Heat Transfer
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Lecture -16
Introduction to convective heat transfer

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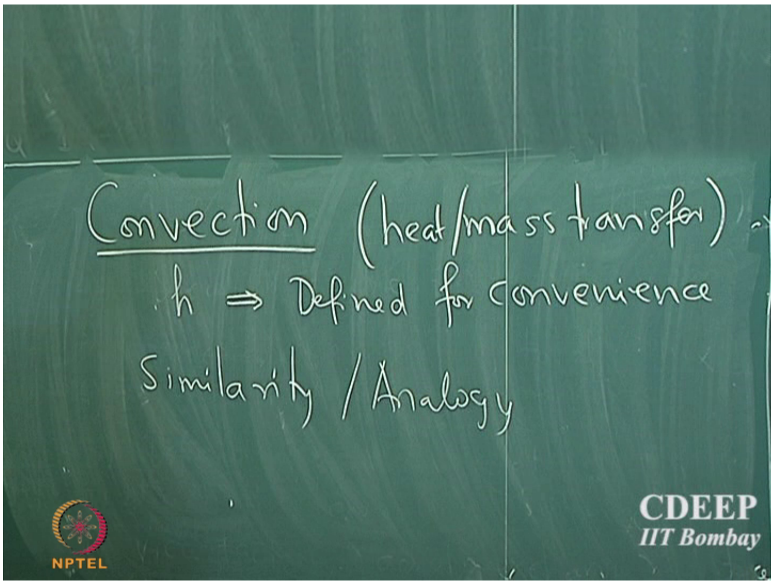

We looked at only conduction and radiation. And we briefly alluded to convection in terms of newtons law of cooling. We said if there is things that are flowing outside, following past an object, and if you assume that heat transfer is defined by rate is defined by newtons law of cooling then what should be the resistance etcetera. Now we are going to actually go and see how to estimate, how to characterize heat transport because of convection. And how to first of all estimate the heat transport coefficient. So, so far, we always assume there is some quantity called heat transport coefficient and it is given to us.

So now we are going to see, it is a we going to see how to estimate this quantity called heat transport coefficient. And in fact, I mentioned before that heat transport coefficient b is not an intrinsic property like density conductivity etcetera. It is a fictitious quantity, which is defined for convenience purpose. It defined for convenience purposes. Instead of solving gori equations all the time, if we can find out what is the net heat transport coefficient, then it becomes very convenient in solving some kinds of problems. And it is very important, because if you have let us say let us say in industry, if you have a heat exchange process. Will see a little bit more about heat exchangers later down in the course.

So, in heat exchangers, what happens is you have let us say you have a pipe, you have some fluid which is flowing through the pipe, and you have some other fluid which is actually flowing in the outside of the pipe. Now if you want to know what is the net heat that is transported, from the fluid which is flowing inside the tube to the fluid which is flowing outside. One simple way or one complicated way rather would be to write all the model equations for both compartments both fluids, and write model equations for the tube wall conduction into tube wall etcetera and you can solve all of them simultaneously. Which is a very boring thing to do.

So, elegant way to do would be to define something called a transport coefficient. It is essentially captures the net amount of heat that is transported from one fluid to the wall and from wall to the other fluid. So, it is very convenient for understanding the principles behind how heat transport occurs, because of convection or enhanced because of convection. And also, it helps in many calculation and design purposes. So, and this will be the first time we will start looking at mass transfer also in this course.

So, far we never looked at mass transfer, because when it comes to conduction mass transport is irrelevant. So, we did not discuss about mass transport, but when it comes to convection, and mass transport also plays a role. So, we will actually while doing different aspects of convection enhanced heat transport. We will also look at corresponding quantification of mass transport processes simultaneously. So, because these 2 are similar transport processes. So, if you can characterize one, you get the characterization for the other for free. And in fact, we will actually see in many maybe next lecture or the lecture after that something called a similarity or analogy.

We will show that there are 3 different transport processes which are momentum heat and mass transport. All these 3 are analogous to each other or they are similar to each other. And in fact, we will show it in a very quantitative fashion, that they are similar to each other. And in in fact, it is that that is the reason why these 3 transport processes are usually looked at from these same lens all right. So, in particular what we are going to see is that we going to look at

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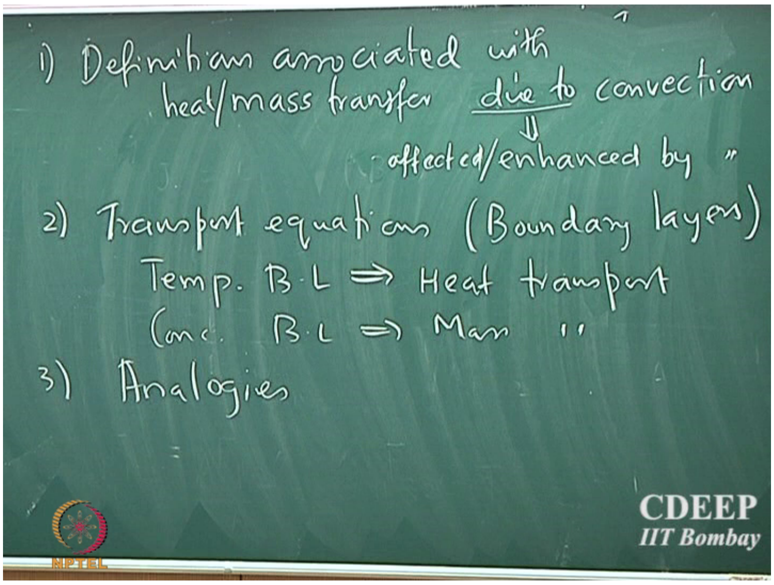

What are the definitions associated with heat slash mass transfer due to convection?

So, you may remember that when we discussed newtons law of cooling, we said that the basic mechanism of heat transport at the interface is actually not convection it is actually diffusion. So, when I say definition associated with heat and mass transfer due to convection, I should rather qualify it by saying enhanced by convection or affected by convection.

So, that is the correct way of looking at it. And in fact, we will see why diffusion is the mechanism by which the transport actually occurs at the interface. Then we will go ahead and look at right transport equations. Transport equations that will quantify the transport process see all 3-momentum heat and mass transport. And we will look at boundary layer. So, not much about momentum boundary layer will be covered in this course. That it is already covered in your fluid mechanics course.

So, we will directly go and do concentration and temperature boundary layer. Temperature boundary layer corresponds to the heat transport, temperature boundary layer corresponds to heat transport. And concentration boundary layer corresponds to mass transport. So, we look at boundary layers, and then we will look at analogies what makes them similar and how similar they are, and how do we take advantage of this similarity to characterize these 3 transport processes. That will be the third topic we look at.

Then the 4th topic is really the bulk of it. Where so, there are 2 types of convective effects that we can see. So, one is called the forced convection.

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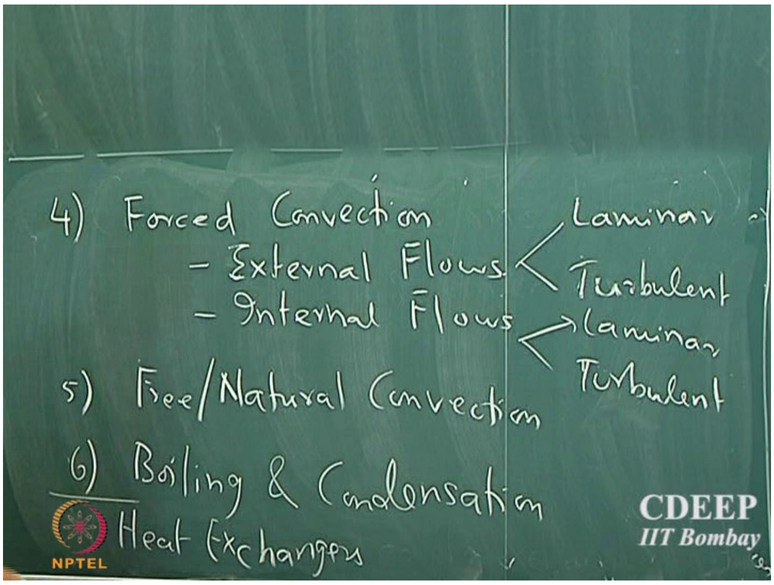

So, supposing if you have a pipe where the fluid is actually pumped into the pipe. So, that is a driven flow where the motion of the fluid particles is because of the external drive external pump, and that is what is called as a forced convection. And the enhancement of heat transport and mass transport etcetera. Because of that situation, will actually be covered in the force convection topic. And here we will look at 2 aspects one is the external flows and internal flows.

So, let us take a look at the pipe example, I described a short while ago. Where you have a fluid, which is going through a pipe, and there is another fluid which is flowing past the pipe the exterior of the pipe. So now, the properties the heat transport from the fluid to the wall inside the tube would be governed by what is happening inside. And so, that is that will be covered in the internal flow section.

And whatever is happening outside because, it is flowing in the curved surface area. The external exterior of the tube is a curved surface area, and the fluid is flowing past the curved surface area. So, that is what is called as an external flow. So, we look at both these topics separately, and we will have 2 different cases for each of them laminar and turbulent flow. And will have laminar.

We already been introduced to the concept of laminar and turbulent flow in your fluid mechanics course. So, we will see how to incorporate the properties of the flow under laminar and turbulent conditions, then how does that affect the heat and mass transport under that situation. And then we will look at free or natural convection. So, a nice example of this is supposing, I purchase a coffee a cup of coffee, I place it on the table. So, the nodes of heat transport. So, eventually the coffee will actually reach an equilibrium and it will reach the same temperature as the atmosphere line 25-degree c.

So, the mechanism by which the coffee loses heat is actually both conduction and convection. Now conduction we understand what it is. The reason why convection plays a role here is that, the density of the fluid depends upon the local temperature. So, when there is change in the density, then gravity will play a role, and then it is going to make the fluid to circulate and that is going to cause some convection. And that is going to enhance the heat transport or mass transport. So, that is what is called natural or free convection. And then in the last section we will look at some applications boiling and condensation.

So, this is the essentially sort of taking us to the design of heat exchangers. First, you might have like a steam which might go into a most of you have been to this plant in r c f right last year. So, you will see that there are several heat exchangers. In fact, steam conservation is actually an important aspect in industry. So, they use steam for boiling many different fluids, or heating many different fluids. So, therefore, boiling and condensation plays a very important role. And so, we look at some of these concepts. And after this is done. So, the next topic will be heat exchangers.

So, that is where we will actually switch gears and go to the next topic of the course which is heat exchanger. Because this is really the bulk of the course is actually on this topic.

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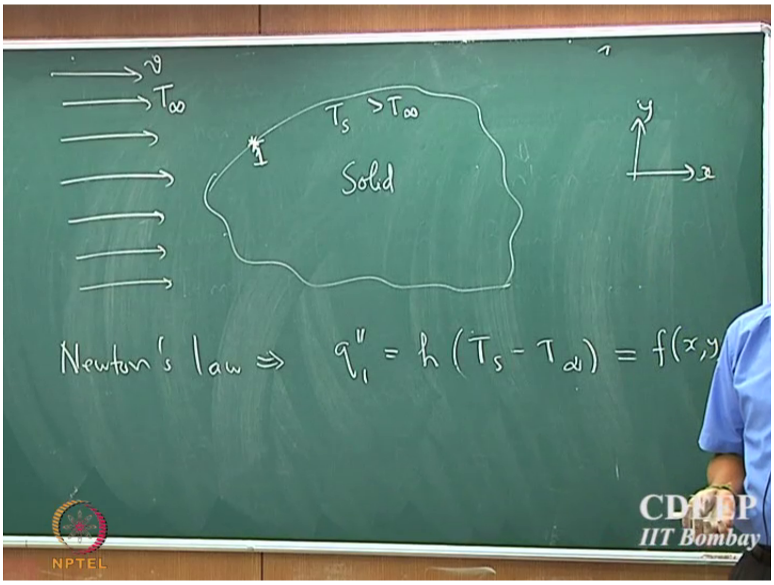

Suppose we take an arbitrary object, and let us say that the surface temperatures maintained at T s, let us say it is a solid. So, so far what we looked at is we assumed we knew all the properties of the liquid, and we lumped everything and we said heat transport is characterized by the heat transport coefficient given by newtons law of cooling right. So now, we do the reverse. We assume that we know everything about the solid. And we know the temperature of the surface. And we do not know what is the what are the properties, or what are the heat transfer rate etcetera of the fluid which may be flowing past this object.

So, let us assume that a fluid is flowing at a velocity v. And let us say that the temperature of the free stream fluid; that is, this fluid is actually flowing past and very far away from this object, let us say that the temperature is T infinity. And even before it sees the object the temperature steam. So now, let us say look at what is the heat transport at that location. Let us say location one. What is the flux of heat transport? So, newtons law of cooling will tell you that the flux of heat transport at location 1, would be given by heat transport coefficient multiplied by the local temperature gradient; if I assume that T s is greater than T infinity. So, that is the flux of heat that is actually transferred from the solid to the fluid at that location.

Now, earlier we would assume that the heat transport coefficient is actually constant along the surface of this object. So now, there is no reason to assume that. Because the fluid the transport properties or the heat transport in the fluid, may not be same at all the locations. So, therefore, this is going to be a function of the position x y and z. I have 3 coordinates. So, let us say x and y. So, that is going to be a function of position.

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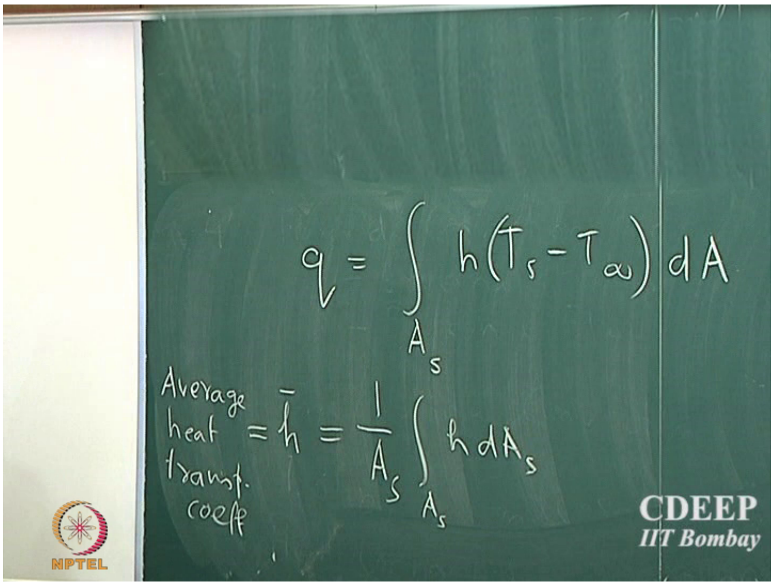

What will be the total rate of heat transport from the solid to the fluid. So, what we have to do is we have to integrate this expression over the surface area of that solid, right. That will be h into T s minus T infinity into d a. So, that is the total amount of heat that is the rate at which the heat is being transported from the solid to the fluid. So now, we can define a quantity called h bar. So, this is the average heat transport coefficient. And that is defined as 1 by A s, that is the overall surface area available for heat transport from the solid to the fluid into integral A s into h time d A s.

So, if I assumed that I knew what T s and T infinity are is not a bad assumption to make, then I can rewrite the net heat transport rate q, that is equal to h bar into a into T s minus T infinity.

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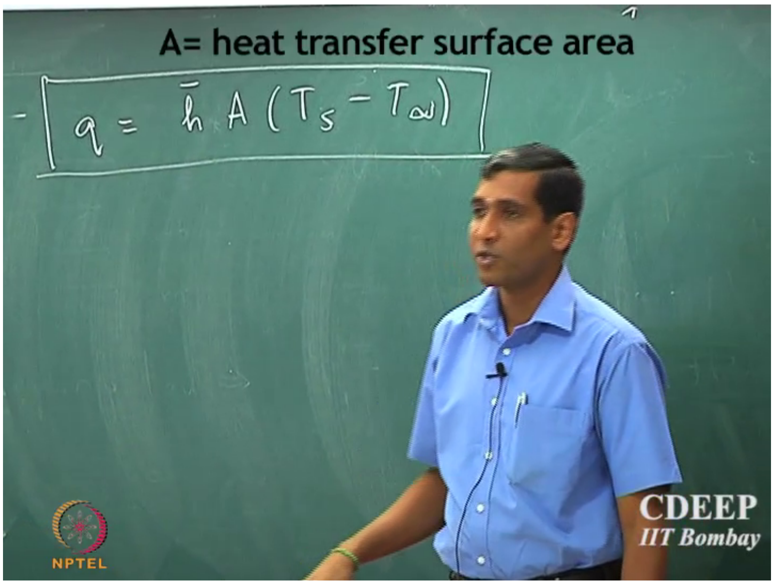

So, I can rewrite the net heat transport from the solid to the fluid in terms of the average heat transport coefficient. So, all along what you have used in all your calculations etcetera is actually the average heat transport coefficient. And what we are going to see for most part of this convection topic is how to calculate this average heat transport coefficient.

So, if you knew average heat transport coefficient you are done. So, you do not have to worry about what is geometry, what is the location, what is the local flux etcetera if you know what is the average heat transport coefficient.

Student: (Refer Time: 16:11).

Yeah, right. So, we have assumed that it is constant. If it is not constant, then you would have be integrated taking up taking into account the locational change of the temperature surface temperature. Any other questions? All right. So, I think it is a good point to stop.