Heat Transfer
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Lecture – 01
Introduction

Welcome to heat transfer course. Let us first look at what is transfer.

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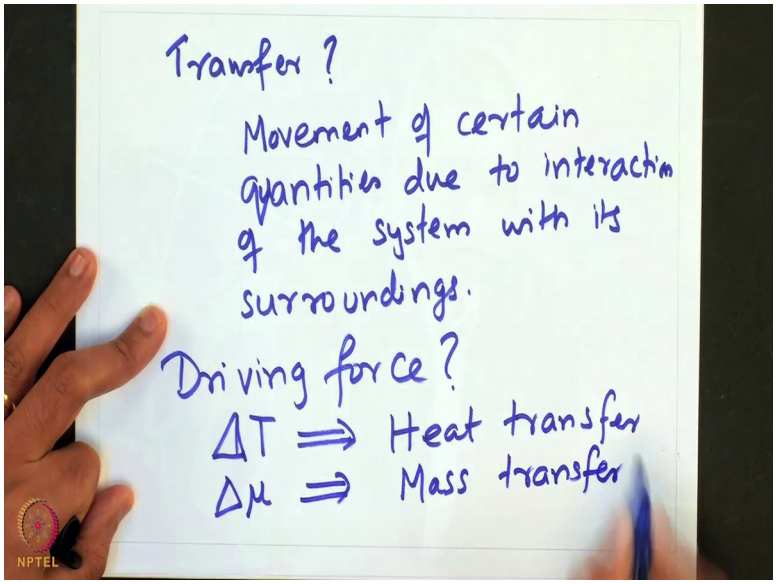

Transfer involves movement of certain quantities due to interaction of the system with surroundings. What drives the transfer process? The driving force, what is the driving force for transfer process? The driving force is temperature difference if it is heat transfer and it is chemical potential if it is mass transfer. So, heat transfer temperature difference which is generally referred to as delta T, it drives the heat transport process or it drives the heat transfer and the chemical potential which is delta mu, drives the mass transfer.

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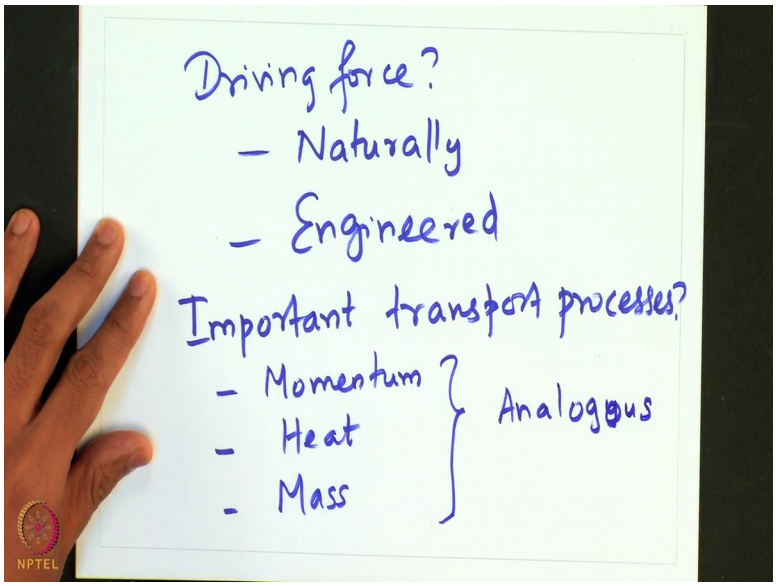

So, the question immediately arises as to what causes the driving force? The driving force may actually be natural what causes the driving force may be naturally created or it may be engineered depending upon the system. For instance, we may have a slab which is actually maintained at different temperatures and one at a higher and one at a lower temperature and you just leave the slab as it is over time. The temperature everywhere in the slab, so, when it reaches uniform temperature then there has to be flow of energy from one end to the other end and that actually involves heat transport. So, this can happen when at steady state as well.

So, what are the important transport processes? There can be momentum transport, there can be heat transport and there can be mass transport. Now, these 3 are actually similar in some nature and in fact, therefore, they are related and they are analogous to each other and so, we will see in this course the primarily the heat transport, heat transfer process, we will focus primarily on heat transfer and let us look at what are the objectives of this particular course.

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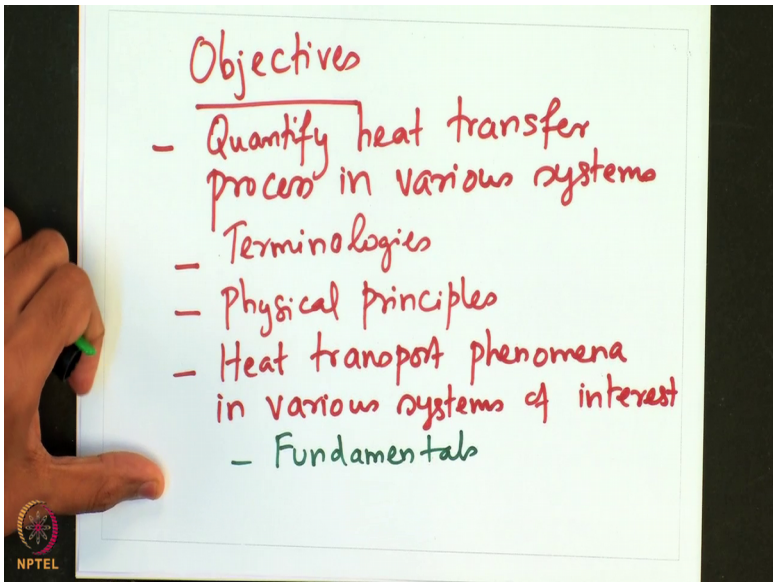

The primary objective of this course is essentially, to quantify the heat transfer process in various systems. In particular, we will start by looking at various terminologies. Various terminologies involved in the course will be defined. The physical principles involved in the heat transfer process will actually be described. The heat transport phenomena in various systems of interest will be described. Particularly, we will be looking at the fundamental aspects in each of these cases and then we will be looking at quantitation of each of these systems.

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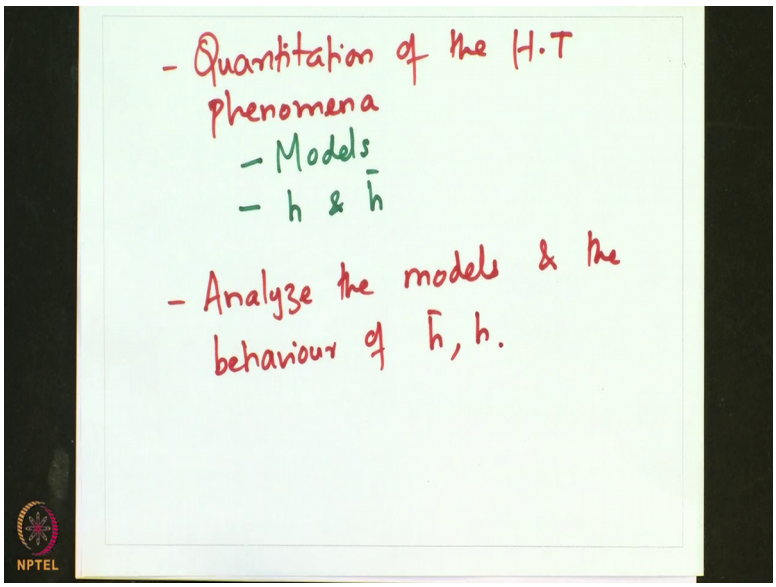

So, we will be looking at the quantitation of the heat transport phenomena in each of these systems. We will actually write models for each of these and particularly, we will compute the local and the overall heat transport coefficient for each of the systems.

We will then analyze the models and the behavior of the local and the overall heat transport coefficients. With these objectives in mind, let us delve into what is heat transfer. let us try to answer this question as to what is heat transfer. So, heat transfer essentially concerns generation, use, conversion and exchange of thermal energy that is heat between different systems.

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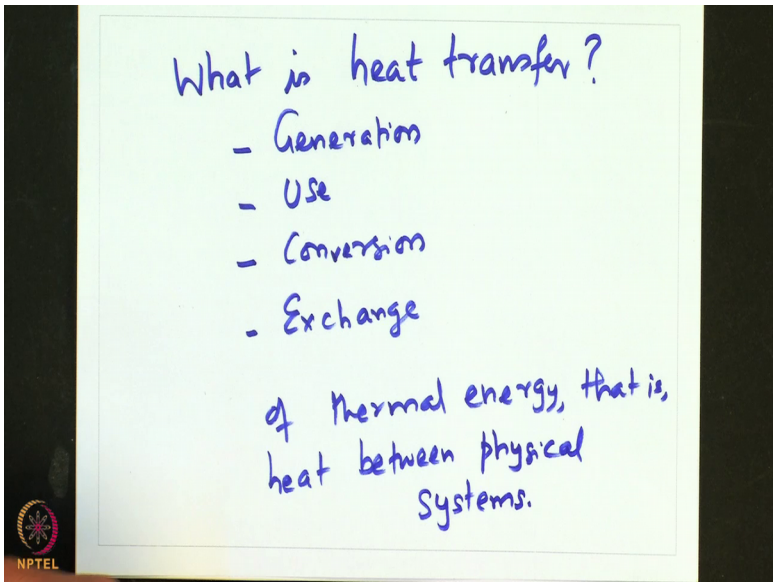

What is heat transfer? It involves generation, use, conversion and exchange of thermal energy, that is, heat between physical systems. So, in fact, heat transfer occurs in the various unit operations in different industries. For example, heat transfer occurs during cooling of fluids and liquids in let us say chemical industries, in petrochemical industries, in power industries, in pharmaceutical industries and so on and so forth.

So, the heat transfer is actually a ubiquitous phenomenon which is actually seen in many different processes in different industries. So, understanding the heat transport phenomena is actually very important in characterizing these unit operations and particularly in terms of the saving cost and transporting heat

between different fluids which is actually an energy intensive process. With this in mind, we will start looking at what are the different types of heat transport process, what are the different modes of heat transfer process.

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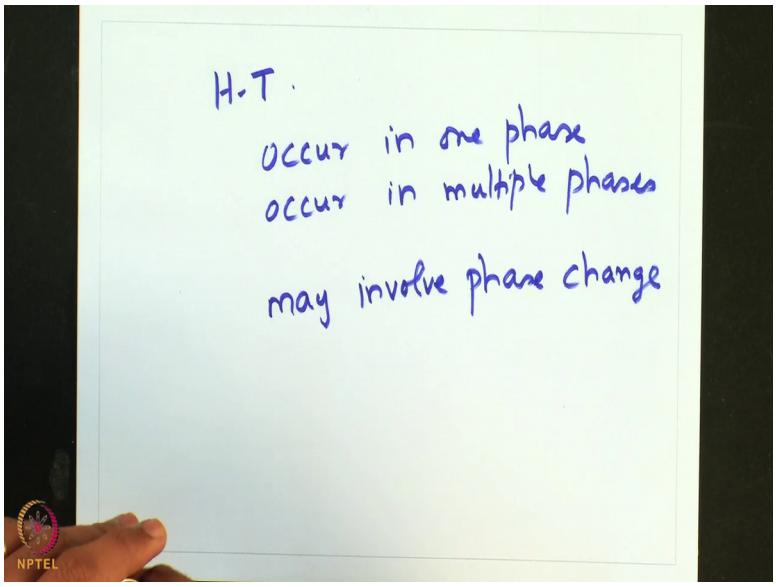

So, heat transport can actually occur in different phases. For example, it can occur in one phase. Heat transfer can occur in one phase, for example; if there is a slab which is actually maintained at different temperatures at the 2 ends of the slab and let us say you have a heat source which is present at one location, then one can actually transfer the heat from one end to the other end of the slab where the heat is transported within one phase.

Similarly, it can also occur in multiple phases. So, for instance, you may have a solid which is actually present at a certain temperature and there may be a fluid which is actually flowing past these solid object and so, the heat might be transferred from the solid to the fluid, which basically involves heat transport in multiple phases.

Besides, it might actually involve phase change as well. It may involve phase change, for example; if one is actually wants to actually heat water then you are looking at transferring heat from the bottom of a beaker which is containing water let us say and you want to transfer heat from the bottom of the surface to the water, where you first heat up the fluid and the fluid once it reaches a boiling

point then actually there is nucleation phenomenon that occurs and the water gets converted from the liquid into a vapor phase. So, there is simultaneous heat transport and phase change which is actually occurring in this case and this also is commonly encountered in the various situations in an industry.

So, we will also look at quantifying these as well in this course.

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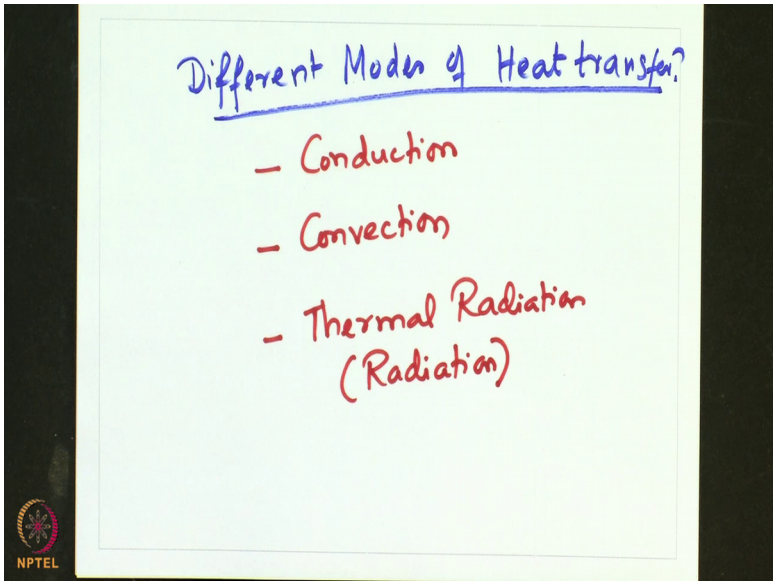

So, what are the different modes of heat transport? So, there are primarily 3 different modes of heat transfer, which are basically conduction, convection and thermal radiation. These are 3 different classes of heat transport modes and each of these actually occur using different phenomenon.

So, the 3 modes are conduction, convection and thermal radiation or simply radiation. These are the 3 different modes of heat transfer. These are the 3 different modes by which heat is actually transferred from one system to the other system or within a given system.

So, let us briefly look into what are these 3 different modes with a specific example.

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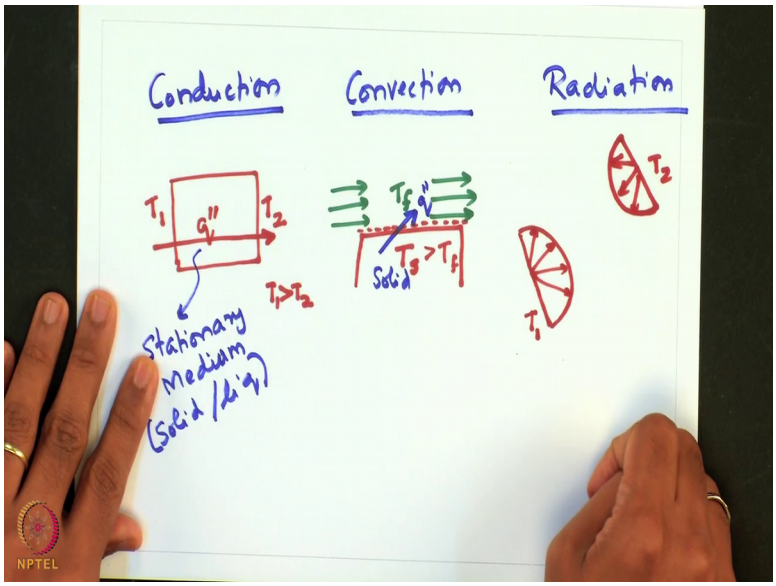

So, let us look at conduction. So, suppose we take a slab and we maintain the temperature of the 2 walls of a slab or 2 ends of a slab at temperature T 1 and T 2 and suppose let us say that T 1 is greater than T 2, then the energy is transferred let us say from this end of the slab or this end of the wall to other end of the wall and let us say that the flux of heat that is actually transferred is given by q double prime and this such kind of a transport typically will occur through a medium which could be a stationery medium. So, a stationery medium is present here and this stationery medium could actually be solid or a liquid. So, such kind of an energy flow through a stationery medium is typically referred to as a conduction mode of heat transport.

So, let us look at the next case of convection mode of heat transport. Suppose, we have a solid which is let us say maintained at some temperature T s and we have a fluid which is actually flowing past this solid object. let us say that we have a fluid which is flowing past this solid object and let us assume that the temperature of the fluid which is actually flowing is given by T f, then because there is variation in the temperature and if we assume that let us say T s is greater than T f, then there is a flow of heat from a flow of energy from the solid to the fluid phase and let us say that the flux with which the energy is transferred is q double prime. And now, there will be an interface which is actually present between a thin interface which is present between the solid and the fluid and the

heat is transported from the solid to the fluid stream through this interface and the heat is eventually carried by the fluid string. So, such kind of a heat transport, where the energy is transferred let us say from one medium which is solid into a fluid phase which is actually flowing due to certain with the certain velocity. So, such kind of a heat transport is actually called as a convective mode of heat transport.

Now, the third mode of heat transport which is called the radiation mode of heat transport. Now, every surface by virtue of it having a finite temperature would actually emit electromagnetic waves. So, therefore, any 2 surface which is present here, the paper on which I am writing, my hands, each of these have a certain finite temperature and due to the virtue of it having a certain temperature, the surface which is actually present on top of this paper and on the surface of my hand due to its finite temperature would actually emit electromagnetic waves. And so, if these 2 are facing each other then even in the absence of a medium the electromagnetic waves which is actually emitting from the surface of my hand let us say would actually intercept and be received by the surface which is actually this paper here.

So, such kind of mode of heat transport is actually called as thermal radiation or simply radiation. So, it can be depicted in this cartoon where if I have a surface which is present here and let us say that the radiation is emitted from this surface in all directions and if I have another surface let us say this surface is maintained at temperature T 1 and I have another surface T 2 and that also emits radiation. So, the exchange of radiation or thermal energy via the electromagnetic waves between these 2 surfaces which does not really require a medium to be present in between the 2 is what is actually described as a thermal radiation mode of heat transfer.

So, with this brief outline of different modes of heat transfer in a few minutes, I will describe what are the different aspects, that will actually be covered in this particular 60 lecture heat transfer course.

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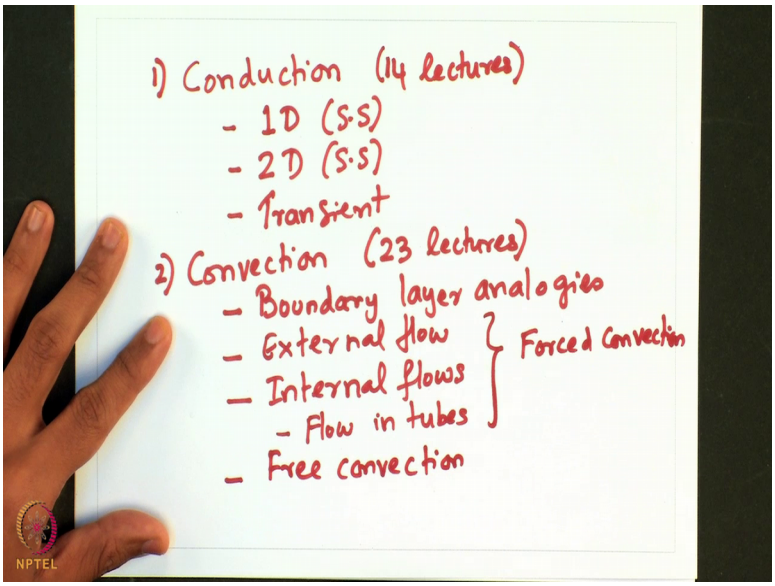

So, starting from the next, starting from the second lecture in this course we will spend about 14 lectures quantitating the conduction mode of heat transport, we will spend about 14 lectures. And, in this topic we will specifically look at conduction steady state conduction in one dimension, we will look at steady state conduction in 2 dimensions, we will also look at transient conduction under transient conditions and how to estimate heat transport coefficient in each of these processes.

So, that will be the first topic that will be covered in this course and then the second topic that we will look at which will be the chunk major chunk of the course will actually involve convective mode of heat transport and we will be looking at it in about 23 lectures. And specifically, we will be looking at the boundary layer analogy.

There are 3 different transport processes, that is, heat transport momentum, transport and mass transport and they are analogous to each other and it is the boundary layer analogy which actually capitalizes on the similarity between these 3 processes and this boundary layer analogy will actually help in estimating the heat transport coefficient for various kinds of situations and various systems that we are going to consider in the convection topic.

So, in particular, we will look at 2 different types of flows; one will be the external flows, where the flow of the fluid is actually past the object and then we will look at internal flows. In the case of internal flows we will actually look at flow within a tube, we will look at flow in tubes and both these would fall under case of forced convection and the next topic we will look at free convection systems and once we finish the convection part which is basically 23 lectures, we will move on to the next topic, where we would introduce, how to quantify heat transport process when phase change is involved.

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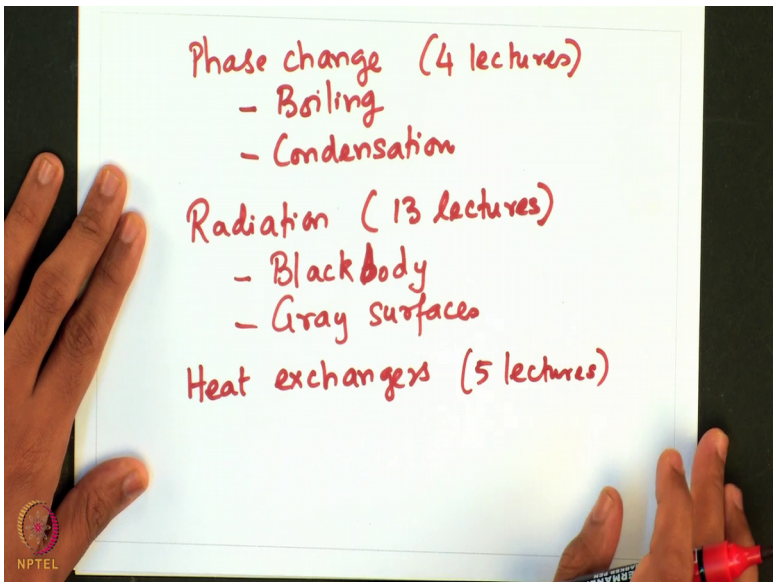

We will look at phase change and essentially, we will be looking at it in 4 lectures, where we will consider 2 particular topics; one is boiling and the other one is condensation, each of these in 2 lectures and then we will go into the third mode of heat transport which is the radiation, we will spend about 13 lectures in the radiation topic. And we will specifically look at quantifying radiation in black body systems and quantifying radiation through gray surfaces.

And after we finish radiation, in the last topic, we will actually look at heat exchanger which is an application of the heat transport coefficient that would be developing to heat transfer coefficient expressions that you would be developing overall of these various topics that we have seen so far and we will apply these in heat exchangers which is actually a crucial equipment and a workhorse in many

industries. We will spend about 5 lectures in looking at quantifying heat exchanging process. So, with this we will move onto the conduction process, where we will start looking at defining conduction and we look at introducing various conduction topics in the next lecture.