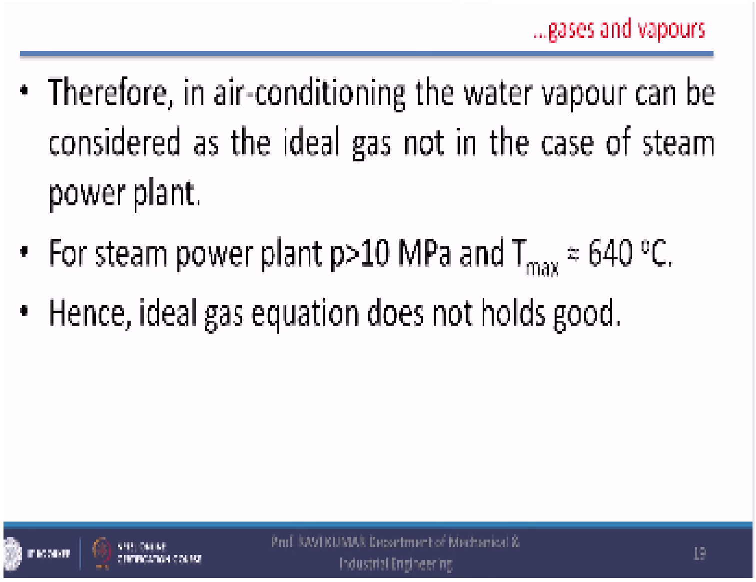
(Refer Slide Time: 29:39)



When the line becomes horizontal, this is critical point beyond critical point, if you draw the curve, the curve you will be getting like this and when the temperature is greater than two times the critical temperature. In that case you will be getting the curve which follow the PV = RT, so a vapor, a vapor can be considered as a gas when the temperature of the vapor is 2 times the critical temperature, it is shown in the slide also we have taken example of water. So water temperature critical temperature of water is 373.95 degree centigrade and in Kelvin it is 647.1 Kelvin.

So water can be considered as a gas at two times of critical temperature that is 1294.2 Kelvin which turns out to be 1021.05 degree centigrade. Now any vapor which is below 10 Pascal pressure can also be considered as a gas. So in air-conditioning processes the presence of water vapor is considered as gas, so water vapor is treated as a gas because, partial pressure of water vapor in here is always less than 10 kilo Pascal. However in the case of steam power plant where the pressure is 10 mega Pascal or 20 mega Pascal the maximum temperature does not exceed 640 degree centigrade.

(Refer Slide Time: 30:37)



So water vapor is not considered as a gas that is why we need steam tables for the calculations for steam power plants. Now this is over here with the concepts of the thermodynamics in the next class we will take up the introduction of refrigeration.

Educational Technology Cell
Indian Institute of Technology Roorkee

Production for NPTEL
Ministry of Human Resource Development
Government of India

For Further Details Contact

Coordinator, Educational Technology Cell
Indian Institute of Technology Roorkee
Roorkee – 247667
E Mail: etcell@iitr.ernet.in, etcell.iitrke@gmail.com

Website: www.nptel.ac.in

Acknowledgement

Prof.Pradipt Banerji

Director, IIT Roorkee

Subject Expert & Script

Prof.Ravi Kumar

Dept of Mechanical and

Industrial Engineering

IIT Roorkee

Production Team

Neetesh Kumar

Jitender Kumar

Sourav

Camera

Sarath Koovery

Online Editing

Jithin.k

Video Editing

Pankaj Saini

Graphics

Binoy.V.P

NPTEL Coordinator

Prof.B.K.Gandhi