Heat Transfer

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Lecture – 54
Determination of View Factors

Whenever we have emission from a surface and there is another surface nearby what is normally going to happen is that all the commission which is coming from surface 1 will not strike surface 2. Therefore, the energy emitted by surface 1 may not be intercepted by surface 2, how much of energy what fraction of energy that is emitted by surface 1, which is going to fall directly on surface 2 is known as the view factor. So, if the two surfaces are very close together then the view factor of 1 to 2 would be obviously, equal to 1; that means, all the energy emitted by surface 1 is going to incident on surface to directly.

So, this concept of view factor, how much of the emitting surface is visible from another surface nearby is important, because it would give us a tool during our calculation of emission and interaction radiative interaction between surfaces which will form part of an enclosure. So, whenever you would like to design an enclosure and we would like to find out, how much and the three surface is forming the let us say the three surface is forming let us say the three surface is forming the enclosure are at different temperatures, one is receiving the heat, the other is emitting the heat and maybe the third surface is insulated.

So, how much of interaction in how much of energy is going to incident on one surface is going to come out of the other surface, how much of energy is to be extracted from a third surface to keep it isothermal, all these are important in industrial calculations for example, the design of a furnace. So, the concept of view factor is therefore, extremely important in the designing of radiative heat exchange processes in an enclosure for example, in a furnace. And we know what are the uses of furnace from baking a surface at a specific temperature to exposing average surface at a very high temperature? The third application could be drying of a surface through radiative heat and so on.

So, the examples of radiative heat exchanger in a furnace are many and from different fields, but the first thing that one needs to know is what is the fraction of energy emitted by one which is going to be intercepted by the second directly, without considering reflection of energy from the adjoining surfaces. So, this is view factor which we have discussed in the previous class.

And we have also seen some of the properties of view factors for example, if you take a view factor and you find out the view factor of that surface to all the surfaces nearby which forms an enclosure. So, whichever room that you are sitting right now, the let us say the floor of that room is your surface 1. And then you have 5 is more surfaces which are forming the enclosure the four walls and the roof which forms so, the 6 surfaces will form the enclosure. The when you consider the surface on the floor, then it has the possible view factors are F 1 where 1 refers to the floor F 1 to from the floor to the roof F 1 3 1 4 and 1 1 5 these are all the walls which we have.

And interestingly there is a view factor of the floor to itself; that means, it is possible so, that some of the energy emitted by the floor is going to be absorbed by the floor directly. The when you considered the floor obviously, if the floor is plain and level there is no chance of energy emitted by the floor absorbed by the floor itself. So, F 1 1 which is the view factor of the floor to itself 1 1 that would obviously, be equal to 0 and the sum of all other view factors would be equal to 1.

So, the first rule is the rule of summation rule which tells you that the sum of all possible view factors from a surface would be equal to 1 which obviously, is intuitively correct as well, since you have since a view factor gives you the fraction. So, the sum of all fractions of energy coming from a surface has to be equal to 1.

The second one which we have derived in the last class is the concept of reciprocity, the reciprocity relations where we have shown that A 1 F 1 2 A 1 being the area of surface F 1 2 is the view factor of one with 2 should be equal to A 2 that is the area of the second surface times F 2 1. So, the reciprocity would give another set of relations between surfaces which are forming an enclosure.

So, the first thing is summation the second rule is the reciprocity relation and the third rule, which applies to convex and plane surfaces for which you can see that A 1 1 is equal to 0. So, for a convex or a plane surface no fraction of energy emitted by the surface is going to be absorbed by the same surface, which we cannot say for the case of concave, because when you think of a concave surface part of the energy emitted by the surface will probably be absorbed by the surface itself.

So, that is fine, but and we have also seen how one can analytically calculate, the view factor of different surfaces and the view factor of obvious, when you talk about the two surfaces the view factor would depend on the magnitude of the area. That means, whatever be the length scale associated with area 1, whatever be the length scale associated with area 2 and obviously, the distance between the 2. So, the view factors are normally expressed graphically based on the relevant dimensions and the separation between the two surfaces.

So, in your text and in any text you would find that these view factors are calculated for some of the standard surfaces and those standard relations for view factors the results for the view factors are expressed in graphical form. And it could be very useful to use those graphs for a number of applications, where at least you would be able to find one of the view factors.

Now, if you find one of the view factors, then the next thing on should do is try to see, if you can use summation rule, reciprocity rule or the nature whether its curved or a flat surface rule to see if another view factors which are forming the enclosure if the other few factors can also be evaluated. So, you would solve we would see some of the problems towards the end of this class, but I will give an some idea of how the how the results of view factors for common surfaces are expressed in the graphical form.

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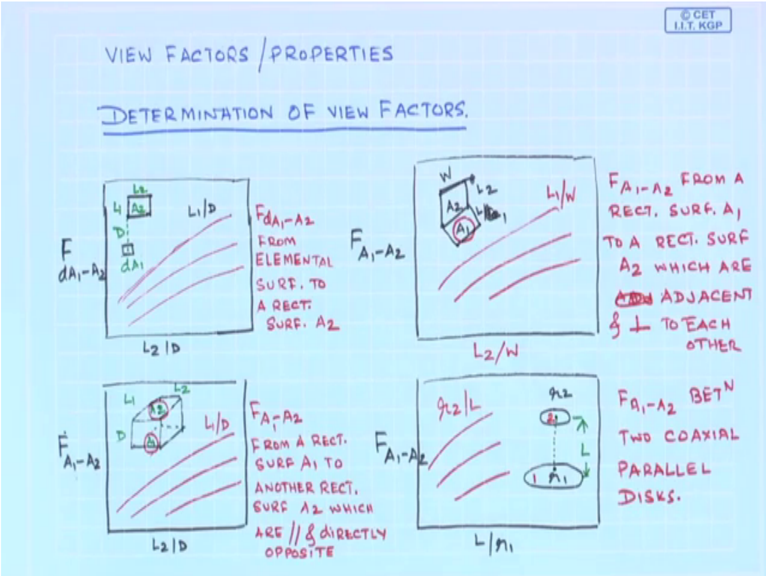

So, the first one that you would see over here, this is the view factor of an elemental area d A 1 to a surface A 2 which dimensions of L 1 and L 2 and d is the distance between them. So, d A 1 is the elemental surface, d is the distance between the surface and the tip this is the corner of the surface A 2, which has dimensions of L 1 and L 2.

So, you will number of curves like this where the x axis is L 2 by D, D is the separation and the family of curves of for different values of a L 1 by D. So, this curve is elemental this is F d A 1 to A 2 from n elemental surface to a rectangular surface, which is having an area A 2 and dimensions L 1 and L 2. So, the curve one is for an elemental surface area please note the location of the elemental surface with respect to the surface so, that is the corner is directly above d A 1. So, if you know this the values of L 2 D and L 1 you should be able to find out what is the value of the view factor.

Now, you come to this one so, this is going to give you F A 1 to A 2 from a rectangular surface A 1. So, this is rectangular surface A 1 to another rectangular surface A 2. So, this top surface is A 2 which are parallel to each other parallel and directly opposite. So, here you see that this is a cuboid and we are talking about the base area which is denoted by A 1 the area which is parallel and directly opposite to A 1 is; obviously, the top of the rectangle. So, I am trying to find out what is F A 1 A 2? So, this is from a rectangular surface A 1 to another rectangular surface A 2 which is parallel to A 1 and directly above or directly opposite to it.

So, these are also expressed in graphical form the L 1 and L 2 are the dimensions of the rectangular surface D is the distance between the between them. So, the x axis as before L 2 by D and the family of curves are for different values of L 1 by D. So, one would be able to obtain what is going to be the view factor for such a case. And if you find out F A 1 to A 2 A 1 to A 3 A 4 A 5 A 6 can simply be calculated using any of the known relations like reciprocity and or the summation rule.

The 3rd one again it gives you the value of A A 1 to A 2 from A rectangular surface A 1. So, this is your A 1 to a rectangular surface A 2 which are touching each other so that means, which are adjacent and perpendicular to each other. So, you can think of you can imagine A 1 and A 2 are the two sides of this rectangle or if you open up like this if you open a book like this.

Where they are there they are perpendicular to each other two surfaces are perpendicular to each other, then the view factor of this surface to this surface, which is adjacent; that means, they are touching each other and which are perpendicular to each other it is that view factor that we are trying to find out in here. So, inside a rectangle the base and the adjoining surface is the value which we are trying to get.

So, again it is going to depend on L 1 L 2; that means the length scales which define the area. So, if you look over here then you have different value so, this is L 2 by W and this is L 1 by W, where W is the width of these two plates, L 1 and L 2 are the other length scales which are present here. So, again you can find what is the view factor from here?

Then last one that you see is F A 1 to A 2 between two coaxial parallel disks. So, these two coaxial parallel disks they are so, therefore, the centre of this and the centre of this one, the they are coaxial and you should be able to find out what is the view factor of 1, with respect to the other provided you know what are the values of r 1 r 2; that means, the radia is radius of disk one radius of disk two and the separation between the two. So, the x axis is L by r 1 the y axis the different values of the curves are r 2 by L and you can find out what is F A 1 F A 1 to A 2.

So, using the mostly these are the four fundamental figures, that can be used to find out what is the view factor of a surface to the other. In some cases a combination of these would be required in some in most of the cases the view factor obtained from these graphs are to be combined with the summation rule or the reciprocity rule relation to obtain the unknown view factor the other unknown view factors. In some cases you really have to reduce some sort of an algebra in order to find out what is the view factor for such cases. So, quickly see some of the examples of the use of these charts to obtain the view factors of unknown surfaces.

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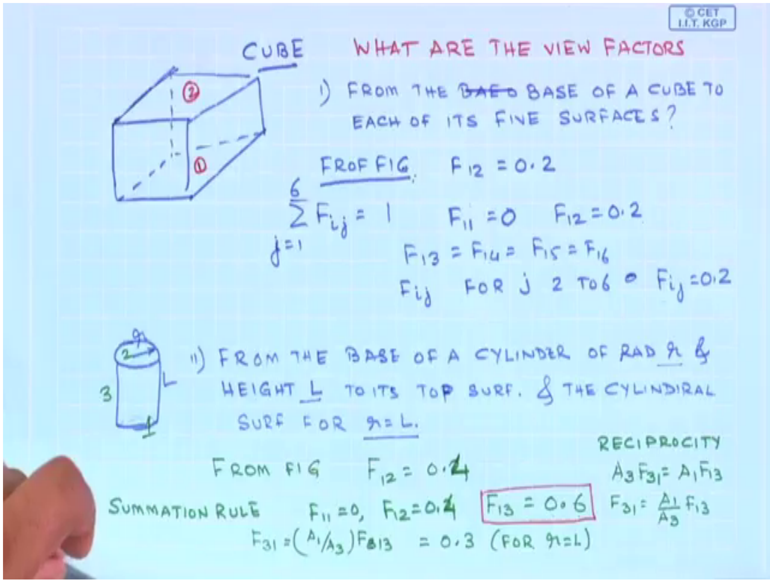

So, the first one that we are going to do is let us think of a rectangular surface like this. So, this is the rectangular surface and you have put this is a cube. So, all sides are same and you have to first find out what is the view factor from the base of a cube to each of these surfaces ok. So, will be not the base surface as 1 the top surface as 2 and the others are 3 4 5; 3 4 5 and 6.

So, from the figure from figure that is this figure you are going to find out what is the view factor your L 1 and L 2 are the same here and it is also equal to D since it is a cube. So, your L 1 by D is 1 L 2 by D is 1 so, from the corresponding point where L 2 by D is equal to 1, you go all the way to the curve which corresponds to L 1 by D equals 1, and read the value of a F A 1 to A 2.

Once again A 1 is the base of the cube A 2 is the top of the cube, since it is a cube L 1 is equal to A 2 is equal to D so that means, both these ratios would have value equal 1. So, you go up to the right curve and find out what is F A 1 to A 2 so, that is the use first use of this curve. So, from the figure what you are going to see that you are going to check on your own is F 1 2 is equal to 0.2 that is from the figure.

You can also write that F i j is equal to 1 and this in this case i varies 1 j sorry j varies from 1 to 6. And F 1 1; that means, the view factor of 1 to itself would obviously, be equal to 0 since it is a flat surface F 1 2, we have just found out to be equal to 0.2. And by symmetry since it is a cube F 1 3 would be equal to F 1 4 would be equal to F 1 5 and F 1 6, F i j for j 2 to 6 should be equal to F i j would be equal to 0.2.

So, F 1 3 F 1 4 F 1 5 and F 1 6 using the submission rule and knowing the value of F 1 2 to be equal to 0 and knowing the symmetry involved in a cube, your F i j should be equal to 0.2. So, all from 1 all view factors except to itself would be equal to 0.2. So, F 1 2 so 0.3 1 4 1 5 and 1 6 all are going to be equal to 0.2.

The second one is a cylinder like this and the question that you have we have to answer is from the what is the view factor so, all these are what are the view factors? So, this is for 1 from the this and this is from the base of a cylinder of radius r and height L to it is top surface and the cylindrical surface is for r equals l. So, we need to find out what is the view factor from the base of a cylinder of radius r so, this is radius r and length L. So, from the base of the surface to the top of the surface for the case, when r is equal to L so, what you need to do is you need to use obviously, this figure, but in this case r 1 would be equal to r 2 and the value of L is assumed to be for the problem given r 1 is equal to r 2 is equal to L. So, therefore, your L by r 1 and r 2 by L will have values equal to 1.

So, you can read what is the value of F 1 2 so, if the radius r and L if both are same, then from the graph from figure, you would see that you should check it on your own F 1 2 so, this is my surface 1, this is my surface 2 and the curved surface is curved surfaces 3. So, F 1 2 is 0.2 and then I invoke summation rule which says F 1 1 is 0, F 1 2 is equal to 0.2 and therefore, sorry this is 0.4 F 1 1 so, this is 0.4 and therefore, F 1 3 must be equal to 0.6. So, this is definitely the value that we are looking for since F 1 one 0 F 1 2 is equal to 0.

When you use reciprocity relation, then A 3 F 3 1 should be equal to A 1 F 1 3. So, we need to find out what is the view factor of 3 from 3 to 1. So, F 3 1 is A 1 by A 3 F 1 3, we know what is the value of F 1 F, we know the value of what is F 1 3 so, your F 3 1 would be equal to A 1 by A 3 times F 1 3. And when you put the values in there you are going to get equal 0.3 for r equals L. So, the value of F 1 3, we have already obtain to be 0.6 so, A

1 by A 3 ratio for r equals L you would give you the value of F 3 1 to be equal to 0.3. So, what you have obtained is F 1 2 F 1 3 and F 3 1 so, all values are obtained in fashion.

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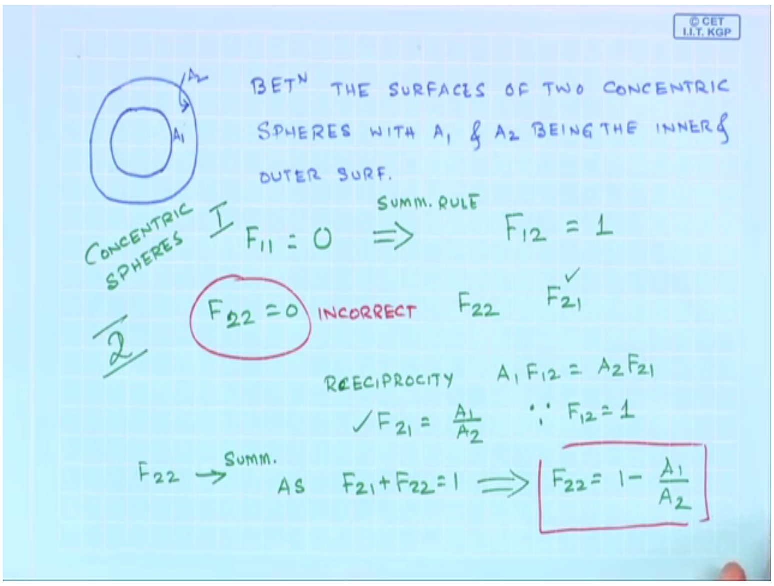

The third one is more interesting so, the third one simply tells you that this is the between the surfaces of two concentric spheres with A 1 and A 2 being the inner and outer surface. So, this is A 1 and this surface is A 2 so obviously, what we can see from here is that for F F 1 1, this is concentric spheres. And we have something in between the intervening space F 1 1 has to be equal to 0, because F 1 1 constitutes a convex surface. So, for a convex surface the view factor to itself of the surface to itself must be 0 it was any emission coming out of A 1 is not going to fall directly on A 1 again, it may get reflected from the inner surface and may incident on surface 1 again.

But, the definition of view factor is that it is the emission the fraction of emission, which falls directly which is emitted by a surface and false directly on itself. So, since for a convex surface, there is no chance of an emission being incident again on the same surface therefore, F 1 1 where one refers to the inside the surface area of the inside sphere F 1 1 must be equal to 0. And you can also say that the summation rule and physically you can imagine that all emission emitted from 1, since it is inside the larger sphere all emission from 1 must fall on 2 therefore, the view factor if 1 1 maybe 0, but F 1 2 will have a value equal to 1.

So, what we can write from here is that the summation rule and common sense that will tell you that F 1 2 will have a value equal to 1 so, this is summation rule. On the other hand you can see that some of the energy which is emitted from to is going to strike 1, but some of the energy emitted from 2 may strike to itself once again. So, this since A 2 the inside area of the outer sphere is a concave 1, I cannot say that F 2 2 is equal to 0. So, this saying this would be incorrect, since it is an since this is the that is not since that is not the case.

So, the two view factor so, this is for surface I and for surface 2 I need to find out what is F 2 2 and what is F 2 1, I cannot say F 2 2 to be equal to 0 which is incorrect so, and whether I should concentrate on F 2 1. Now, how can I find if 2 1, I know what is the value of F 1 2. So, if I know F 1 2 and if I know F 1 2, then F 2 1 we can be calculated from reciprocity relation, that is the other relation which we have so, reciprocity gives us A 1 F 1 2 must be equal to A 2 F 2 1 that is the reciprocity relation.

So, F 2 1 is equal to A 1 by A 2 since F 1 2 is equal to 1. So, that is the other relation and you can then therefore, calculate F 2 2 from summation as F 2 1 plus F 2 2 is equal to 1. So, this must give you F 2 2 as 1 minus A 1 by A 2. So, that is the other relation which I would like to highlight a little bit more.

So, simple use of reciprocity and summation would give you the value F 2 2. Now, A 1 is the surface area of the inner sphere and A 2 is the surface area inside surface area of the outer sphere. Now, let us think of a situation in which the a very small sphere is placed inside a very large sphere. So, the sphere inside is very small therefore, A 1 is small and the sphere outside is very large and therefore, A 2 is large.

If that is the case then all emission coming out from surface 2 is going to fall directly on itself, the small area the small sphere which is located at the centre it really does not matter. So, common sense tells us that when A 2 becomes very small, sorry A 1 becomes very small the inside sphere becomes very small, we can in the limiting case we can assume that it is not going to observe anything which is coming out of 2. And therefore, the fraction of energy emitted by 2 which is going to be incident on to itself directly will have to be equal to 1.

So, whatever we thought to be correct from an intuitive point of view, if you look at the equation this is going to corporate that. So, when A 1 becomes small and it becomes large, F 2 2 will have a value equal to 1. So, what I would suggest is the if you look at your text book and some of the other text books on radiative heat transfer you would see that there are several configurations which are provided as examples or as exercise is for to preferred you to practice to see whether or not you can correctly evaluate what is the view factor for such cases.

So, I urge you to practice the concept is very simple, the two relations are also very simple the summation rule and the reciprocity relation, I have shown you three examples of how to calculate the unknown view factor there are examples, which you should solve yourself to see if you have understood the concept clearly. And as I mentioned before the concept of view factor is going to be extremely important, when we are going to calculate radiation exchange between surfaces which form an enclosure for example, a furnace. So, we will see how this is to be how this is to be done in the subsequent classes.