Basic Thermodynamics

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Lecture – 01

Introduction and Fundamental Concepts

Good morning to all of you in this session of thermodynamics. I welcome you all to this session. Now first I will describe you, what the subject thermodynamics is? What its contents is, which is very important to know before going to learn this subject. Now the word thermodynamics originates from the word therme, it is a Greek word. We can write this therme.

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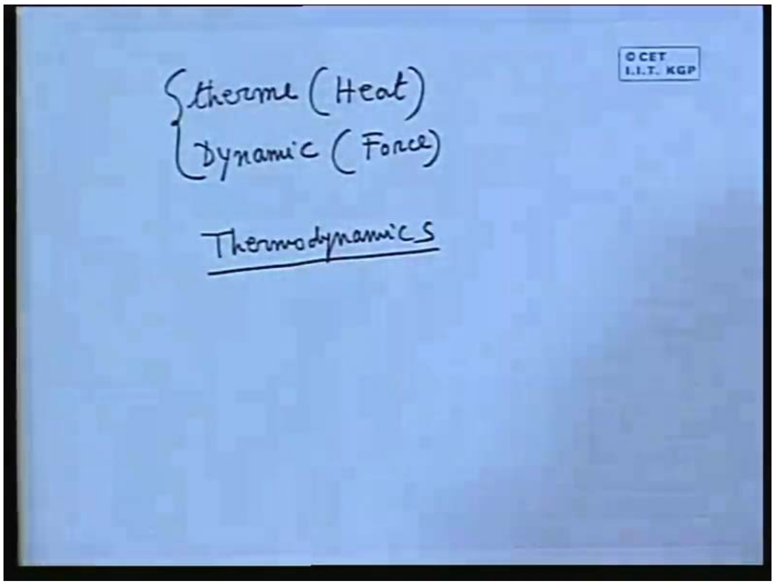

Therme is a Greek word which means heat and dynamic which is force. The word thermodynamics originates from these two words. This is the classical history of thermodynamics. Little bit you should know these things. In primitive days understanding of thermodynamics centered around the concept of getting power from hot bodies or getting power from heat, abilities of hot body to produce work, which is partly the scope of mechanical engineering thermodynamic student but the scope of thermodynamics is much wider or much broader. Before going to define this subject thermodynamics in a formal way, I just tell you like this, thermodynamics is probably encountered in our daily life.

In all corners of physics just we start this way before going to give a formal description or definition of thermodynamics. There are several physical processes that occur in nature. There are some spontaneous processes that occur in nature. There are certain processes which we cause to occur in nature for our own purpose, but all these physical processes are not at random or occur in any arbitrary way. There is always a rhythm for all physical processes in nature to occur.

Even the random motions of molecules have got a typical correlation coefficients or correlations. Probably you have heard or you have learnt these things at first year level, that is school level, and statistical properties are defined. Similar is the case of turbulence in fluid flow. So this way, all natural processes in nature have got a rhythm. They occur with certain directional constraints that I will discuss it in detail afterwards. For an example, the spontaneous processes that a water falls from higher elevation to lower elevation. Heat flows from high temperature to low temperature not the reverse way but there are many processes which we cause to occur, they also do not occur in the reverse way. For example, the conversion of mechanical energy into heat or intermolecular energy is possible.

For example, if we stop a moving body, the body becomes hot that means mechanical energy is converted into intermolecular energy, but the reverse does not happen. But at the other end there are many processes which can be caused to occur in both the directions. For example, we can heat a body, we can cool a body. We can expand a gas, we can compress a gas but in those cases also we will see that there is some change in the external surroundings, when you cause the process to occur in both forward and reverse direction that will come afterwards in detail.

When we will discuss the second law of thermodynamics that means today at this moment, we want to tell that all natural processes occur with certain rhythm. There are certain natural laws or natural constraints imposed on these processes. Now if we consider the conversion of energy which is very important in the context of thermodynamics transformation or transfer of energy from one system to another system, there are certain basic laws to be followed.

For example, the law of conservation of energy which we know since childhood, but at some point of time, we have to know this law that means energy can neither be created nor be destroyed.

If we keep aside the conversion of mass to energy otherwise the mass plus energy is constant. But if we keep aside that particular physics or mass is being converted into energy, we can tell that total energy is constant. It is basically the first law of thermodynamics. So at one point of time we have to know. Another thing is that when we convert energy in this case, the conversion is not efficient in all directions just for an example I am telling you. These are all popular things.

For example if we want to convert mechanical energy into electrical energy or electrical energy to mechanical energy generator motor principle you know. You can conceive physically an ideal system where 100 percent conversions is possible without violating the conservation of energy principle. But if you want to convert heat energy into work continuously then 100 percent conversion is not possible even in an ideal case. Physically also we cannot conceive this thing. These are the constraints but if we do the reverse, we convert mechanical energy into heat just I told, a moving body may be stopped to generate internal energy or heat it will make the system insulated.

So that entire kinetic energy can be converted into heat energy or intermolecular energy more precisely. It does not valid the conservation of energy. We cannot get more but you can get one is to one correspondence if there is no loss, but it is not so when we convert heat into work. So these are the directional constraints on the processes where transformation or conversion of energy associated with.

That means we see that for all natural processes involving energy transfer, energy conversion, there are certain rhythm, there are certain directional constraints, quantitative constraints imposed on these processes, which subject guides these principles, that is thermodynamics. Moreover the relationships between physical properties of these systems which are affected by these processes are also being established by this science of thermodynamics.

So with this knowledge we can define thermodynamics like that which we can get in book we do not have to write these things. The thermodynamics is a fundamental subject that describes the basic laws governing the occurrence of physical processes associated with transfer or transformation of energy and also establishes the relationship between different physical properties which are being affected by these processes. This is the domain of thermodynamics.

Now the entire subject thermodynamics is based on laws of natures formed by our observation and common experience. That means if we consider the thermodynamics as a table then the legs are nothing but the laws of nature which are sometimes observed in nature by day to day experience.

For example, we grow old, we do not grow young, the hair grow grey not black. These are also part of thermodynamics. These are the directional laws, second law of thermodynamics. So these are laid by the leg that is the basic frame work of thermodynamics from the laws of nature by our observation or common experience and at the same time by experimental observations in the laboratory which frame the base work of thermodynamics.

In thermodynamics, there are two views. One is macroscopic views another is microscopic or statistical views. It is not always true for thermodynamics for all physics probably at this stage we know that there are two views. One is the macroscopic views, sometimes we tell as classical physics.

For example, one is classical mechanics, another is the quantum mechanics, one is the macroscopic views, and another is the microscopic views. Macroscopic view is sometimes referred to as classical, the adjective classical comes and microscopic view is the statistical in case of thermodynamics we call it as statistical. These are all recapitulations of the basic things.

Now in macroscopic view what we do? We fix our attention to certain quantity of matter or substance without going into the events occurring at the molecular level. We specify the characteristic features of this system which we will define afterwards as properties of these systems those are being affected by the processes or its interactions with the surroundings by some macroscopic quantities which can be directly sensed by human senses can be directly measured. This is also not 100 percent true, afterwards we will see in thermodynamics.

There are properties which cannot be sensed by human senses or even cannot be directly measured but at least they can be related by some expressions with some primary characteristic features or properties which are directly sensed or measured and those relationships are established either by theory or by experiments at a macroscopic level.

So this is the domain of macroscopic thermodynamics or classical thermodynamics or the classical physics in general, whereas in microscopic view, what we do? We try to analyze the behavior of a certain quantity of matter from its molecular actions that means we go in detail to the molecular activities. So that is the microscopic or statistical view.

So the relationship is very simple that macroscopic behavior is always explained through the behavior of individual molecules. This is because any matter or substance is composed of number of molecules. Therefore one can relate that any macroscopic behavior can be looked as an average over a long period of time of different or a large number of microscopic behaviors or microscopic characteristics but here one very important thing is that microscopic behavior or any explanation or any theory in microscopic behavior may change but this has to be calibrated against the macroscopic behavior.

For example we know that pressure is a macroscopic property which we sense and which can be directly measured but what is its microscopic explanation? The pressure is because of the change of momentum due to molecular collision that means if we want to find out the pressure exerted by the fluid on a wall we just explain from a molecular point of view that it is the time average of the change of momentum due to molecular collisions that means the average of the change of momentum due to molecular collisions taken over a large time.

Now if this theory changes little bit at the molecular level but the pressure it sense, its measure, its change with certain other pertinent parameters remain the same because this is the truth. So any molecular theory has to be calibrated against the macroscopic theory or macroscopic observations and it must have the capability of describing the macroscopic behavior.

So what macroscopic science or classical science tells us the truth? So that is the relationship between classical physics and the quantum physics or the classical thermodynamics and the microscopic or statistical thermodynamics. This we should know at the beginning to appreciate the course. So our course will focus only on classical thermodynamics. Some basic part of the thermodynamics that you are at your under graduate core level course. Now with this introduction, the course outline of this course package is the first session.

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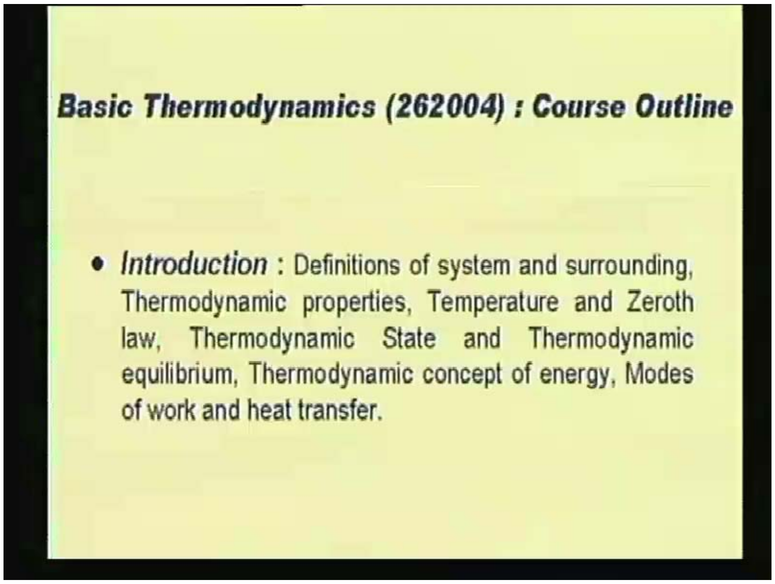

So now the first one is you can read it, you can take it but I will distribute the hand outs that the prints to you so you may not have to write it. So first is introduction, basic definitions of systems and surroundings thermodynamic properties, temperature and zeroth law, thermodynamic state, thermodynamic equilibrium, and thermodynamic concept of energy, modes of work and heat transfer. Actually this part introduction forms the basic background of understanding the other things that means this gives the basic concepts and introductions then after that if we see the first law of thermodynamics.

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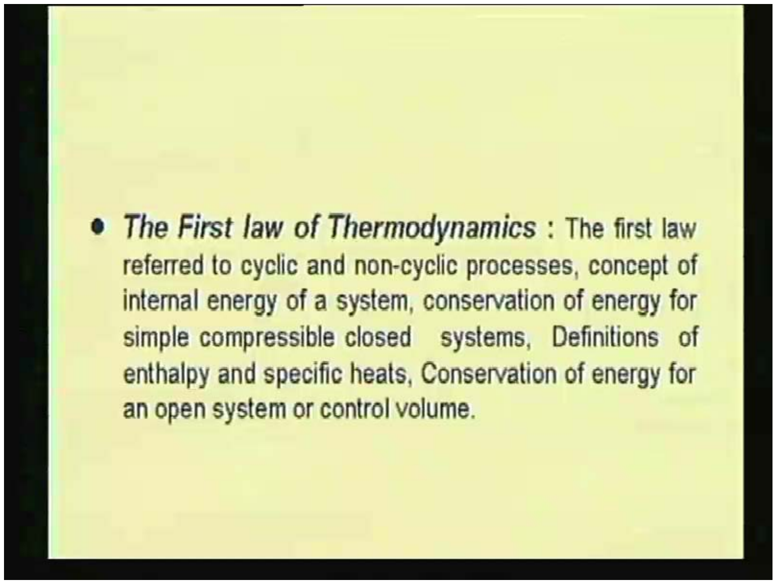

The first law of thermodynamics referred to cyclic and non-cyclic processes. These all I will describe, concept of internal energy of a system, conservation of energy for simple compressible closed systems, definitions of enthalpy and specific heats, conservation of energy for an open system or control volume.

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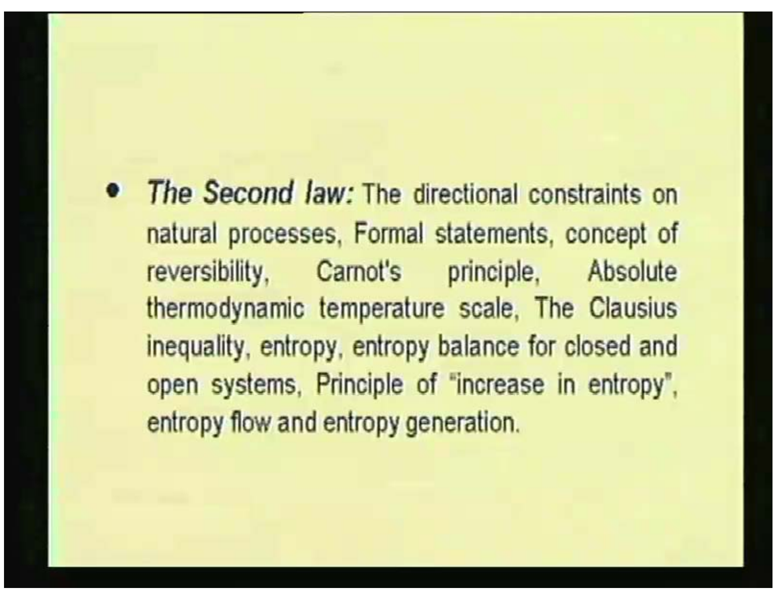

Next is second law which is very important. In this context, I will tell you something afterwards.

The directional constraints on natural processes, formal statements, concept of reversibility, Carnot's principle, absolute thermodynamic temperature scale, the Clausius inequality, entropy, entropy balance for closed and open systems principle of increase in entropy, entropy flow and entropy generation.

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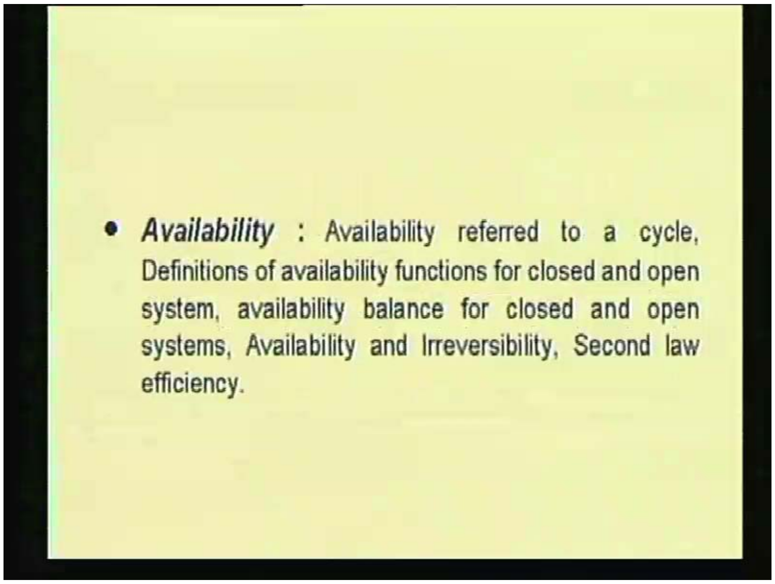

Next is the availability. So this is another part of the second law. It is a corollary of the second law. Availability referred to a cycle, definitions of availability functions for closed and open system, availability balance for closed and open systems, availability and irreversibility, second law efficiency. This may not be known to you all the terminologies.

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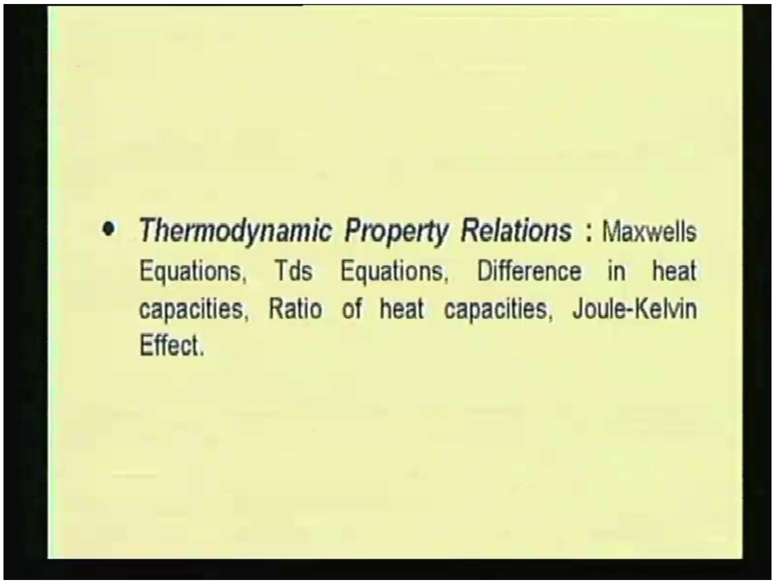

Thermodynamic property relations are very important. The thermodynamics is a subject which establishes the relationship between different properties when there is a change in the properties because of a process occurring due to the interactions between the system and the surroundings. So Maxwell's equations, Tds equations, difference in heat capacities, ratio of heat capacities, Joule-Kelvin effect.

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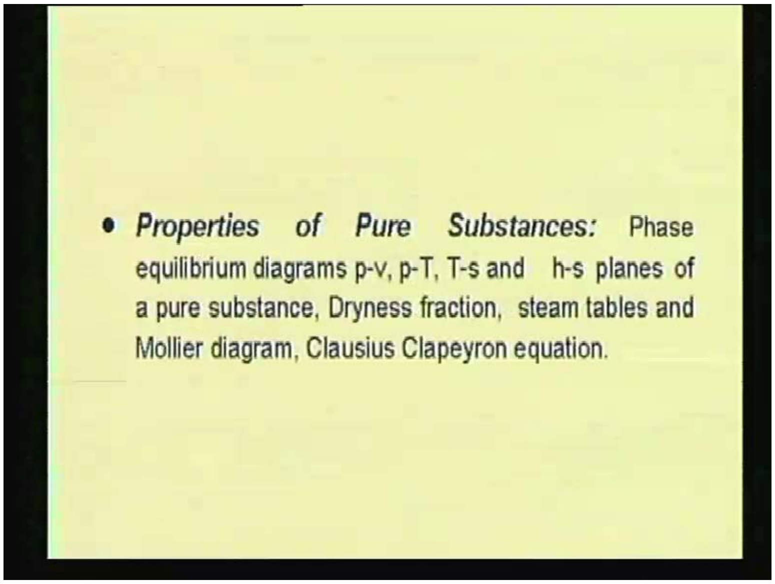

Then properties of pure substances, a part of which already we have studied in physics, phase equilibrium diagram different thermodynamic planes p-v, p-T. These are basic properties of a system, T-s, s is the entropy, h-s, h is the enthalpy. This will be taught afterwards in this course. Then dryness fraction, steam tables, Mollier diagram, these are the things we will know afterwards. Clausius Clapeyron equation probably you have heard of it at your under first year level or school level, equation relating pressure and temperature during the change in phase of a system.

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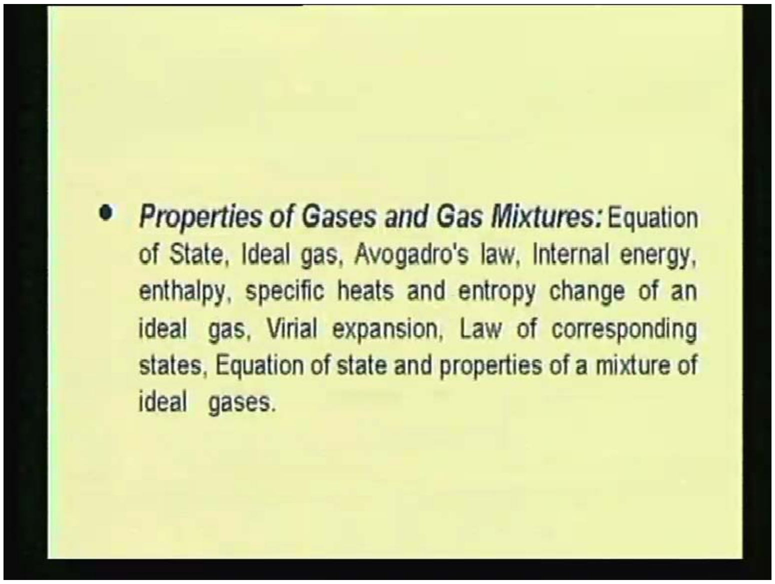

Then properties of gases and gas mixtures is an equation of state ideal gas, a part of which already you have started at the school level. Avogadro’s law, internal energy that means this discusses the properties of gases, specific heats, entropy change of an ideal gas, virial expansion, law of corresponding states, these are the aspects of the gas laws, equation of state properties of a mixture of ideal gases.

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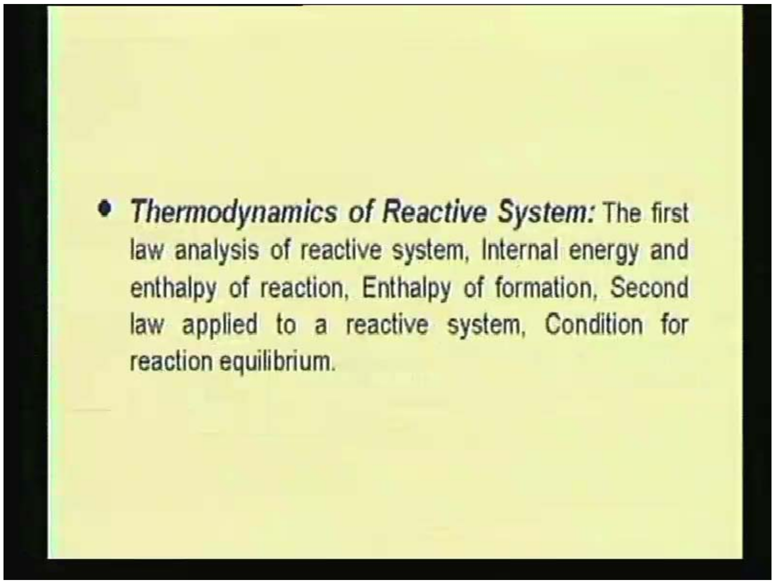

Then thermodynamics of reactive system which is also important when the reaction takes place because chemical reactions are always there in many of the physical processes for our use, engineers are much more interested of the reactive system as because our basic interest centered on getting motive power from fossil fuel. So we have to go through chemical reactions, so it is very important. The first law analysis of reactive system, internal energy and enthalpy of reaction enthalpy of formation, second law applied to a reactive system, condition for reaction equilibrium.

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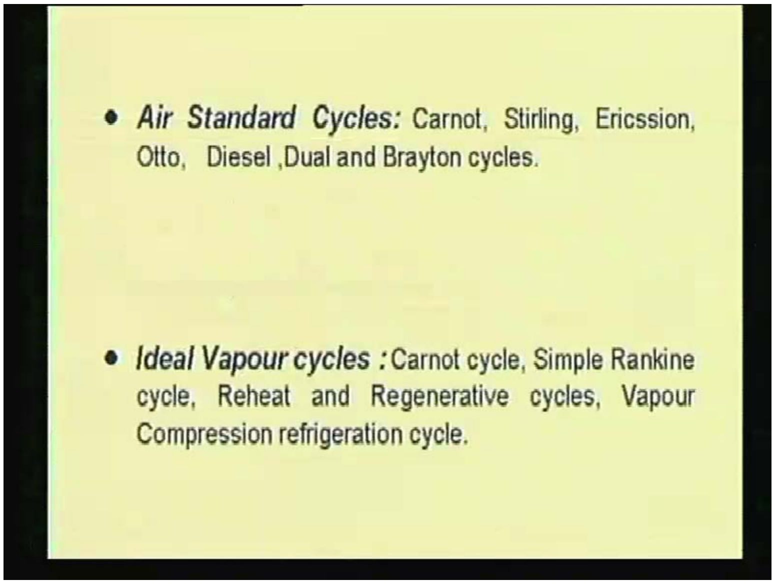

Air standard cycles: Carnot, Stirling, Ericssion, Otto, Diesel, Dual and Brayton cycles. These are the thermodynamic cycles but I will tell the implications of these cycles when I will teach you. Do not feel that this is something very boring all these cycles. What is the meaning it that will be knowing afterwards, so then I am now showing the course curriculum. There are implications of these thermodynamic cycles. There are extended cycles. There are vapor cycles. The extended cycles deal with air as the working system. Vapor cycles deal with vapor that means the system which changes from liquid to vapor phase as it goes around the cycle. There are number of vapor cycles, Carnot cycle, simple Rankine cycle, reheat and regenerative cycles, vapor compression refrigeration cycles.

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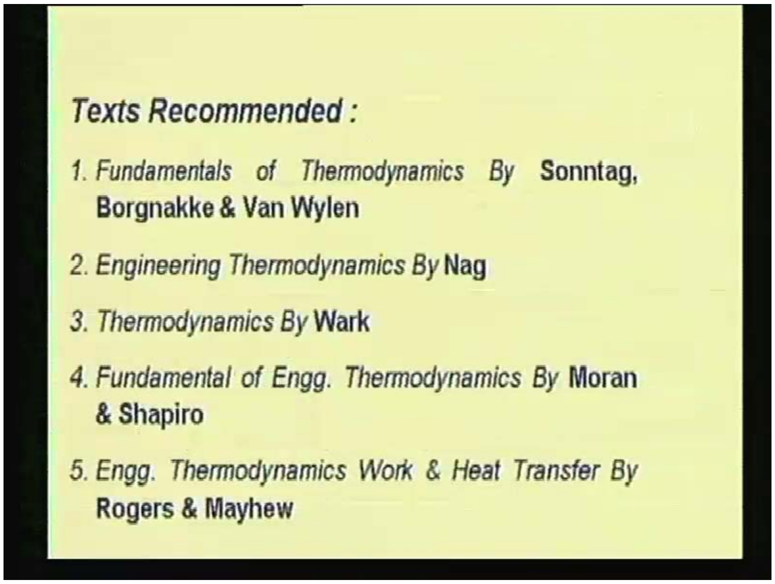

So now after that this ends your course outline texts recommended which is very important. Now in this context, the books which are shown here are all equally good and are all recommended the same way not that the way one, two, three, four means the number one book is recommended as the best book, all the books are equal but sometimes it has been found some chapters of some books are very good fundamentals of thermodynamics by Sonntag Borgnakke and Van Wylen. This book will be available in our library. Then engineering thermodynamics by Nag, this is one of the best books in Indian market. Thermodynamics by Wark, Fundamentals of engineering thermodynamics by Moran and Sharpio which is very good for this some aspects of second law specially the availability principle and engineering thermodynamics work and heat transfer by Rogers and Mayhew.

But I will not be following a particular book ditto for this course. My lecture will be a compilation of materials from all these books even from books of by different authors. So you can consult any of these five books, you can purchase also professor Nags. So if you get any of these books from the library these are good books in the field and you can consult any of these books as additional materials apart from my course.

Now before we start the course I will like to tell you again one thing that importance of thermodynamics can again be emphasized in two ways. One is the practical importance that is both are practical importance but one is more emphasis can be given to the practical field that today all of you know that we are very much aware of conservation of energy.

What does it mean? It means that nowadays we see that there is a threat of rapid depletion of fossil fuels. Our basic objectives as engineers here you are mechanical engineers and energy engineering students. So our basic objective to get mechanical power or electrical power from fossil fuel but there is a rapid threat day by day as we hear to Tv news or we read that there is a rapid depletion of the natural resources of fossil fuels. Therefore there is a concern for efficient utilization of this energy. At the same time the access to the alternative energy resources. For example, solar energy, wind energy is limited because of certain inherent physical difficulties in the physical processes.

Therefore we have to put more concentration or we have to put more effort on efficient utilization of these energy resources. So to efficient utilize the energy, we have to follow very strictly the rules and the principles which have been followed in converting energy from one form to other form. At the same time, we are concerned today about the environment. We want a clean environment that means whenever we transform energy to get power from its fossil fuel terms of chemical energy, geo thermal energy, that energy in the fossil fuel or energy stored in that in mechanical power, we will have to utilize it efficiently and at the same time we will have to use it in a clean way so that the environmental pollution is less.

Therefore in doing so all the processes which are necessary in doing so have to be known very clearly and their basic principles are guided by thermodynamics, this is one way. Another way there are other subjects also fluid mechanics, other branches of basic science and basic engineering and science subjects which guide also the principles of the physical processes. But thermodynamics is the primary one which gives you the primary direction. Just for an example, whether process is feasible or not and if it is feasible, to what extent it is feasible whether it is feasible in all the directions or not these are the things which will be told by thermodynamics .

Another important aspect of thermodynamics in this way tells us that there are certain things which we cannot do which is very important to know because in our life, it is always much better to know which we cannot do rather than knowing everything which we can do.

For example, if we miss some of the things which we can do in short life time, it doesn’t matter because there are number of things which we can do, and we can miss some of it because we cannot cover all these things in our short life time. It is very important to know which we cannot do. For example, if an engineer or scientist does not know that a heat engine with 100 percent efficiency can never be done even in an ideal case. So he may put his entire lifetime effort to build a heat engine which will give almost 100 percent efficiency but it will not be possible. Just like making the tail of a horse straight, we know it cannot be done. So like this there are many cases you know that a reaction cannot be made to occur under this circumstance in a particular direction but a chemist if without knowing he always puts his effort to make so, he is a fool.

Therefore this negative statement that means what we cannot do is provided by thermodynamics which is another aspect of thermodynamics of prime importance as compared to other physical sciences that we can find out things which cannot be done which comes from the law of nature.

So with this now I will start course, this subject. Very first I will recapitulate the definition of systems. Probably this has already been done in fluid mechanics course or in solid mechanics course, I think in fluid mechanics course it will be a recapitulation of that.

How do we define a system? Because in thermodynamics, whatever analysis will be done will be referred to a system. In all branches of physics, probably we have come across the definition of system because the analysis or the law of conservation is all applied to a system. Therefore we must learn carefully, what is the definition of a system. This is a recapitulation so now we will brush up our earlier understanding if there is any problem you can ask me the question.

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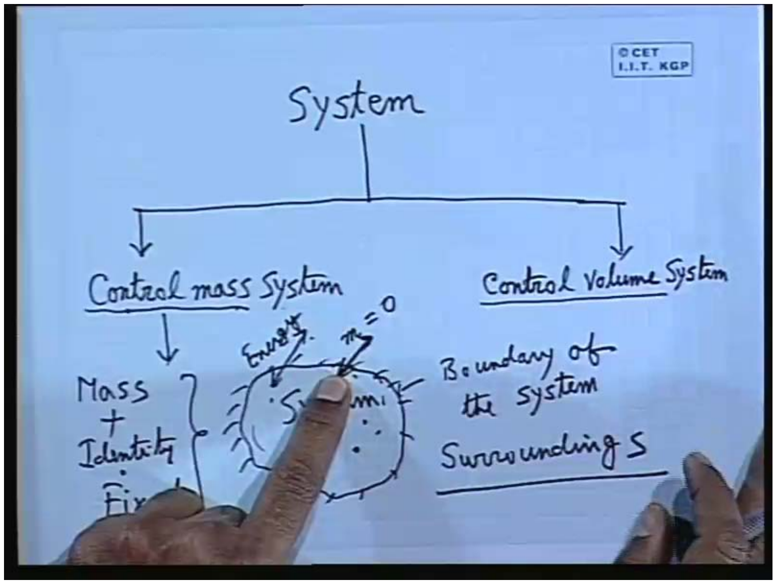

Let me start like this a system basically can be divided into two broad parts. One is the control mass system, the word control mass is very important. Another is the control volume system. First one class will be recapitulation control volume system. Now tell me what is the definition of control mass system? First of all a system in general both the cases the system is common so a system is always a certain quantity of matter on which the attention is paid and this is always bounded by a boundary so two requirements of a system is that, certain quantity of matter which is bounded by certain boundaries. Let this be the boundary I hatch it like this. So a system has two characteristic features certain quantity of matter and surrounded by the boundary.

I cannot write everything in this paper. So you can write it. Now this boundary may be a solid boundary or may not be a solid boundary. Sometimes this boundary may be imaginary type of boundary also. We can imagine certain boundary but we have to track that boundary always to define the system that means a particular quantity of matter as separate from the rest that is the surroundings.

Now the two characteristic feature of the system is certain quantity of matter within a space which is defined by some boundary. This is known as boundary of the system, this boundary separates the system from its surroundings. So everything external to the system that means on this side of the boundary is the surroundings. Therefore a system is characterized always by their surroundings that mean the boundary separates the system from the surroundings.

Now we come to these two things, what is control mass and what is control volume. So control mass system is a system where the mass remains fixed by its quantity and also by its identity not the volume, volume may change that a system boundary may expand, system boundary may collapse. It is the mass and identity of the system has to be same for control mass system.

So for a control mass system, mass plus identity fixed. So when we define a control mass system by this thing that mass plus identities are fixed that means the mass is controlled then automatically it takes care of the fact that there should not be any mass interaction that means mass interaction m is zero.

Mass can neither go out of this system, mass neither come in to the system that means the system boundary does not allow any mass interaction because if the mass interaction takes place, we can make the mass of the system or the quantity of this system same because we can take some mass and we can add the equal amount of mass but the identity will be changed.

That means a closed system contains the same mass that means there is no mass transfer across the system boundary. This is the basic definition of a control mass system. But there may be energy interactions that mean energy interactions may take place between the system and the surroundings in any of the ways. Energy can come into the system, energy can go out of the system to the surroundings. The boundary of a closed system restricts the mass transfer but does not provide any restrictions to the energy transfer.

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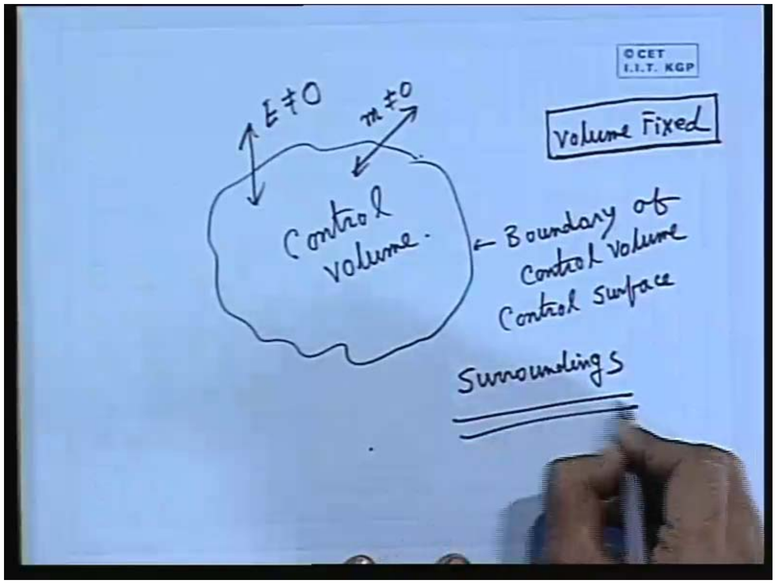

Energy transfer is possible but mass transfer is not possible whereas the control volume system as the definition is control volume. So what it should be which should be fixed?

[Conversation between student and lecturer- not audible ((29:06 min))]

Only volume correct volume fixed. But it is also not always true. There are deformable control volumes also if we leave aside the deformable control volumes under all usual conditions in a control volume, the volume is fixed. Usually we define control volume in that way that it is a region in space which is bounded by certain boundary of control volume which includes some quantity of matter within it and this is known as control surface. These are the terminals control surface that means the boundary of the control volume is known as control surface.

Now the identity may not be fixed which means a control volume is a region in space bounded by a boundary known as control surface which contains some matter and the boundary may allow both mass transfer is not zero and energy transfer that means there is no restriction that means may interact with its surroundings in terms of both energy and mass transfer. Therefore, the total mass of the control volume may go on changing but under certain conditions it may so happen the mass coming in and mass going out becomes equal to each other so that the mass of the control volume remains same. In that case in which way does it differ from the control mass system?

[Conversation between Student and Professor - Not audible ((30:45 min))]. Identity very good.

So this is known as the steady state control volume when the mass coming in and mass going out remains the same and energy coming in and energy going out remains the same we will come across this thing afterwards then the properties of the control volume remains invariant with time mass being one of the properties become invariant with time. In that respect it is almost similar to a control mass system but difference is that the identity is changed that means a control mass system allows the mass transfer to take place across this boundary.

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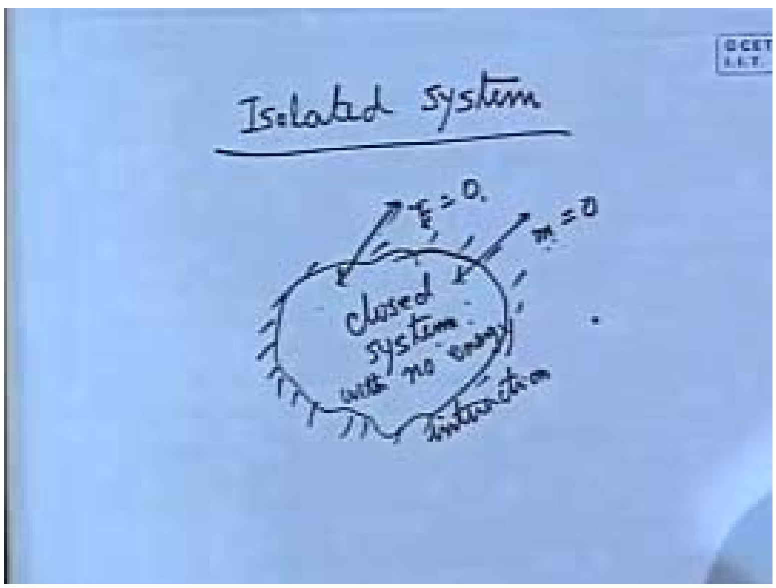

Now apart from these two main categories of systems another system called isolated system it can be better understood through a closed system. Isolated system we can tell is a closed system. Let us consider a closed system with no energy interaction that means if we consider a closed system, if boundaries are such that there is neither mass interaction there is no energy interaction. That means a closed system with no energy interaction closed system already has no mass interaction see if we define with a control volume we can do it that control volume with no mass interaction no energy interaction. That is why it is better to define from a closed system where already mass interaction is restricted but along with that there is no energy interaction in that case the system is closed that means there are only two ways by which a system can interact with the surroundings in form of mass transfer that mass can come out and come in energy can come in and go out so mass and energy interactions.

So if both the interactions are 0 then a system is isolated then the properties of the system whatever is there containing in the system remains invariant in time. The system is not at all specific to the surroundings so it has got no link with the surroundings this system is known as closed system. So now these are the definitions of the systems then I come to the definition of thermodynamic properties which are very important.

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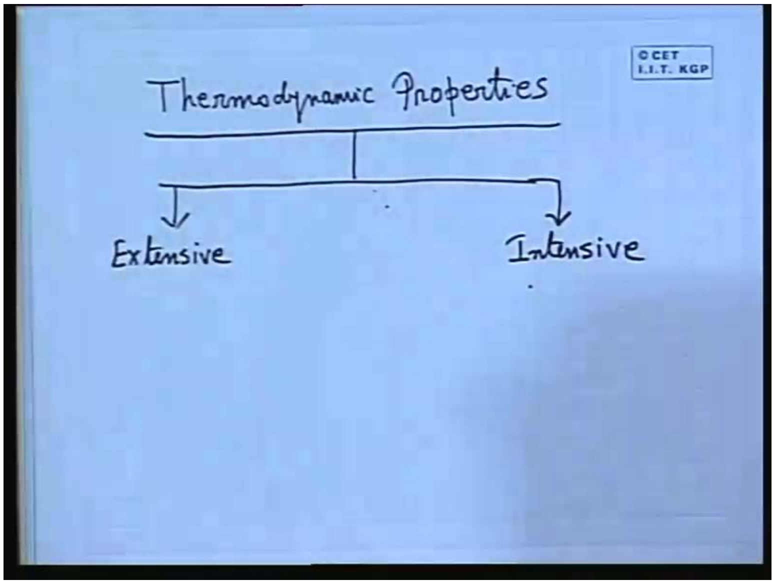

What do you mean by thermodynamic properties? Now very basic definition of properties you go back to our school level because these are again recapitulation. How do you define properties? Very simple is that these are the characteristic features of a system that is identifiable and observable characteristic features of a system by which a system can be specified. For example as we know a system how do you specify a system of certain mass, certain pressure, certain temperature, certain volume these are the properties. That means any characteristic feature that specifies the system that is the property.

So there is nothing much to understand in a properties but we have to know that how a system is specified? That leads to the definition of state of a system. There are some characteristic features by which a system is specified. This is the system of this mass this pressure this temperature this volume and there will be a number of such properties. Now next is that this property can be divided into two groups. One is extensive property another is intensive property. Can you tell me the difference between extensive and intensive property? What is extensive property? Some properties are extensive properties what are those?

[Conversation between Student and Professor - Not audible ((35:06 min))]

depend on the mass very good.

Extensive properties are properties which are directly related to mass which depends on the extent of the system. That means which are directly related to mass when mass is more the extensive properties are more. If mass is less extensive property values are less that means if the mass tends to 0 that means system collapses to a point then what is the value of these extensive properties? Zero. Because there is no point mass of the particle. The examples of these extensive properties are mass, volume, internal energy this we will see afterwards. There is no internal energy at a point enthalpy, entropy and what are the intensive properties?

[Conversation between Student and Professor - Not audible ((35:52 min))]

Just the other way intensive properties are properties

[Conversation between Student and Professor - Not audible ((35:57 min))]

No this is second that specific extensive properties or intensive properties that come afterwards but what is the basic definition of intensive property. The properties which do not depend upon the extent of the system or its mass that is even if system collapses it is not related to the mass that is system for example internal energy of a system of certain mass of gas if the system collapses to a point internal energy goes on reducing to 0 but it is not so that means it does not depend on the mass on the other hand when the system contracts to a point the intensive property attains a finite value just like a stress.

How do we define stress in mechanics that is force by area as area tends to zero because stress is defined at a point of the system as a stress but the system contracts to a point it is also having a stress that means in a system point to point there are stresses. So similarly here also intensive properties are those properties even though in a system contracts to a point it has a finite value pressures and temperatures we define pressure at a point we define temperature at a point so these are the intensive properties.

Now next is that what you told earlier is correct the specific values of the extensive properties now extensive properties are directly related to mass this can be specified by their specific values that means per unit mass. For example internal energy per unit, mass enthalpy per unit mass entropy per unit mass these quantities are intensive properties because specific internal energy is defined at a point. In this way that internal energy per unit mass is the specific internal energy now when you tend the mass to be zero you take limiting value then internal energy per unit mass reaches a finite value that means both internal energy tends to zero and mass tends to zero and the question reaches a finite value. So that is the reason for which these specific extensive properties or the intensive properties all right so these are the two categories of properties now in this context we will recognize it afterwards.

Now initially we start with those things as properties which can directly be measured which can be directly sensed. For example pressure, temperature, volume but we will see afterwards there are large numbers of thermodynamic properties for example enthalpy, entropy which cannot be sensed or directly measured. Sometimes it appears that it is abstract but it is not abstract these are being derived through certain postulates certain equation certain laws so a broad definition of properties is these which specify the state of a system.

So any parameter which is a point function or which defines the state of a system are the properties which may be or may not be directly measured or directly sensed so by keeping this in mind we can identify many such properties of a system. So with this now I tell you what is a thermodynamic state? Now when we define a system in thermodynamics and these are the properties or the characteristic features by which I specify the system. This is a system it has got this pressure this temperature this internal energy this enthalpy and so on.

Now question comes if there is a distribution how do you specify it by which temperature? If I tell the system of temperature this that means a system is having a uniform temperature that means I quote only one unique value to specify the state of a system. So therefore the requirement is that there should a be a uniform value of these properties throughout the system even if the system is a finite one so that requirement is very important and it may not be in practice but to define the state of a system it is a requirement that means only when these properties are uniform throughout the system.

We can specify the system by these properties otherwise there is no point of putting a single value that means the first requirement to specify a property to fix the states is that all these property value should be uniform throughout the system. And this should not change continuously with time that means they should be invariant with time. At least for a temporary period try to understand I am not writing everything at least for a temporary period that means in practice what happens when a process takes place and a system changes from one state to other state throughout the process the system always changes the state that means at any instant of time the system is in a dynamic state that means there is a continuous change of its property values.

So we cannot define a state of a system that way because how can we recognize the property it is continuously changing so it has to be fixed it has to be invariant with time at least for a moment it has to be invariant with time so that for that moment I can specify the state of the system this is a very important condition.

So two conditions have to be satisfied one is that the properties should be uniform throughout the system there should not be any variation of the property if temperature is a property then temperature of the system has to be uniform, pressure has to be uniform specific internal energy has to be uniform these with respect to intensive property because extensive property is in the gross properties total properties which are dependent on mass.

But all the extensive properties should be uniform throughout the system and they should be invariant with time at least temporarily for the moment when the state of the system is defined then only we can tell this system is at that state defined by these properties. Then otherwise it is meaningless it will be meaningful when these properties are fixed uniform throughout this system and invariant with time so this is the definition but this is the way how you fix the state of a system.

We know that there are n numbers of properties we can list on properties we will see in thermodynamics we can go on entering properties in a list and there is a big list of properties if there is a point function there is a property. Now we see that point function means why I am telling point function because the state of a system is a point that means state we can represent as a point in any thermodynamic co-ordinate diagram. So that is why sometimes the property values are told as state variables or the point functions of the systems state variables that means which define the state of a system. Now question comes there may be number of state variables or state point functions which describe the system which are the characteristic feature of this system or the property of the system like pressure, volume, temperature, internal energy, enthalpy, entropy gives function.

Now the very pertinent question come to specify a system there must be some minimum number of independent properties or there should be some independent properties to fix the state so that other becomes automatically dependent that means out of n number of properties there should be some independent properties, that independent parameters that means out of n properties there must be some m number of properties which are independent that means if we specify the system by those m properties other m minus n are automatically fixed by certain equations the property relation.

So we have to know what are the number of independent properties required to fix the state otherwise what happens if I have to fix the state of a system should I have to prescribe or quote all some hundred properties that is system having temperature, pressure, volume, internal energy, enthalpy, entropy, Gibbs function and so on. So I have to know that what are the number of independent properties by which we can specify the state of a system so this was given by Gibbs and is known as Gibbs phase rule the derivation of which is out of scope of this class.

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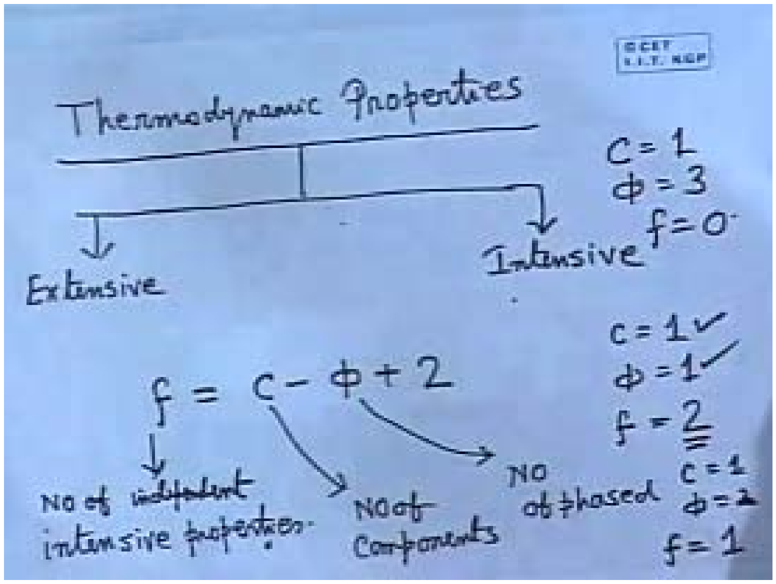

But I will tell you the formula that the number of independent intensive properties f is given by this formula c minus phi plus two, f is the number of independent intensive properties, where c is the number of components, phi is what?

[Conversation between Student and Professor - Not audible ((44:49 min))]

Number of phases this you have learnt at your school level in physics c minus phi plus two.

Now, we consider a simple case where number of components c is one and number of phase that means a single gas or a single liquid that means a component is one and it is in single phase. Then what is f?

[Conversation between Student and Professor - Not audible ((45:16 min))]

Two, that means only two independent intensive properties are required to fix the state of the system.

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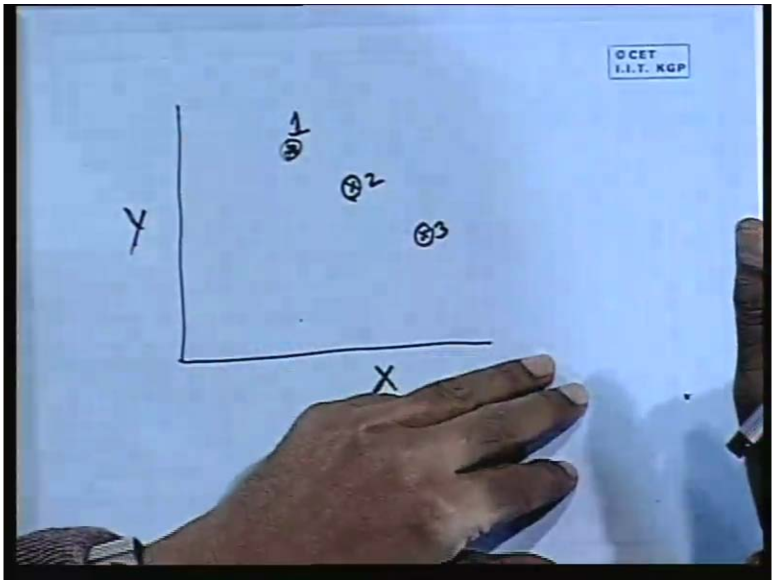

Which means that I can show in a two dimensional plane with x, y as the thermodynamic properties that is the state of the system let this is one so a point that means we can represent the state of the system for a single component single phase system as a point in a two dimensional thermodynamic property diagram where x and y represent any two out of so many properties we can choose which are required to specify the state of the system. If two properties are fixed that means others are automatically fixed of course this is for a single component and single phase and we can relate from here other interesting things.

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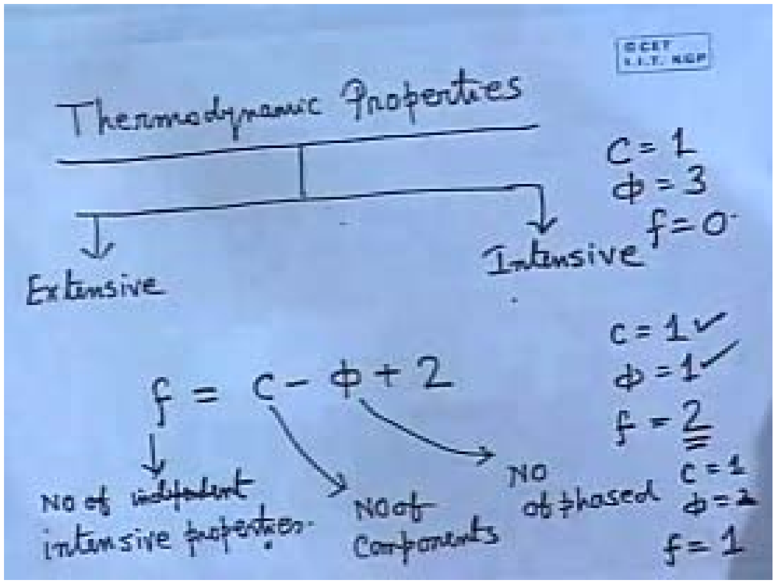

When c is equal to one but phi is equal to two what the value of f is? One.

[Conversation between Student and Professor - Not audible ((46:15 min))]

What is this? This is the one component but two phases that means if a component co exist in two phase. For example water and its vapor steam, water and ice solid liquid or liquid vapor then only one independent parameter is enough. For example if water and vapor, steam that means the single but two phase are in equilibrium there is a system which contains water and steam at one atmospheric pressure.

What is the temperature? 100^0c that means temperature is also fixed and when these two things are fixed everything is fixed that means only one parameter is sufficient to identify its states. Another interesting result is that if c is equal to one and phi is equal to three what is f? Zero. What is this? Triple point.

That means the three phases can coexist in equilibrium and only at a unique state that means there is no variation of state property, that is one unique state that is known as triple point. So the number of independent properties becomes zero in that case. We will be discussing mostly the cases with single component and single phase and single component with two phases in our course.

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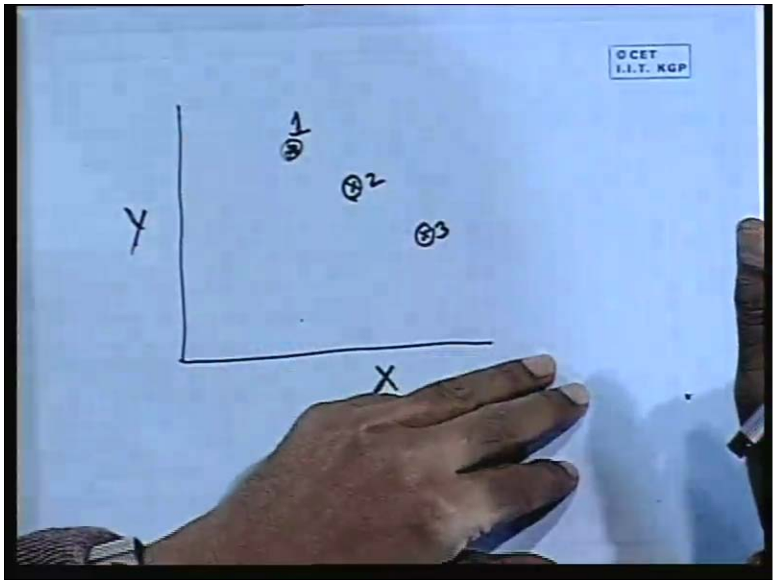

Now this way we can represent these state points of a system now question comes that a system's state can be prescribed when this is invariant with time and this is uniform throughout the system when we can get it if the system continuously interacts with the surrounding then properties go on changing and there may be an internal process going on within the system one part of the system heat may be transferred to other part, so therefore the temperature there may be a temperature gradient.

For example heat is being conducted through a rod as you know if you consider the rod as a system there is a temperature gradient that means from one part of the rod heat is being transferred to other part a heat transfer process is taking place even if you take the rod as system then in that case this is not a system to be specified by a single temperature.

Therefore if we have to specify this system with single fixed properties requirements are like that there should not be any processes within the system and there should not be any processes between the system and the surroundings. In this case we tell the system is in total thermodynamic equilibrium that means it does not interact with the surrounding and it is true that if a system is prevented from interacting with the surrounding then automatically the system will come into an internal equilibrium also that means the process within the system will cease after sometime and the properties will be uniform.

So the requirement for the system to be in equilibrium means that it will not interact with the surrounding so that the properties will be invariant with time and automatically any internal misbalance of the properties will die out and ultimately it will give a uniform property by which we can specify the state of the system. How can I make it? There are two ways of making one is that you make the boundaries such that in spite of a gradient now when the process takes place there may be certain imbalance of properties of surrounding and system because system will interact with the surrounding when there is an imbalance between the system and the surrounding there is a affinity of a process to take place. So we can do it in two ways we make the boundaries such that no process will be allowed just like an isolated system. For example surrounding there is a cals in the surrounding so affinity is to immediately go out from this classroom.

If you consider classroom as the system but I do not allow you to go out that means the boundaries are such that it does not allow the system to interact with the surroundings by creating those boundaries. Another way this is one way even if there is an imbalance between the properties which can cause processes another way of doing this thing that system properties are such that they are same with those of these surroundings that means there is no difference or imbalance between the properties causing the processes between the system and the surrounding and in those cases systems are defined as dead system or the state of the system is known as dead state because a dead man cannot interact with the surrounding.

So dead state of the system that means either the system has to be dead state or the system is such that its boundary does not allow it to interact with the surroundings that means it has to be isolated system. Then the next question comes from the student sir then you want to mean in practice if the systems are not dead then only the isolated systems where we can define the state of the system.

This is the very interesting question and very intelligent question and this is the question to understand the thermodynamic equilibrium. So what happens for all systems which interact with the surrounding not isolated system because interaction between the system and the surrounding is our goal this process we want from which we are benefited we extract something so system is never in equilibrium.

So all this successive states are in non-equilibrium but for our thermodynamic studies we consider the system the intermediate states to be equilibrium in a limiting case that in that case only we can specify the state points of the system, intermediate state points that I will come afterwards when I will discuss the thermodynamic process.

So therefore one should know only the state points one two three we can define. When the system comprises of certain matter is the properties are fixed uniform invariant with time and uniform and we can define the state points of the system. Then next we come to the concept of equilibrium.

Today I think time is almost up so I do no want to go with more materials ah well you can ask any questions so far we have discussed time is there so I think it will be better if you interact so far whatever I have told if any questions are there you can ask

yes please yes

[Conversation between Student and Professor - Not audible ((52:49 min))]

No no A cannot come because identity is fixed to one material only one particle there can each and every species having different identity you have to concive like that you had only alone you are unique in this universe there cannot be any other person even with the twin brothers there are differences so identity fixed means identity is fixed. One thing now here when we define the system and surrounding good thing has come up that one system is interacting with another system.

For example then if you consider a system A interacting with system B in that case system B is surrounding to system A and system A is surrounding to system B that means interactive system one is system another is surrounding. Surrounding definition is very important that means is that part of the external things which interact with the system. For example if two bodies are interacting with each other with nothing own then what happened one is the system another is the surrounding A and B, A is the system B is the surrounding, B is the system A is surrounding to B and this interacting systems together constitute an isolated system that is very important.

So what he is telling that if system A interacts with system B well system B is surrounding to system A system A is surrounding to system B. Whenever there is a mass transfer neither of the system is a control mass system because the identity is lost identity is unique. Therefore sometimes it is difficult to understand through identity so better to understand it there will be no mass transfer across the boundary of a closed system. All right any other question please?

[Conversation between Student and Professor - Not audible ((54:37 min))]

No that is the thing that you will be able to understand afterwards to be in thermodynamic equilibrium system ideally speaking has to be isolated correct or has to be dead state. It is true ideally hundred percent equilibrium means either system has to be dead that means its property should be same as that of the surrounding or it is to be isolated. But in normal cases when a processes takes place there is an interaction between the system and the surrounding then it is never in equilibrium but we conceive it in limiting equilibrium that is known as squash equilibrium that means we consider a process to take place for infinitely long time and system comes through several stages that means if there is a process with an infinite small gradient and it departs from an initial stage to a intermediate stage and it stops there for some time.

Again it starts that means we divide the entire process to a large number of infinite small process. that I will explain in the next class so that the idea will be much better and you have got a clear idea . How we reach in practice or how we can conceive in practice equilibrium states but 100 percent equilibrium state means that either it is a dead state or it is isolated that means by the boundary the interactions are being prevented. Any other question please yes?

[Conversation between Student and Professor - Not audible ((56:03 min))]

Certain quantity of matter yes whatever absolute vacuum we do not define a system then absolute vacuum the system is never defined no system is defined in absolute vacuum. In space technology if you go when a rocket goes to the space no analysis is made with considering the surrounding as a system you understand only the gas which is being ejected and the nozzle from which the propelling nozzle from which it is being ejected.

So if there is absolute vacuum the definition of system is not there consider the absolute vacuum never defines a system and no physics deals with absolute vacuum as a system. Vacuum means what there might be some material vacuum is a word which is used in defining the units of pressure when the pressure is sub atmospheric we tell this is a vacuum condition so gate pressure is negative that means some material will be there that is a system but absolutely why that is no absolute pressure is zero absolute vacuum is not a system.

Any other question so I think this is all right for today and I will be happy that if you read before coming to this class and you interact this way so that is why am telling next class we will be describing I have already shown

The thermodynamic processes what is meant by thermodynamic process? The thermodynamic equilibrium consists of thermal equilibrium, mechanical equilibrium, chemical equilibrium then concept of temperature and the concept of energy transfer by thermodynamics.

Thank you.

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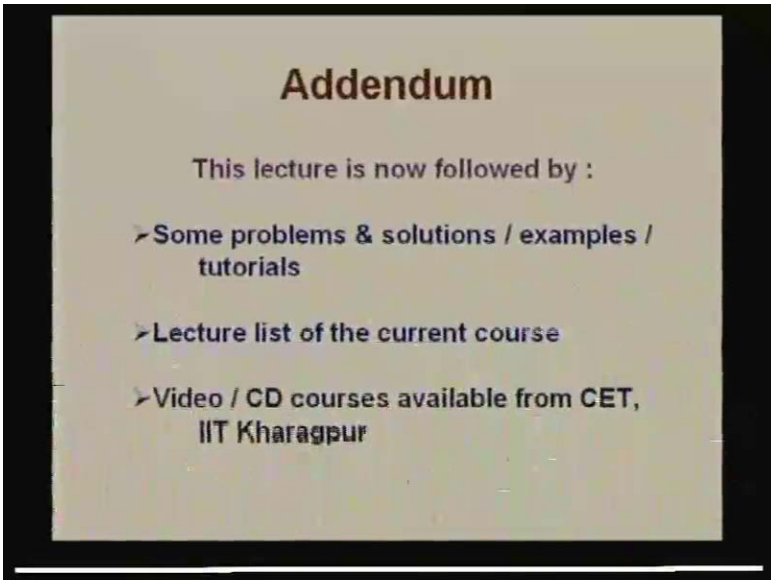

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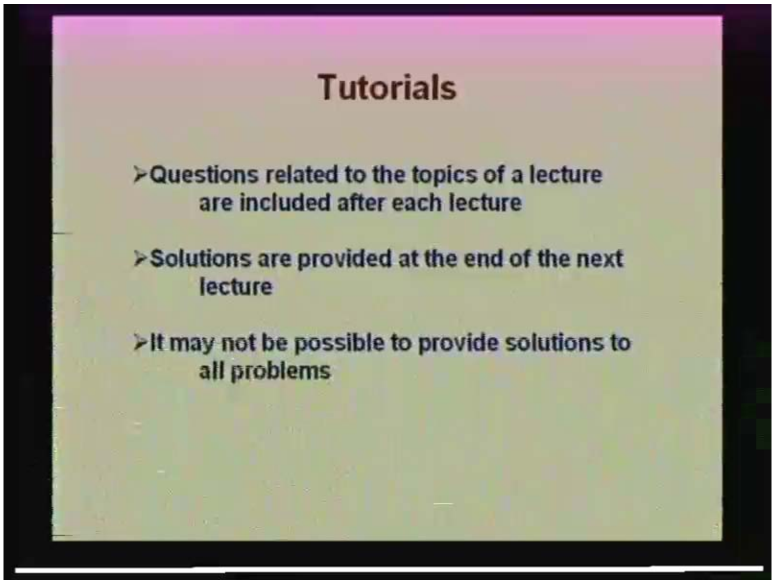

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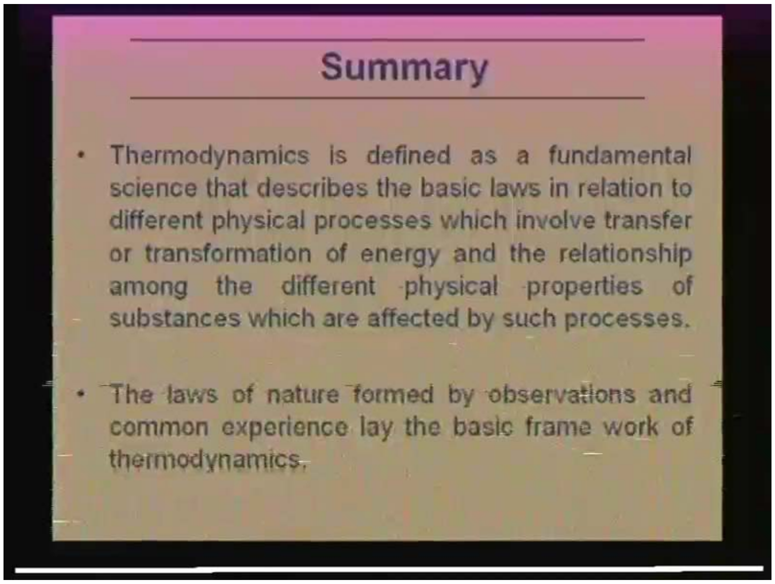

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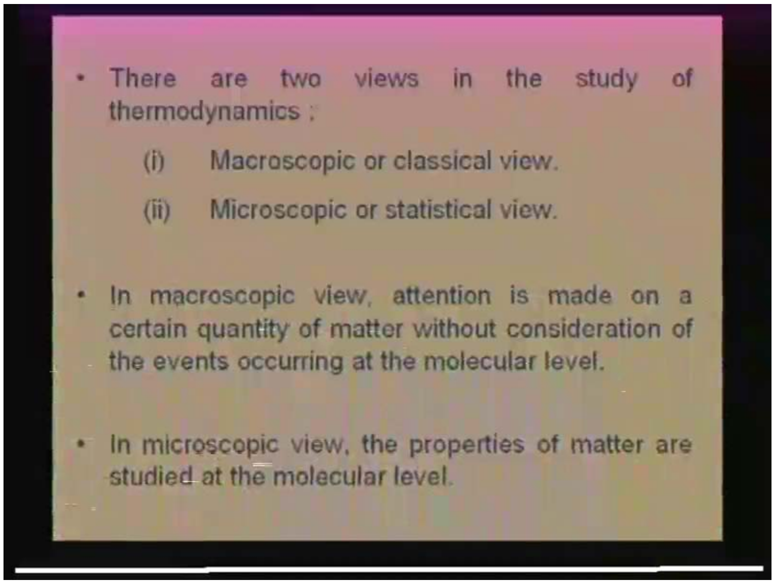

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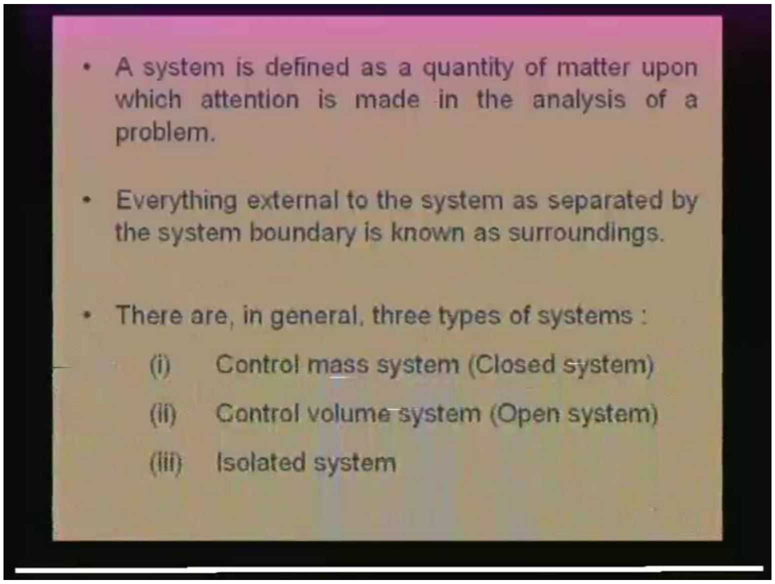

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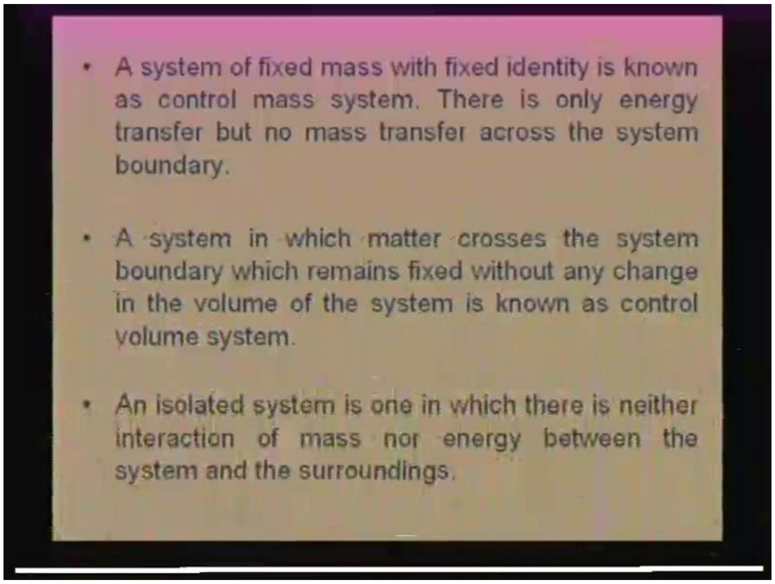

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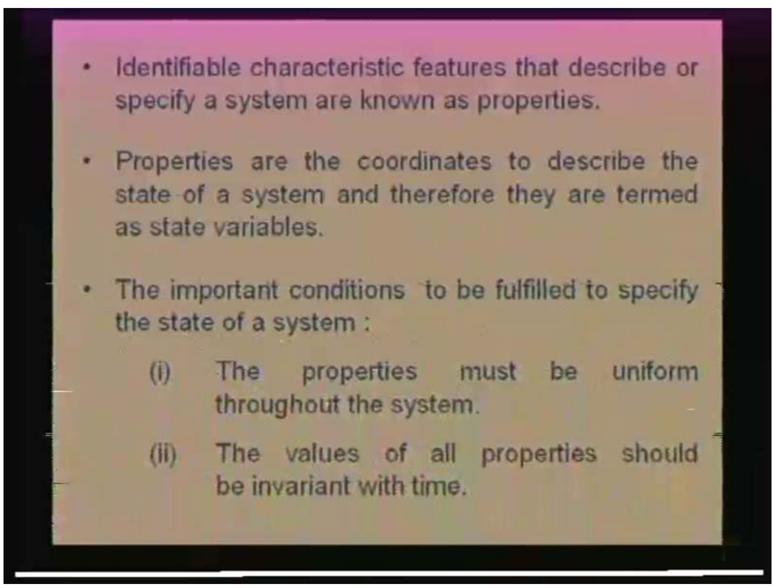

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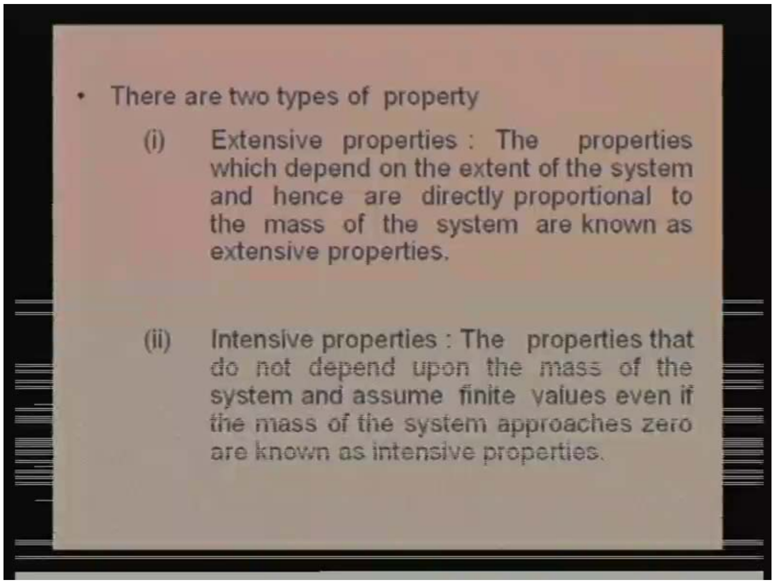

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