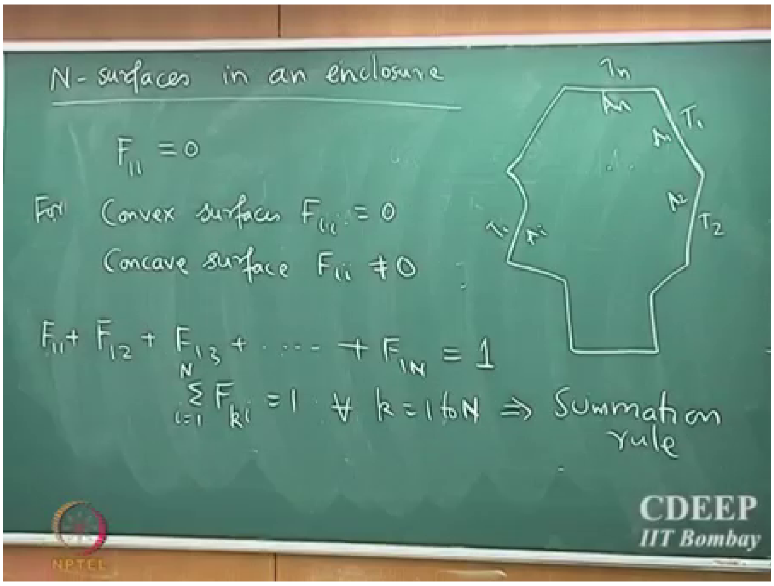
Heat Transfer
Prof. Ganesh Viswanathan
Department of Chemical Engineering
Indian Institute of Technology, Bombay

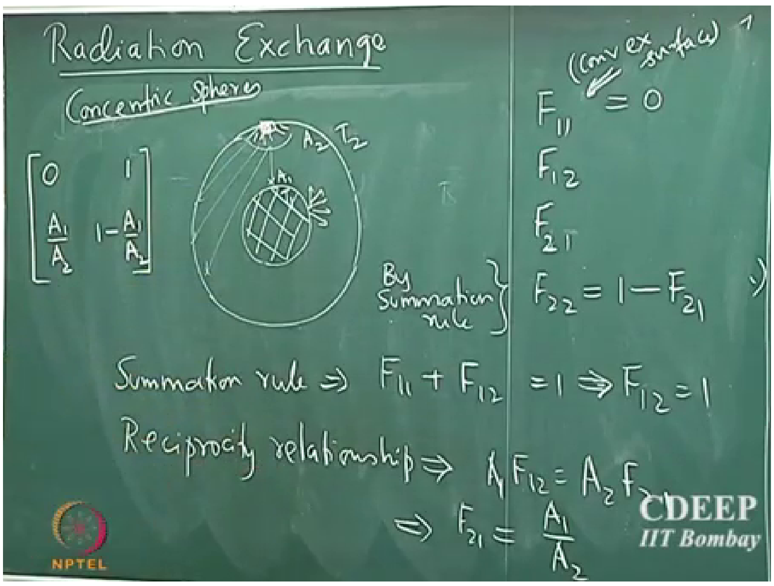
Lecture – 50
View factor examples

(Refer Slide Time: 00:14)



So, let us take a specific example where this is applied.

(Refer Slide Time: 00:20)



So, let us take the case of concentric spheres and let us assume that this is its solids sphere in between and there is a vacuum space and this is let us say maintained at some temperature T 1 and this is maintained at some temperature T 2 and the inside curved surface area is A 1 and A 2, outside curved surface area of first object is A 1 and the inside surface area is A 2. How many view factors are there? So, what are all the possible view factors F 1 1, F 1 2, F 2 1 and F 2 2. These are the four possible view factors, F 1 1 is 0. So, the non zero view factors are three, but there are actually four view factors, one is 0, its trivial, but these are three nonzero view factor. How do you find them? How do we find the other three view factors now?

Student: (Refer Time: 01:41).

Yeah?

Student: (Refer Time: 01:43).

So, I claim that you can do it without integrations. Yes.

Student: (Refer Time: 01:50).

F 1 2 will be 1.

Student: (Refer Time: 01:56).

Correct.

Student: (Refer Time: 02:00).

Ok.

Student: (Refer Time: 02:03).

And, use the summation rule the same thing. So, we know from summation rule F 1 1 plus F 1 2 is 1, but we know that F 1 1 is 0, it is a convex surface. So, F 1 1 is 0, because it is a convex surface and from here F 1 2 equal to 1. In fact, one could easily intrude because it is a convex surface you expect that no radiation emitted by the surface one is going to be received by itself which means that all the radiation that is emitted has to be received by the second object if it is a closed system. So, therefore, F 1 2 should be 1, which means all the radiation emitted by surface one is actually intercepted by surface two.

So, now we have reciprocity relationship which says that A 1 F 1 2 equal to A 2 F 2 1. So, it essentially relates the view factor from surface one to two and from surface two to one. So, from here you can find that F 2 1 will be equal to A 1 by A 2. So, that tells you what is F 2 1. So, that is the view factor of emission that is radiated from surface two and as intercepted by surface one. What about F 2 2. So, F 2 2 is nothing, but 1 minus F 2 1, simply by summation rule. By summation rule, F 2 2 is 1 minus F 2 1. So, now, we can write the view factor matrix. So, F 1 1 is zero F 1 2 is 1, F 2 1 is A 1 by A 2 and F 2 2 is 1 minus A 1 by A 2.

So, note that we did not do any integration. So, depending upon the system you may have to integrate you may not have to integrate. So, I will show you some other example in a short while where there is no other way other than to integrate the expression to get the view factors. So, you first have to intrude as to what is the geometry and can we find out the view factors without doing the gori integration. So, the question is if I take differential element, how to make this argument. So, if you take a differential element supposing I take a differential element here, it is emitting radiation in all directions and equally if it is a diffuse emitter and, some of it is received by here and some of it is received by some other place. So, now, one could actually you should construct a 3 dimensional angles and if you do the integration this is exactly what you will find.

Student: (Refer Time: 05:39).

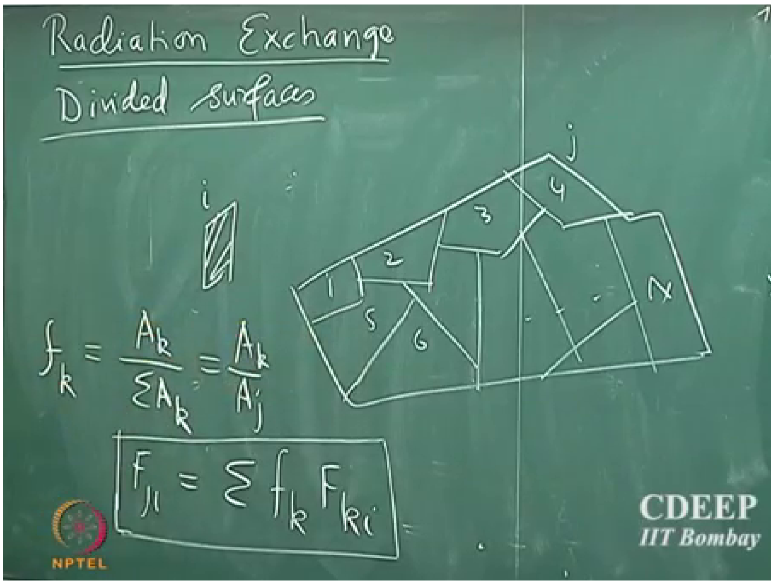
Yeah, does not matter know. F 1 2 whatever emission that goes out from here they are all always going to be received by two irrespective of whether it is a point source or a differential element, because it is a convex surface due to the nature of the geometry whatever emission that is going to come from this surface is always going to be intercepted by surface two.

Now, the question is what if there is only one small location where the emission is occurring not from every section in the surface, correct, is that the question. So, now, you will have to account for what is the surface of that location and. In fact, may not be today's lecture, next lecture we probably I am going to show you an example of how to how to find out the view factor if you have a differential element on a sphere. So, when you say non uniform you really mean that not all locations on the surface is emitting radiation. We are going to see that in the future. Any other question?

Student: (Refer Time: 06:42).

It could be. So, for example, you could paint with different colours and you could change the emissivity. So, note that emissivity is a surface property. So, you change the properties of some locations of the surface you are going to change the radiation properties.

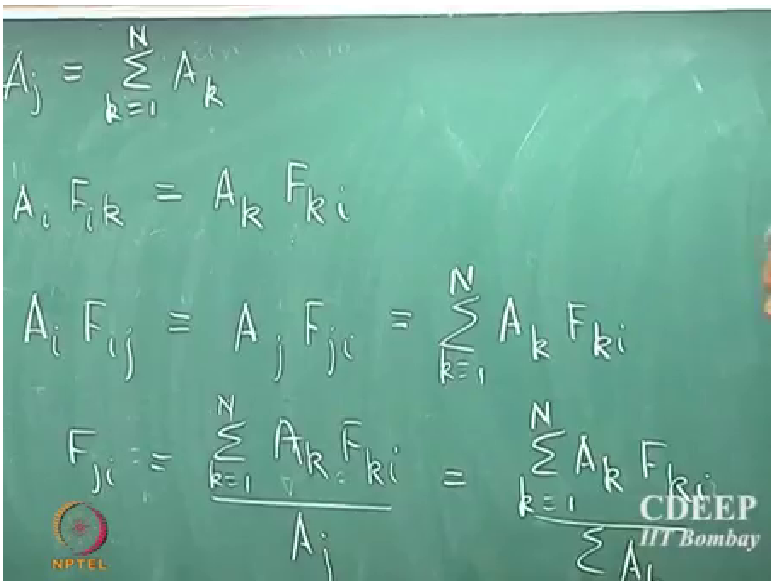
(Refer Slide Time: 07:05)



Next we are going to look at divided surfaces. I am going to look at divided surfaces. So, let us say that there is there is a surface i and, there is another surface and in principle without loss of generality we could assume that different parts of the surface are actually having different properties or having different properties whatever way by which you achieve them and. So, you want to now calculate the view factors for individual exchange between these fraction of the surface.

So, over all surfaces let us say called j and you want to know what is the view factor for radiation exchange between surface i and the individual surface. So, there can be two situations; situation one is where each of these surfaces will have different properties or it could be a complicated geometry. So, instead of estimating the view factor for the whole surfaces in one go you may want to divide them into small pieces and find individual view factors and find the overall view factor for surface j. So, there could be two reasons for doing this.

(Refer Slide Time: 08:44)



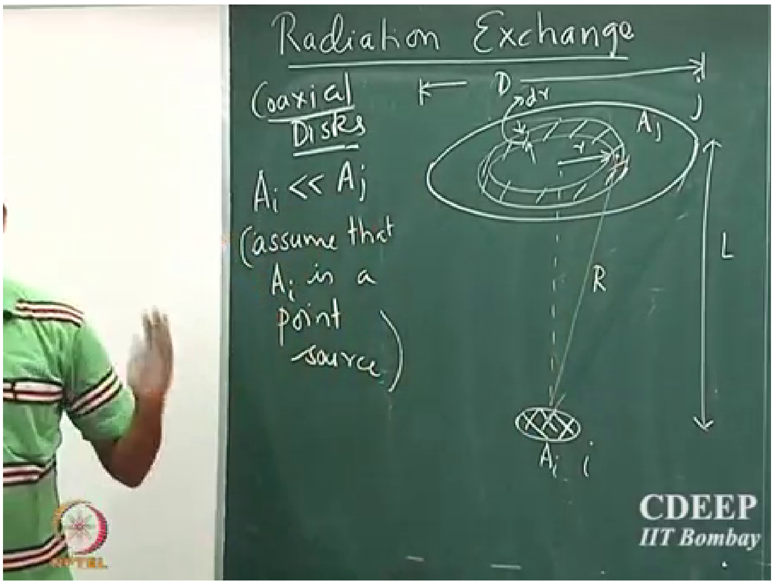
So, now by definition the overall surface of surface j is nothing, but sum over all k; k going from 1 to n, that is obvious. Now, A i F i k, I want to calculate the view factor between i and any other surface k and that is also equal to A k F k i by reciprocity relationship. So, now I want to find A i F i j . So, that is nothing, but A j F j i that is from reciprocity relationship for the overall surface. So, that should be equal to sum of A k F k i, k going from 1 to n and so, it is just the sum over all the divided surfaces, any question on this so far?

So, now, F j i is nothing, but sum k equal to 1 to n, A k into F k i divided by A j. What is A j? That is nothing, but sum of all the individual areas. So, that will be F k i, 1 to n divided by sum over all areas. So, what this expression tells you is that, F j i which is the overall view factor between surface j and i is simply given by sum over the fractional area multiplied by the corresponding view factor. What is A k by sum A j it is the fractional surface area.

So, if I call small f as the fractional surface area A k by sum that is nothing, but A k by A j. So, F j i is nothing, but sum over all k F k i. So, that is an important relationship. So, if we have divided surface then you could use such summation formula to find the overall view factor between the two surfaces or if you know some of them you should be able to calculate the view factor for the other divided surface for which you may want to calculate some of the radiation properties.

So, we are going to look at a specific example now, where we do not have a choice, but to use the integral.

(Refer Slide Time: 12:18)

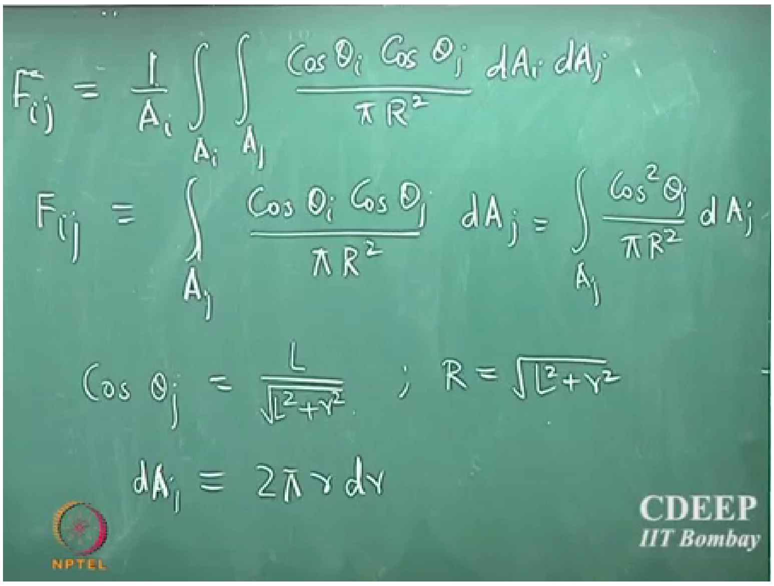


So, let us say you look at the coaxial disk. So, this is surface j and this is surface i and the surface area is A i and if the surface area is A j. So, as a first example I will assume that A i is much smaller than A j, we assume that A i is a point source. You will relax this assumption in the next lecture where I will show that there is another method to calculate when A i is not a point source. So, now assume that A i is a point source. So, let us construct the geometry.

So, supposing I take a differential element, let us say that the centres are connected I mean it is not connected its aligned and if this separation distance is let us say L and the diameter of the larger disc is D. So, let us say that, note that when we define the view factors R is the distance between the element that you are considering and the emitting element . So, if this distance is R and I refer this as small r and if I say that the thickness is d r; d r is the thickness of the element.

So, note that it is a 3 dimensional system, now, you actually have a cone. So, it is a element which is actually a ring on this surface and so, the solid angle is essentially because of the cone which is subtended by this element on this surface.

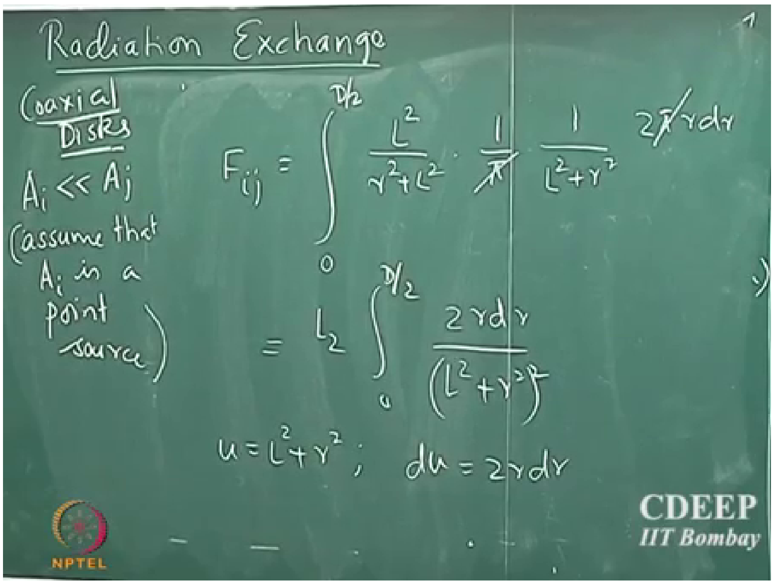
(Refer Slide Time: 14:51)



So, the view factor F i j is given by 1 by A i integral A i A j cos theta i theta j divided by pi R square d A i d A j. So, I have assumed that i is a point source, so, I can simply integrate it out and this is essentially integral A j cos theta i cos theta j divided by pi R square into d A j. What can we say about theta i and theta j? What is theta i? Theta i is this angle, this is theta i and this is theta j, by simple geometry we know that they are one and same. So, this will be integral A j cos square theta j divided by pi R square into d A j.

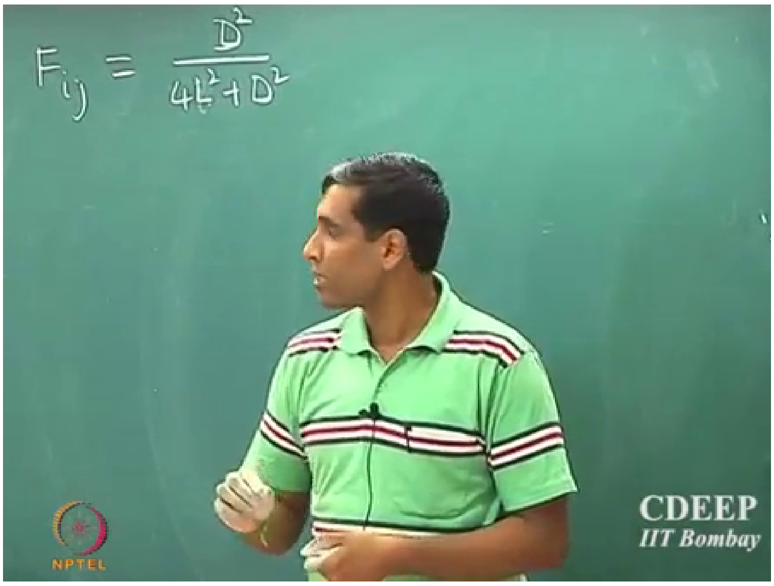
What is cos theta j? Cos theta j, look at the geometry its L by r. So, it is L by square root of L square plus r square. So, r is this distance here. So, the hypotenuse is square root of L square plus r square 2 cos theta j is L by square root of L square plus r square and R is square root of L square plus r square. What is d A j? 2 pi r d r, we plug in all these in the integral. So, it will be F i j will be integral 0 to D by 2, so, that is the radius from 0 to D by 2.

(Refer Slide Time: 17:28)



And, cos theta square is L square by r square plus L square into 1 by pi r is root L square plus r square that will be 1 by L square plus r square we have 1 by r square and d A 1 is 2 pi r d r. So, we can integrate this; pi goes away, it will be L square D by 2, 2 r d r divided by L square plus r square the whole square. How do we integrate this? You make a substitution. So, you say u is L square plus r square and d u is 2 r d r, you plug in all this.

(Refer Slide Time: 18:41)



So, the view factor F i j will be D square by 4 L square plus D square, where D is the diameter of the larger coaxial disc and L is the separation between them. Is that cleared everyone?

So, in this particular case, we have no option, but to do the full integration. You have to one important thing you have to keep in mind is whenever you do these integration these area that you are calculating and the solid angle it involves 3 dimensions. So, you have to be very careful how you construct the geometry. So, this is a very simple example where constructing the geometry is very easy, but there are many cases, where constructing the geometry can be completely non trivial.

So, I really encourage you to take different examples from your textbook. In fact, there are tables in your book which tells you what is the view factor for different shape geometries and you should really attempt to derive these view factors and convince yourself that you are able to construct the geometries properly. So, all the expressions given in the book are right, so, you should be able to convince yourself that you are able to derive it. It is very important to learn how to construct the 3 dimensional angles and 3 dimensional geometries.