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Course
on
Laws of Thermodynamics

by
Prof. Sankar Kumar Som
Department of Mechanical Engineering
Indian Institute of Technology Kharagpur

Lecture 06: Zeroth Law of Thermodynamics

Good morning and I welcome you all to this lecture of the course laws of thermodynamics, now today I will introduce you with the zeroth law of thermodynamics that is the starting point of all the law.

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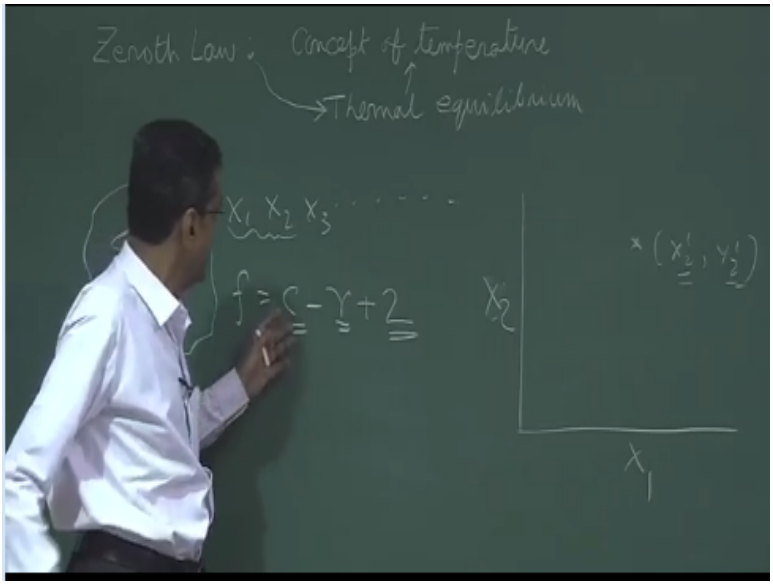

That is zeroth law of thermal energy as I told you earlier the zeroth law provides the concept of temperature the zeroth law provides the concept of temperature through the concept of thermal equilibrium through the concept of thermal equilibrium through the concept of thermal equilibrium concept of thermal equilibrium the concept of temperature the zeroth law first tells us what is thermal equilibrium then through this concept of thermal equilibrium it provides the

concept of temperature now at this moment we know everything the thermal equilibrium we have already discussed you have ready that concept of temperature.

Now temperature as we know but the very first definition is that by hotness or coldness of a body temperature can be defined from various angles for example in statistical thermodynamics from viewpoint of kinetic theory of matter the microscopic approach the temperature is the manifestation of kinetic energy of the molecules due to this random motion, so this way we define temperature it is the sense of hotness or coldness or this is the manifestation of the kinetic energy of the from the molecular or microscopic approach.

But in classical physics how do you define temperature usually we tell temperature that it is a property by virtue of the difference of which between the two systems and energy transfer takes place that we call as heat or when we define heat energy we tell heat energy is that energy that is transferred between one system to other system because of the temperature difference or from one point to another point of a system by virtue of the temperature difference and temperature is that property which allows the heat to flow or heat to be transferred.

This way we defined temperature thermal equilibrium also you know by this time because you have already come to know the thermodynamic equilibrium of a system which requires three criteria the mechanical equilibrium thermal equilibrium and chemical equilibrium to be there simultaneously and thermal equilibrium means there will be no change in temperature that means if two bodies are kept into contact and there is no difference between the temperature between the two bodies or two systems the temperature will remain unchanged.

If there is a difference in temperature the heat transfer will take place and the temperature will change so long they come to a common value which will not be changed any further, so this way we know that temperature is the property that allows the system to come into thermal equilibrium and because of the difference of which the heat is being transported this is known to us but how at the beginning the zeroth law evolved to define the concept of temperature in classical thermodynamics that I will tell you today through the concept of thermal equilibrium.

Now earlier class one of the classes I told and of course we have come to know by this time that when we define the state of a system by a number of properties like X_1 X_2 X_3 like this the question comes that all the properties cannot be independent cannot be independently varied

there maybe some number of properties which are independent, so that if they are fixed other properties are automatically fixed by the relationship of thermodynamic properties which is very important aspect of subject thermodynamics.

So therefore the number of independent properties to fix this state is fixed and you know by this time this is given by this equation known as gives phase rule that number of independent intensive properties to fix the state of a system is given by C - R + 2 where C is the number of component, R is the number of phases +2 and for a single component with single phase for example a mass of gas in a tank or in a closed chamber in a piston cylinder this is one component one single gas one phase.

So two independent intensive properties are required to fix that state and in that case the state of a system of course it has to be in equilibrium otherwise system cannot be prescribed it goes on changing I told earlier then I cannot specify this system for the given values of the intensive property, so that other properties will be automatically fixed other intensive property so therefore this will be at thermodynamic equilibrium then we can since in this particular case of one component 1 phase 2 and 3 dependent properties.

Let the property be x and y instead of x_1 x_2 or you can write x_1 x_2 does not matter x_2 x_1 two independent properties intensive properties for the special case we can fix or we can show the state of the system in a two dimensional property plane given by $x_2$and x_1 with the value of some $X'_2 - y'_2$ - some given value X_2 y_2 Z_n so this so therefore with this as the background I now explain you what is zeroth law rather how the zeroth law how the zeroth law evolved in which way today we know everything what is thermal equilibrium what is temperature all these things you have learnt.

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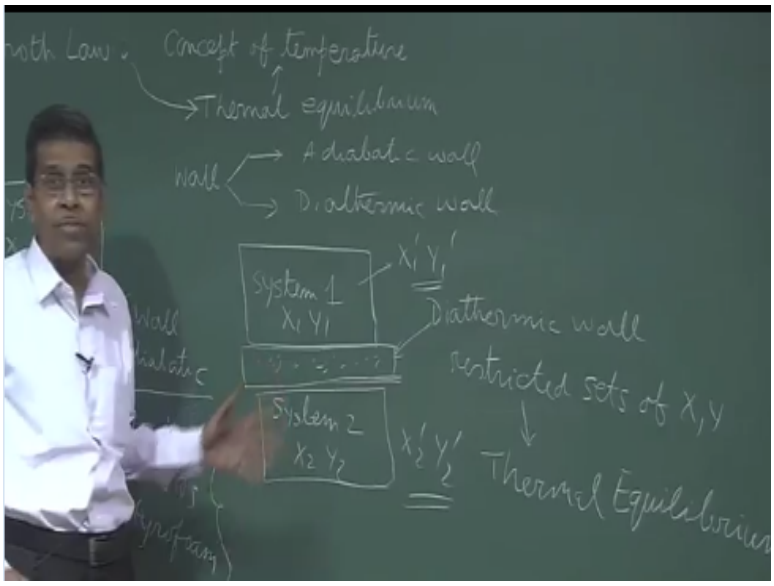

But now the concept temperature how did it evolve through the definition of thermal equilibrium by Zeroth law now with this thing we consider a system 1 with single component single phase so that two intensive properties are required to fix it State and let us consider -properties at x_1 and y_1 and another system will consider here system 2 which is specified by x_2 y_2 now in this context I will tell that there are two boundaries defined or two walls are defined how now if we consider that the two systems interact with each other through a common boundary which is known as wall like this.

And with nothing else the two system interacts with each other and with nothing else and it interacts through one common boundary or wall like this wall then in this context there are two types of wall are of two types one is adiabatic wall another is known as diathermic wall today immediately we will tell from our knowledge that adiabatic wall is the wall which does not allow the heat to for heat to be transferred from one system to us and diathermic wall is the wall which allows the heat to flow or heat to the transport from one system to other system.

But if you do not know all these things but if you do not want to define through that I do not want to use all these things which you already know the adiabatic wall let this wall is adiabatic and you have it, so adiabatic wall is defined in wall so in zeroth law was first postulated by fowler then it was postulated like that then adiabatic wall is such an wall that if we make these two systems in contact through this wall then the system can attain any value of x_1 y_1 x_2y_2 any

attainable values of x_1 y_1 and x_2y_2 we may have or we have through these adiabatic wall provided.

The adiabatic wall is strong enough to withstand the stress develop due to the difference in the sets of this XY between the two system for example if the pressure difference is there one of the xx properties x_1 is p_1 pressure of the system on excuse pressure of the system now I am defining terms of general but it can be any two properties for example pressure due to that difference in pressure there will be a force acting on this net force and that will cause a stress, so therefore provided the wall can withstand any stress develop due to the difference in these sets of X values x_1 y_1 sets of that XY values.

Then we can attain any properties of x_1 y_1 x_2 y_2 with this wall that is known as adiabatic or an practical example of the adiabatic wall is would asbestos these are insulating material Styrofoam all these things are as we saw Styrofoam all these things are adiabatic wall so this is the way the adiabatic wall is defined but if we make this system 1 and 2 x_1 y_1 and the system x_2 y_2 system 2 and x_2 y_2 another said through another kind of wall which is diathermic wall this is that let this is represented like this is diathermic wall.

So another kind of wall which we call as diathermic wall if the two systems are in contact through this wall and they interact only through this wall like the derivative was then the system properties XY will have a spontaneous change we will go on changing and the equilibrium state will come when this will attend let some property X_1' Y_1' and X $_2$' and Y_2' and the value of this set X_1 that is why you want there is an X'$_2$ dash Y_2' will depend upon the initial value of x_1 x_2 these are not very arbitrary or some any in for any choice able values we can have.

That means the system at some initial state x_1 Y_1 and system 2 at some initial x_2 y_2 if they come into contact by adiathermic wall they will go to some X'$_1$ Y'$_1$ X' $_2$ Y' $_2$ value and this value this set depends upon the initial set of this XY by the 2 system so therefore we can say here that in this case the system will come to equilibrium through some restricted sets of XY through some restricted this is very important restricted sets of XY like this we cannot have any attainable values of xy for the two systems if it is in contact with adiabatic or provided it can which can be stress associated with the difference in this xxy.

But here the system will come to equilibrium with restricted sets of XY that depends upon the initial state if ax t through diathermic wall which is also sufficiently strong enough to withstand the stress associated with this xxy and this type of equilibrium through the restricted states of xy okay the restricted states of xy due to interaction through a diathermic wall is known as thermal equilibrium thermal equilibrium is known as thermal equilibrium, so this is the concept of thermal equilibrium without defining the temperature how we evolved through the first step of zeroth law okay.

Now with this as the background I come to another case what is this let us consider, now let us consider now two systems AB.

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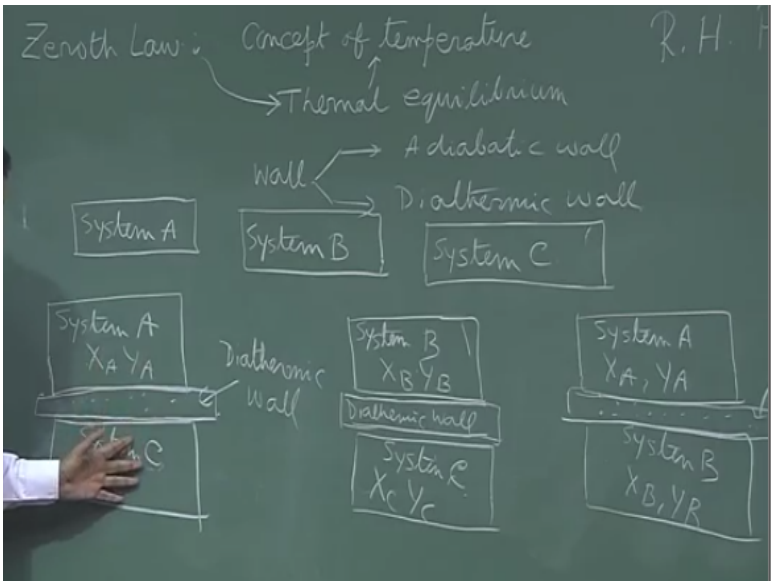

Now let us consider this way whether I tell you in a different way let us consider three systems one is system A another is system B another is distance, now let us consider system a and system B system A and system B are made in contact through adiathermic or say this is diathermic wall sorry not the system B let us system C that will be better to understand system C A and C and if it is found that with this state XAYA that again XY is the set of the property independent property fixing the state and with this state XC YC for this system they are in equilibrium.

These share states I am not bothered with the start with equilibrium state that diathermic wall they interacted with each other and a come to equilibrium when the system is attained the state by Xay set and XCy similar way if the system B this is that one week one system B and C are

made into contacts - diathermic wall and with the values XC YC of this system if system be attained a thermal equilibrium state that I have defined earlier with its value of XY as XV YV you understand with the XB YB that system A comes into thermal equilibrium system CX CY C at XA YA.

And similarly this system becomes into thermal equilibrium with this system see with XC YC when its value will be XB YB under this situation if the two system A and B with this state of defined by XA YA for system A and XB YB of system B through a diathermic wall 3 this is that through a diathermic wall we will see that state will not change that means the state XA and XB YB is nothing that means it will be thermal equilibrium that as I discussed earlier the first step of the zeroth law defines the state of thermal equilibrium.

Then we see that how the thermal equilibrium is rich what is thermal equilibrium to the concept of diathermic wall that when two systems are made in contact with diathermic wall and it interact only through this thermal wall interaction between the system and they do not interact with nothing as then they come to an equalrein state with the specific some values of the set XY the two properties then we call it is a thermal equilibrium and that fits the restricted states not any state they can appear then that set depends upon the final equilibrium set depend upon the initial sets of XY for the two systems.

That we have already discussed that first step then the second step is that if system A and system C comes into thermal equilibrium through the diathermic wall at this specified state XA YA + XC YC and similarly the system B comes to that specified state XC YC of the system C at thermal equilibrium that means obviously through data we contact to diathermic wall at systemic with the state xB YB then the two systems are kept into contact through a diathermic wall.

Or they allowed they are allowed to interact with each other to the diathermic wall then they will not interact that they will remain at the equilibrium that means there will be no change in this state and this is actually the zeroth law and this was postulated by the man R.H. Fowler, in this fashion that I will not write in on the board but I will tell you slowly.

That this was postulated this phenomena was postulated like this if the two bodies are in thermal equilibrium with a third body they are in thermal equilibrium with each other if the two bodies or two systems are in thermal equilibrium with a third body or third system then they are in thermal

equilibrium with each other and this beside this is precisely the statement of zeroth law this is very obvious today.

So nobody will feel anything great to know these things but the most important thing is that how did this evolve today we know what is thermal equilibrium we know what is the concept of temperature either by classical physics or classical thermodynamics or by microscopy or statistical thermodynamics or statistical physics. But how in classical thermodynamics or classical physics is the concept of temperature initially originated by the zeroes law is a very important today for us to know.

When you run the subject thermodynamics you know, how the thermal equilibrium concepts came to the zeroth law and how the definition of temperature came here through this law as stated by Fowler that two are in thermal equilibrium two systems in thermal equilibrium system A and B with a third system third system is C then they will be in thermal equilibrium with each other at that given state.

The property which enables us which enables us which enables the system enables us to make this is known as temperature that means the property which enables the two systems to come into equilibrium that is the temperature that means one property definitely which allows this spontaneous change when they come into contact so diathermic wall for system A and system B.

It is probably the same so that when they are kept into contact with each other to the atomic or nothing is happening that means there is some property common to them some property common to them is same, so that when they come into thermal equilibrium with the system and that property in system C is also the same that means there is some property which for system ABC are same for which this phenomena the entire phenomenon can occur.

At which the two systems are in thermal equilibrium with a third one are in thermal equilibrium with each other okay, so this is the concept of thermal equilibrium in concept of image this property is the temperature and this type of equilibrium as I have told earlier in the first step of zeroth law is the thermal equilibrium. So this is the concept of thermal equilibrium and at the same time this gives the concepts of temperature measuring instrument, a thermometer.

That means C with which the system A and B rather is calibrated what is thermal equilibrium is gives the concept of temperature measuring instrument thermometer, that means system A and

system B has the same property so that they are in thermal equilibrium with each other that is temperature which is same for system C that means system C gives the concept of measuring instrument of temperature.

For example thermometer, so therefore zeroth law gives basically the concept of temperature through the concept of thermal equilibrium and finally provides us also the concept of temperature measuring instrument the third body C is actually the temperature measuring instrument or thermometer so this way the definition of zeroth law originates and which is very important in thermodynamics to know it way how the zeroth law is defined, okay.

I think today I will not discuss anything else so we will start the first law of thermodynamics in the next class okay, thank you.