Heat transfer
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Lecture - 54
Resistanes: Examples

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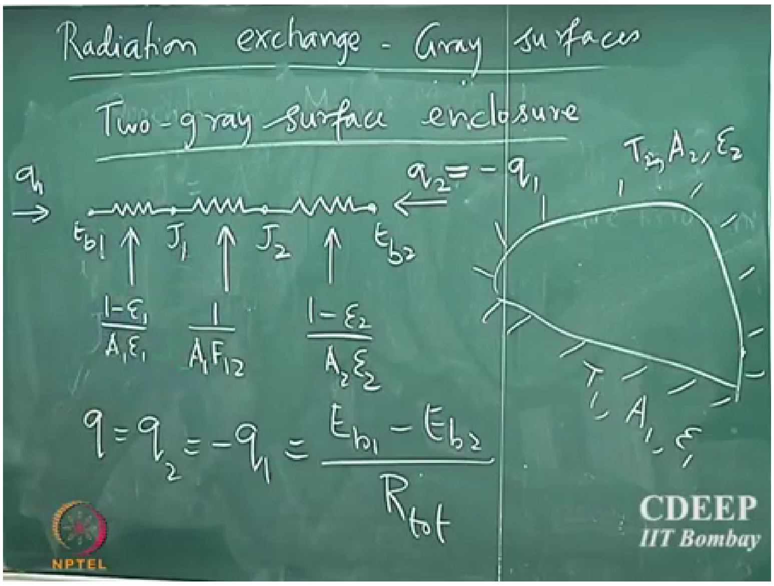

Radiation exchange - Gray surfaces

Two-gray surface enclosure

$$\frac{1-\varepsilon_1}{A_1\varepsilon_1} \qquad \frac{1}{A_1F_{12}} \qquad \frac{1-\varepsilon_2}{A_2\varepsilon_2}$$

$$q = q_2 = -q_1 = \frac{E_{b1} - E_{b2}}{R_{tot}}$$

So, let us say we have A 2 grays of surface enclosure; we have A 2 grays of surface enclosure ok. So, this is the surface 1, which is maintained at temperature T 1 and, let us say the area of that surface is A 1. And let us say that the emissivity is epsilon 1 ok. And similarly you have another surface which is T 2 A 2 and epsilon 2 ok. So, I want to find out the net radiation exchange between these two surfaces ok, how many resistances are there how many yeah.

Student: 6.

6 why is it 6?

Student: (Refer Time: 01:16).

Ok.

Student: (Refer Time: 01:26).

So every surface ok. So, supposing if the if the black temperature of of the blackbody radiation of the first surface is E b 1 and, the blackbody radiation of the second surface is E b 2 ok. Now if I maintain the 2 at the same temperature ok.

What will be the emission, or what will be the radiation exchange between itself. Suppose I maintain it at the same temperature ok, the whole surface is maintained at the same isothermal temperature. So, what will be the radiation exchange this is total quantity right we are looking at J 1 and J 2 looking at J 1 and J 2.

So, what is it functional? It is function of temperature and anything else or that is it this is total quantity right. So, this is the integrated over all angles and, it is integrated over all wavelengths. So, this is only a function of temperature correct. So, if it is a function of temperature then, what will be the radiation exchange between itself let radiation exchange between itself will be 0 right.

Because the amount that is emitted from one location to the other location is exactly the same and so, the net radiation exchange so, note that you may have a small differential element whose view factor with another differential element here could be different, but the net radiation exchange over the whole surface within itself is going to be 0 because, you are maintaining it at a constant temperature. So, therefore, the total number of resistances will boil down to 3.

So, this will be with J 1, J 2 and E b 2 ok. What are these resistances what is this resistance what is this resistant? 1 minus 1 minus epsilon 1 pi A 1 epsilon 1 and what about this resistance 1 upon A 1, F 1 2 and this is 1 minus epsilon 2 by A 2 epsilon 2 ok. So, now simply based on the resistance concept so, if q 1 is the net radiation exchange between the 2 surfaces from the surface 1 ok, then q 2 will be what will be q 2. So, this is the net radiation exchange with respect to surface 1 right. What is q 1? q 1 is the amount of heat either released from 1, or it is supplied to surface one in order to maintain a constant temperatures.

So, what should be q 2 then it will be minus q 1 right because, it is just there are just 2 surfaces and both are maintained at constant temperature. So, first from simple energy balance it will be q 2 will be equal to minus q 1 ok. So, from here q equal to q 2 equal to minus q 1 so, based on resistance networks, you can simply write it as E b 1 minus E b 2 divided by the total resistance ok. So, the resistances are in series. So, the total resistance is the sum of individual resistances.

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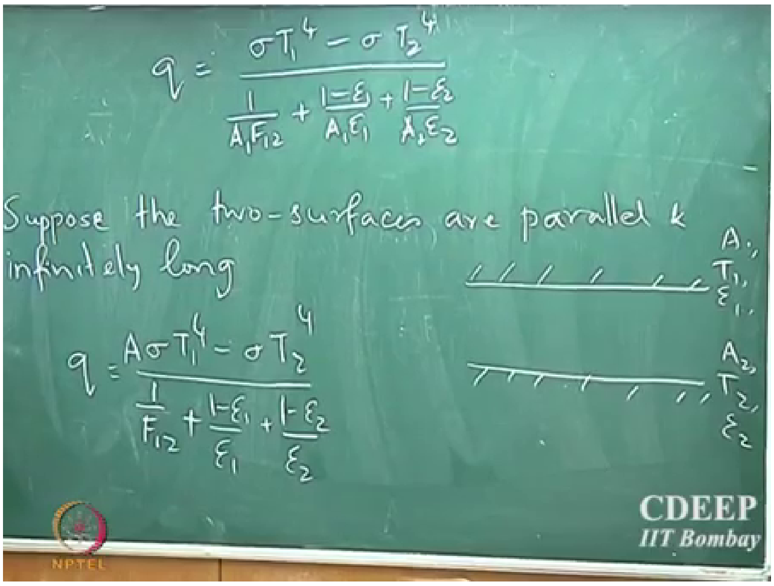

$$q = \frac{\sigma T_1^4 - \sigma T_2^4}{\frac{1}{A_1 F_{12}} + \frac{1-\varepsilon_1}{A_1 \varepsilon_1} + \frac{1-\varepsilon_2}{A_2 \varepsilon_2}}$$

Suppose the two-surfaces are parallel & infinitely long

$$q = \frac{A\sigma T_1^4 - \sigma T_2^4}{\frac{1}{F_{12}} + \frac{1-\varepsilon_1}{\varepsilon_1} + \frac{1-\varepsilon_2}{\varepsilon_2}}$$

So, therefore, q will be sigma T 1 to the power of 4 T 2 to the power of 4 divided by 1 by A 1 F 1 2 oops plus 1 minus epsilon 1 by A 1 epsilon 1 epsilon 2 by A 2 epsilon 2. So, that is the net radiation exchange between these 2 surfaces ok.

So, let us add a little bit simplification here, suppose if the enclosures are parallel to each other. Suppose the 2 surfaces are parallel and infinitely long ok. So, if it is parallel and infinitely. So, it is a essentially a parallel plate. So, you have parallel plates and this is maintained at temperature T 1 maintained at T 2 and the emissivity is epsilon 1 epsilon 2 and the area is A 1 and A 2 ok.

So, if it is infinitely parallel, then you could assume that these 2 areas are equal to each other. So, therefore it is the same system like what we looked at short while ago, except that it is infinitely parallel long and parallel now. And so, the radiation exchange is still the same maybe sigma T 1 to the power of 4 T 2 to the power of 4 divided by 1 by A 1 and A 2 are same. So, we can take it up there. So, if I say area of the parallel plate is A. So, that will be 1 by F 1 2 plus 1 minus epsilon 1 by epsilon 1. What is F 1 2? It is it is 1 because whatever radiation that leaves surface 2, it has to be seen by surface 1.

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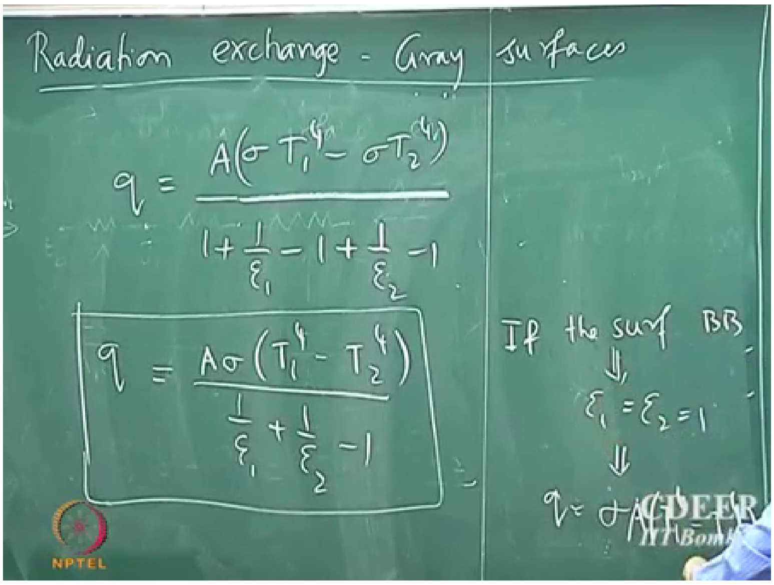

Radiation exchange - Gray surfaces

$$q = \frac{A(\sigma T_1^4 - \sigma T_2^4)}{1 + \frac{1}{\varepsilon_1} - 1 + \frac{1}{\varepsilon_2} - 1}$$

$$\boxed{q = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}}$$

If the surf BB

$\Downarrow$

$\varepsilon_1 = \varepsilon_2 = 1$

$\Downarrow$

$q = \sigma A(T$

Therefore, so the net radiation exchange will be A sigma T 1 to the power of 4 minus sigma T 2 to the power of 4 divided by 1 plus 1 by epsilon 1 minus 1 epsilon 2 minus 1. So, that will be A sigma T 1 to the power of 4 divided by 1 by epsilon 1 into minus 1 that is the net radiation exchange between two gray surfaces.

So, note that if they were to be a black body. What will happen? The emissivity is A 1 right it is a black body emissivity is A 1. So, if it were to be a black body surface is black body, then emissivity is A 1 and so, this is simply become sigma A into T 1 power 4 minus T 2 to the power of 4, this is the classical relationship that all of you have seen right.

So, remember that when you have radiation exchange which is the infinitely parallel and, the view factors are 1, this is the radiation exchange between the 2 surfaces, if it were to be a black body. So, that comes out clearly from the expression that we actually derived. This is an important thing you should check whenever you have a real surface, whenever you derive the net radiation exchange for real surface, it is actually useful to check the corresponding relationship and see if it actually boils down to the corresponding blackbody relationship, if you assume all the emissivity is to be 1 ok.

It is a very good thumb rule to check you know, if you put F on 2 as 1 it becomes parallel, it will be careful you can put epsilon as 1 that is correct, then the surfaces are blackbody, but then if you put F 1 2 as 1 you also have to put the areas to be 1, areas to be equal not 1 right you understand. So, the areas and the view factors they are; obviously correlated. You cannot completely separate the 2 and assume make some approximations for each of them.

The area is going to change then there is some effect on the view factor because, the view factor already contains the integral over the whole area right. So, area has already taken into account in the view factor

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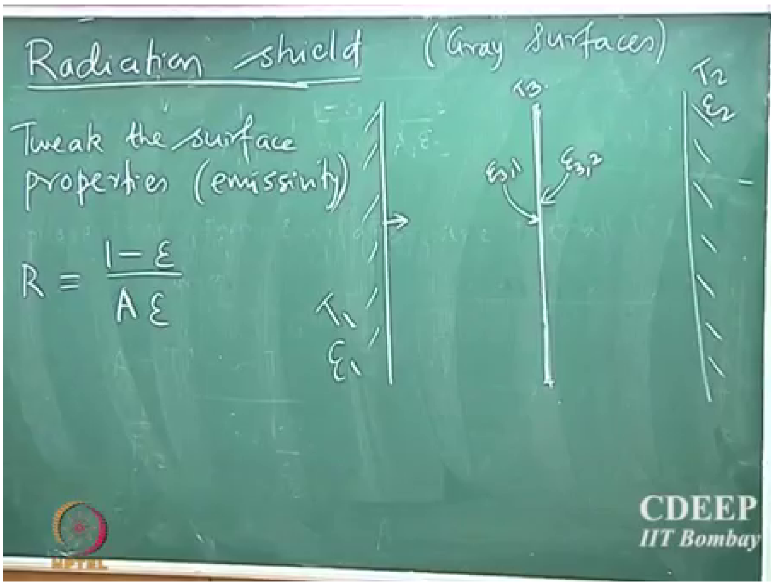

So, we are going to look at a little bit more extension of this radiation shield ok. So, this is a very important aspect of quantification of any radiation system. So, for example, if you have a nuclear reactor ok, now you do not want any of the radiation to leak out of the system right, you do not want radiation to leak out because it is a hazardous right. So, what happens in radiation when it leaks is that particularly for human beings one of the first things that get us affected is the thyroid gland. So, you know how many of you have heard about thyroid gland oh most of you. So, so the first thing one of the first thing that get us affected is the thyroid gland that is because, the iodine which is present in the body.

So, the radioactive isotope of iodine is something which can be very easily triggered. So, whenever there is an exposure to radiation, one of the first thing that get us triggered is actually the normal iodine get us converted into the radioactive form of iodine. And so, that hurts the thyroid gland very easy. So, that is why when there is a radiation exposure a couple of things that is generally done is, they ask people to drink a lot of milk which is again radiation free milk.

So, that somehow seemed to protect the thyroid gland, I do not know how, but somehow it does. So, that is one thing and the second thing is you know cover the cover the neck as for as far as possible because, the thyroid gland is actually sitting in the neck here right. So, these are the two general seditions that is given. So, anyway the radiation shield is actually very important because, you do not want radiation to be to leak out from a nuclear reactor or, some other system where radiation is active.

So, the way it is done is let us take a very simple case of course, a real eye system is not as simple as this. So, the way the radiation shield is actually designed is by playing with the emissivities of that surface ok. So, we will look at only gray surfaces here, of course 1 could derive all the relationships for a normal surface, but we will not do that in this course ok. So, the way it is done is we tweak the emissivity of the surface particularly emissivity, we tweak the surface properties.

So, supposing we have 1 surface which is maintained at temperature T 1 and let us say you have another surface whose emissivities epsilon 1. And it is emitting radiation on the inside of that particular surface, let us say that there is no radiation on the other side, or let us say there is a reactor sitting on the other side. So, what is relevant is only radiation which is emitted by the outer surface of that particular object that we are looking. And let us say this is the receiving object, which is let us say at temperature T 2 and emissivity is epsilon 2.

So, we need to place something in between, in order to protect the second surface from receiving the radiation emitted, or minimize the radiation that is received from surface 1 cannot be completely 0, but you minimize it as much as possible. And the way it is done is you put a finite thickness material a surface which is in between, let say it is a parallel plate ok, then if let us say the emissivity I call this surface 3, which is at let us say temperature T 3.

So, I create the surface maybe I paint the surfaces 2 surfaces in some other way, or I alter the surface roughness of that surface as such that the emissivity of the 2 sides of the same object is different ok. So, I create a system where the emissivity of 1 side is completely different from the emissivity of the other side of the same object. So, that way I can actually cut down the total amount of radiation that is actually transferred from 1 to 2, why is that because the resistance that is offered by the surface to exchange radiation, or to emit radiation from the surface it depends upon the surface property such as emissivity.

So, we know that the resistance offered by the surface, is 1 minus epsilon by the area time epsilon. So, by playing with the value of epsilon, we should be able to control the total amount of radiation that is emitted by the outer surface of that particular object. So, if you want to characterize this we can now use the resistance network concept, how many resistances are there here how many resistances are there for this system 6 what are they ok.

So, there is one resistance for radiation that is emitted by surface 1, there is 1 resistance for exchange between surface 1 and the surface 2 which is facing this surface and, then there is there is exchange from the surface resistance of 3 to 3 1 and, their surface resistance of 3 2 and resistance between the 2 surfaces and the other 1.

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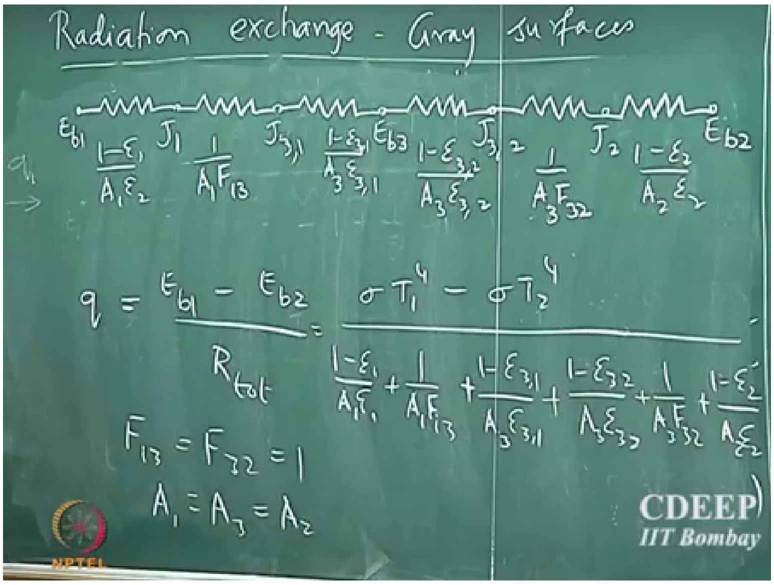

Radiation exchange - Gray surfaces

$$q = \frac{E_{b1} - E_{b2}}{R_{tot}} = \frac{\sigma T_1^4 - \sigma T_2^4}{\frac{1-\varepsilon_1}{A_1\varepsilon_1} + \frac{1}{A_1F_{13}} + \frac{1-\varepsilon_{3,1}}{A_3\varepsilon_{3,1}} + \frac{1-\varepsilon_{32}}{A_3\varepsilon_{32}} + \frac{1}{A_3F_{32}} + \frac{1-\varepsilon_2}{A_2\varepsilon_2}}$$

$$F_{13} = F_{32} = 1$$

$$A_1 = A_3 = A_2$$

So, they are totally 6 resistances so, this is E b 1 and, this is E b 2 ok, this is J 1, J 2, J 3 that is on the side which is facing surface 1 and, this will be E b 3 that is the corresponding blackbody radiation for the third surface and, this is J 3 2 and this is J 2.

Now, here off course I have assumed that the resistance for conduction is negligible in the third surface, wall radiation that actually goes from 1 to 2 will be with will be from 3.

Student: (Refer Time: 17:45).

There is 0 yeah that is right the view factor is 0.

Student: (Refer Time: 17:48).

Correct because of the view factor. Now supposing if the shield at your place does not completely cover the 2 surfaces, then there will be exchange between 1 and 2. So, this is 1 minus epsilon 1 by A 1 epsilon 1, this is 1 by A 1 F 1 3, this is 1 minus epsilon 3 by epsilon 3 1 by A 1 A 3 epsilon 3 1. So, note that the emissivity is now on different sides are different. So, you have to account for that in the resistance is 3 2 by A 3 epsilon 3 2 and 1 by A 2 A 3, F 3 2 and will be 1 minus epsilon 2 by A 2 epsilon 2 ok. So, now we can find the net radiation exchange between the first and the second surface. So, that will be E b 1 minus E b 2 divided by R total.

If you have the resistances in series that is the total resistance and so, R that will be sigma T 1 to the power of 4 minus sigma T 2 to the power 4 divided by 1 minus epsilon 1 by A 1 epsilon 1 plus 1 by A 1 F 1 3 plus 1 minus epsilon 3 1 by A 1 epsilon T 1 A 3 plus 1 minus epsilon 3 2 by A 3 epsilon 3 2 plus 1 by A 3 F 3 2 plus 1 minus epsilon 2 by A 2 epsilon 2 ok.

So, what is F 1 3 and F 3 2, it is a parallel plate view factor is 1 right. So, therefore so, F 1 3 equal to F 3 2 equal to 1 and A 1 equal to A 3 equal to A 2 ok.

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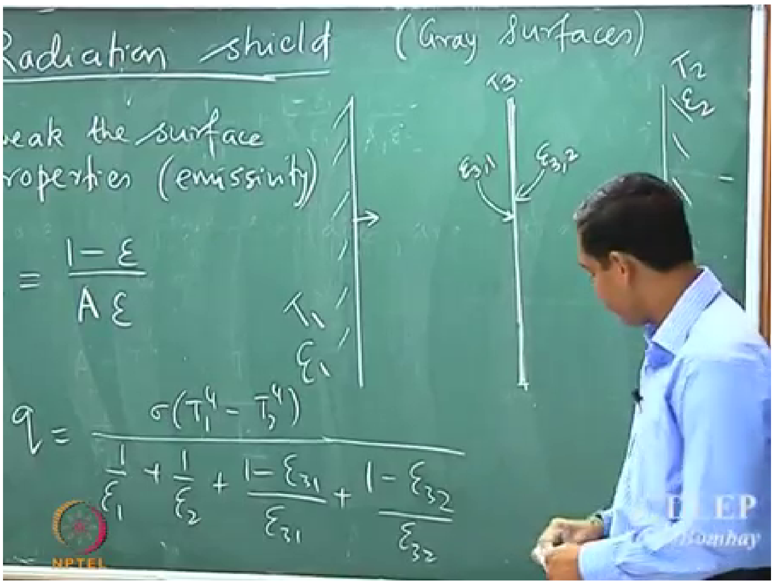

So, if you plug in all these factors, you will find that the net radiation exchange q is given by the sigma T 1 to the power of 4 minus T 2 to the power of 4 divided by 1 by epsilon 1 plus 1 minus epsilon 3 1 by epsilon 3 1 1 minus epsilon 3 2 by epsilon 3 2 ok, I mean that is the net radiation exchange between the 2 surfaces 1 and 2.

So, clearly you can see it by tweaking epsilon 3 1 and epsilon 3 2, you can actually minimize the net radiation exchange between 1 and 2. So, that is the concept of using this radiation shield all right. So, I think it is a good point to stop. So, there are a couple of small topics and radiation, that we will finish in the next lecture. So, 1 is the reradiating surface and 1 is the effect of the next one is the effect of medium. So, far we never considered. What is the effect of medium that may be present between the 2 surfaces? So, we will try to quantify that in the next lecture.