Heat Transfer
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Lecture – 47
Surface adsorption

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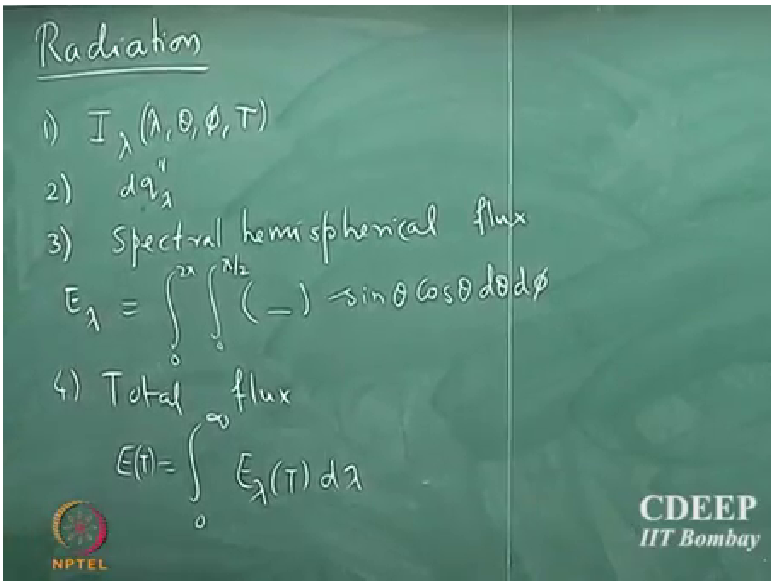

Let us get back to what we are doing; so, just a little recap for the next five minutes. So, the first thing is that we define intensity of radiation and we define intensity which is going to be a function of the wavelength at which the emission or irradiation occurs and of course, it is going to be a function of the position and temperature. So, that is the first definition we had and then we defined what is the, that is, the flux of radiation emitted or received etcetera at a certain wavelength and note that these flux is defined based on the if it is an emission, it is defined based on the area of the surface which is emitting and if it is receiving it is based on the area of the surface which is receiving radiation.

And, then we define the all this huge integrals spectral hemispherical etcetera hemispherical quantities and that is pi by 2, whatever is that intensity quantity multiplied by sine theta cos theta d theta d phi, where theta and phi are the angles in the 3 dimensional quadrate system and then we define total then we define total flux because it is a function of the wavelength. So, we need to define, so, if this is called as let us say E lambda, then for emission then you have E lambda T, E lambda that gives you the total flux, that is E, ok and this is only a function of temperature.

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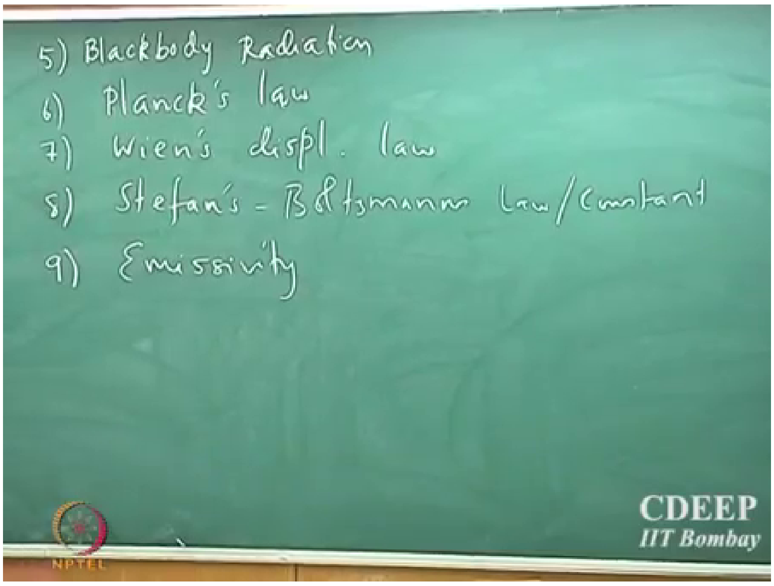

And, then we looked at we looked at blackbody radiation and we looked at some of these laws on Stefan, no, it is a Planck’s law. It is a Planck’s law and, in fact, Planck’s law is the constitutive relationship similar to what we saw as we Fick's law or Fourier’s law in heat transport and Fick's law in mass transfer. Planck’s law is the fundamental law which describes radiation and from that we found the Stefan Wien’s displacement law and we also found Stefan’s – Boltzmann law slash constant for describing radiation properties that is what we call, yes.

Student: (Refer Time: 03:44).

Hm.

Student: (Refer Time: 03:44).

Ok. So the question is what happens when you integrate from 0 to pi? If it is a surface emission you cannot do that to start with. That if it is a volumetric emission, that is a different story; we will deal with it later. In volumetric emission that is correct you will have to integrate it everywhere and we will see because there you have absorption and you also have transmission. So, that we take care of it being non zero. So, in this case if it is a surface emission you cannot integrate it with 0 to pi, it has to be 0 to pi by 2 on the angle theta because it is a surface emission you cannot see the other surface you cannot see the other side of the surface it is only seeing the top side. So, you have to integrate only in the upper hemisphere. Any other question?

All right, so, we going to and we also looked at we also looked at definition of emissivity, so, that is where we stopped in the last lecture. So, we are going to take it forward from here today.

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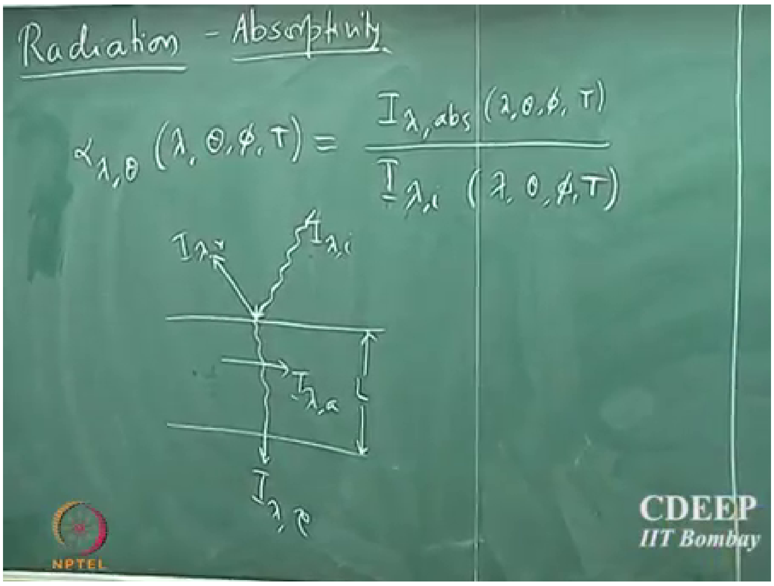

So, we initiated discussion in the last lectures for definitions of absorptivity. So, that is where we are going to start. As observed in the last lecture the purpose of such definitions is that in a real surface, so, note that blackbody is a is considered as a standard. So, if you want to describe the radiation emission from real surfaces it comes very handy if you know these parameters these intrinsic properties such as emissivity and absorptivity. So, note that emissivity is described based on the corresponding blackbody radiation while absorptivity is defined based on the total incident radiation. We are going to see in today's lecture how to characterize it for a for a real surface.

So far we never in radiation the last two lectures we never looked at the actual real surface and today we are going to see how to actually characterize some of the real surface properties, all right. So, so alpha is the symbol which is given for absorptivity which is in line with the nomenclature given in your textbook, that is going to be a function of the wavelength and that is going to be a function of the position as well, that is defined as the ratio of the intensity of radiation that is absorbed which is a function of position and the wavelength divided by the total incident radiation that is received by that surface ok.

Now, supposing I draw a surface here. There is a certain amount of radiation that is received by the surface. So, that is an incident radiation. So, there are 3 possible ways in which the radiation can be split; one is it could be reflected some amount of radiation can in principle be reflected and if it is a finite surface of let us say thickness L, then some of it could be transmitted if I say tau for transmission and some of it could increase will be absorbed and so whatever incident radiation that comes in to a surface can actually be absorbed or reflected or transmitted. So, if the incident ray if we know what are the total incident radiation then the absorptivity is simply defined as a local absorptivity is simply defined as the ratio of the amount of radiation or intensity of radiation that is absorbed divided by the total incident radiation.

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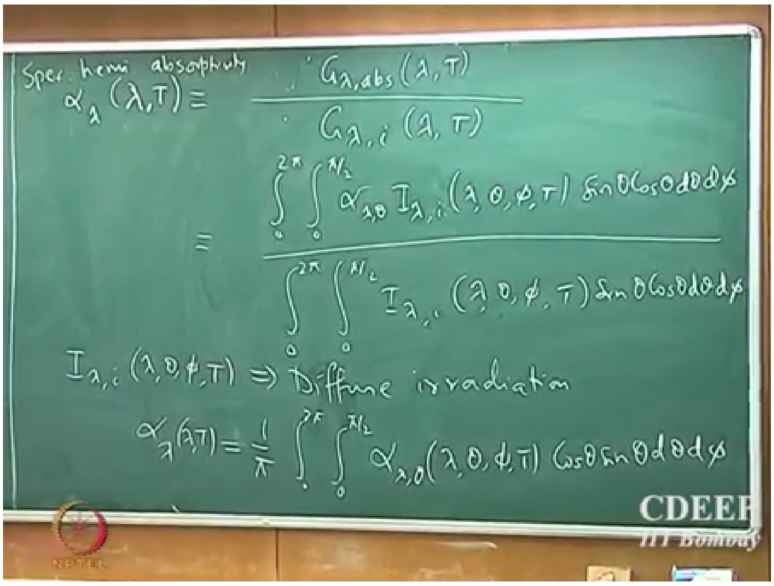

So, once again we can define things like spectral hemispherical etcetera because it is positional dependent and wavelength dependent. So, we can define, we can define quantities called the spectral hemispherical absorptivity. So, this is spectral hemispherical absorptivity and that is defined as what is it, what will be the definition based on what we have seen in the last lecture and before, be the ratio of.

Student: (Refer Time: 08:53).

Right. So, it is the spectral hemispherical. So, that is given by G lambda absorb that is the spectral hemispherical radiation, irradiation that is absorbed by the surface divided by the spectral hemispherical that is incident to that surface. But we know from definition right of the spectral hemispherical quantity this is 0 to 2, pi by 2 absorbed sine theta d phi divided by d theta, but from the definition of absorptivity we can replace the incident absorptivity in terms of it is the incident intensity of absorption with the absorptivity which is an intrinsic property of that system. So, that we can rewrite as, so, we can simply replace this as alpha I lambda i into alpha lambda theta. So, that is the absorptivity multiplied by the incident irradiation.

So, supposing if the incident irradiation if this is a diffuse irradiation it means that irradiation that is received by the surface is same in all directions in the hemispherical coordinates at every direction in the hemisphere the incident irradiation is the same. So, in which case what will this be, what will be alpha lambda 1 by pi.

Student: (Refer Time: 11:29).

So it will be 1 by pi. So, I lambda i will come out because it is independent of theta and phi. So, that will cancel out and the integral of the sin theta cos theta d theta d phi is nothing, but solid angle of a hemisphere, so, that will be 1 by pi integral 0 to 2 pi alpha d theta d phi.

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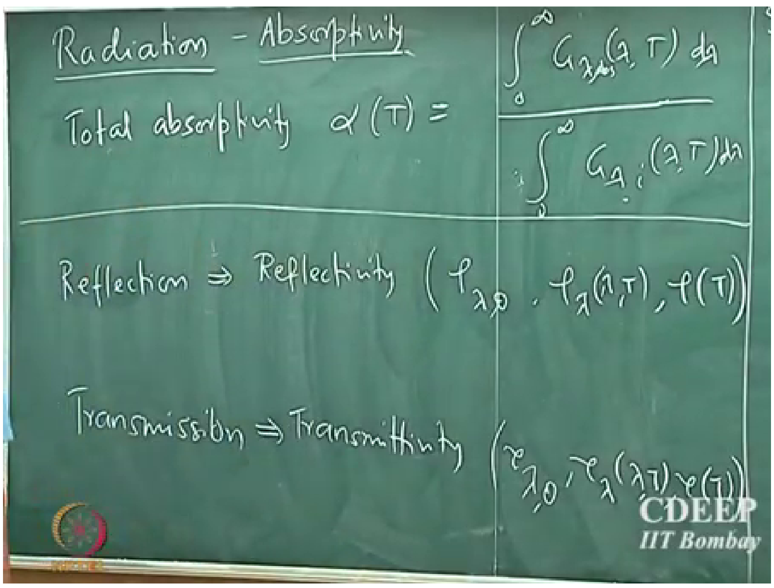

Similarly, one could define what is called the total absorptivity. Total absorptivity and that will be alpha which is only a function of temperature, once again by definition will be integral G lambda divided by integral 0 to infinity absorbed. So, that is the definition. So, so once you I am sure most of you would have practiced how to write these integrals and understand what these integrals are. So, you have to practice a lot more to get a feel of how to write these spectral hemispherical quantities because anytime you deal with any radiation problem you going see this all over the place and in fact, maybe after this lecture I will probably not even write these spectral hemispherical integrals when I say it is a subscript lambda it is understood that it is spectral hemispherical, if I write simply alpha without a subscript it will be total quantity.

So, you must understand what these integrals are as quickly as possible otherwise it will be very difficult to follow what is happening in the class. So, so, we said that in a surface that can also be reflection and that can also be transmission, right. So, one could in principle similar to absorptivity one could define quantities called reflectivity and transmitivity. I am not going to write all these gory integrals again. The reflectivity which is defined as which is the symbol that is used is rho, so, lambda comma theta means it is the local reflectivity rho of lambda is the spectral hemispherical reflectivity which is only a function of lambda and temperature and rho of T is the total reflectivity which is only a function of temperature.

Similarly, one could define what is called the transmitivity, tau is the symbol that is used for transmitivity, once again you can define local transmitivity, so, only a function of lambda, which is the spectral hemispherical transmitivity and total which is only a function of temperature.

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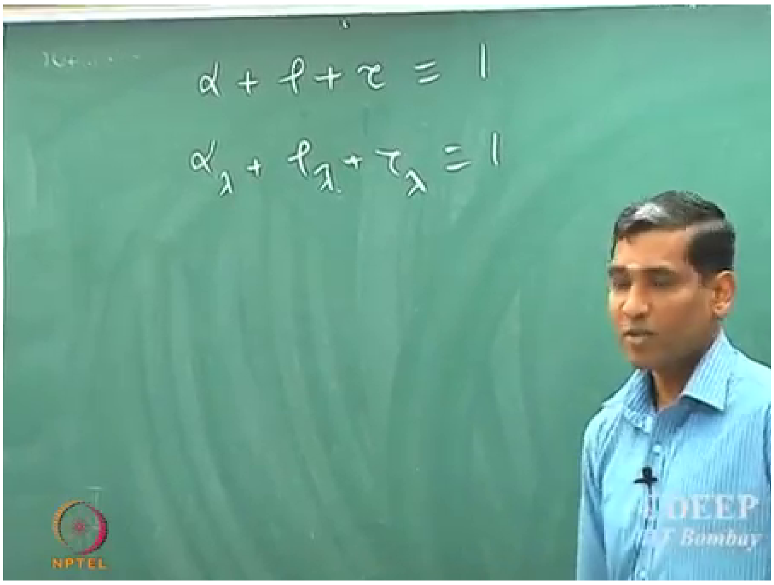

So, what is alpha plus rho plus tau, total absorptivity plus total reflectivity plus total transmittivity.

Student: (Refer Time: 15:12).

Yeah?

Student: (Refer Time: 15:14).

Hm?

Student: (Refer Time: 15:16).

Is 1. Because all the ratios are defined based on the incident intensity, so, the only three possible ways by which the irradiation can be split is these three modes and therefore, this should be equal to 1. Similarly, that is also equal to 1, all right. It is very easy very straightforward to see this. Any questions so far? All right.

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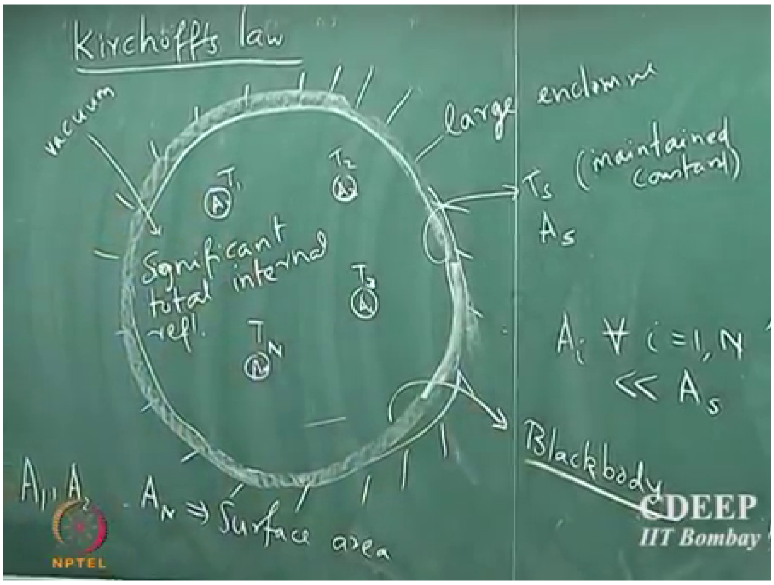

So, we going to move to the next topic which is basically it is Kirchhoff's law. So, just like how we wrote energy balance then we discussed conduction. So, Kirchhoff's law is actually the first step towards quantifying radiation in any real surface. So, we had looked at blackbody radiation in fact, we are going to start by looking at blackbody radiation Kirchhoff's law actually relates to blackbody radiation, but eventually what you will see what comes out of this law is essentially some quantifying aspects of the real surface.

So, note that real surface blackbody is an idealization and there is no surface which can emit more than blackbody, fine. So, it is important to come up with characterizing principles of blackbody and that will help us to understand or quantify the radiation from a real surface, simply because we have defined emissivity which is actually ratio of the emission from a surface with respect to the black body. So, if we know black body we are done fine.

So, what Kirchhoff's law would do is, supposing you assume that there is a large enclosure that is a large enclosure and let us assume that it is adiabatic. There is no heat that is being lost and let us also assume that there is somehow some heating is done to this large surface, such that the internal temperature is maintained constant, so, internal temperature is isothermal. So, it is a large enclosure and the surface internal surface temperature is maintained constant and let us assume that it is vacuum conditions inside we have not dealt with what happens if it is non vacuum. We will see that towards the end of this radiation section how to incorporate the effects of media.

So, let us assume that there are let us say n objects which are suspended. There are n objects which are suspended inside these this large enclosure and this surface area of each of these is A 1. So, that is the surface area. So, A 1, A 2 these are the surface area of the objects and supposing if the surface area of the large enclosure is A s and let us assume that A i, for all i going from 1 to n is much smaller than A s, ok. So, it is just a mathematical notation for all.

So, let us assume that the surface area of all the n objects which are suspended inside this enclosure is significantly smaller. So, these are all minuscule particles which are actually floating inside this large enclosure and let us say that the temperatures are T 1, T 2 etcetera up to T n. So, that is the temperature of the surface cleared everyone.

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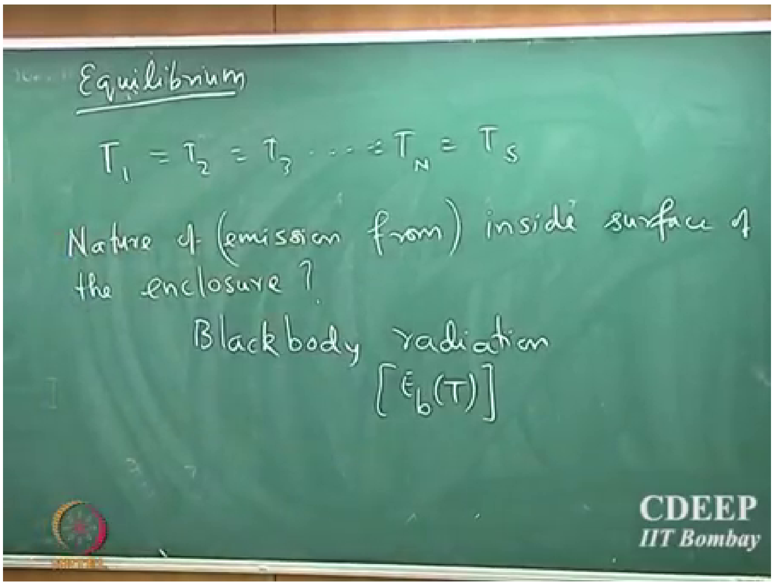

Supposing if we wait for a long time, wait for a long time and the system has achieved a certain equilibrium.

Student: (Refer Time: 20:04).

The exterior is adiabatic.

Student: (Refer Time: 20:09).

Supposing, I say that there is a; this a wall here and I know how to heat it I put an electrical wire inside and heat it, I can maintain a constant temperature inside. Why is that a problem? I can always do that.

So, let us say. So, the purpose of saying it adiabatic is that there is no heat loss from the surface to outside that is all it is a complete system. So, let us say at a long time if the system achieves in equilibrium, what will be the temperatures of these small objects inside? What will be, the what will be the temperature? It will be T s, right? Because the only temperature which can be maintained is T s. So, T 1, T 2, T 3 etcetera that will be equal to the temperature of the surface at equilibrium.

Now, what will be the nature of the inside surface of the large enclosure or let us say nature of emission let us say. Nature of the inside surface or let us say nature of emission from the inside surface, what will it be, at equilibrium? Yeah.

Student: (Refer Time: 22:01).

Only.

Student: (Refer Time: 22:04).

Yeah, let us assume that the temp there is only radiation process, let us not worry about conduction right now. Blackbody is a diffuse emitter, it absorbs everything. What is the object which is closest to a blackbody approximation?

Student: (Refer Time: 22:25).

So, you have a large enclosure with a small pinhole somewhere and that body behaves like a back body because there is a significant internal reflection of radiation and so, everything which comes in is actually kept inside. So, what you see here, this surface is very similar to the approximation that we made for a blackbody. So, whatever emission that comes from, so, because the surface area of all the objects that we have considered is significantly smaller than the surface area of the enclosure there will be significant total internal reflection inside the enclosure and therefore, the inside surface of this enclosure is going to behave like a blackbody, that is a fair assumption to make.

So, it is going to behave like a black body and therefore, the emission that comes out of the surface is a it is a blackbody radiation, fine. So, the answer is and that is, so, the total blackbody radiation is going to be E b, it is only a function of temperature. So, note that I have already skipped the integrals gori integrals. So, when I do not put lambda here and angular dependence it means it is a total quantity.

Student: (Refer Time: 24:14).

There is no need for a pinhole, because these objects they behave like that, these are real surfaces. So, there is emission that is going to occur from these objects. So, note that in the blackbody approximation we said there is a pinhole and some radiation comes through the pinhole and it gets totally reflected inside and this these objects exactly do the same. In a blackbody approximation the emission from that hole is only to the surroundings, it does not mean that there is no emission inside. Whatever is emitted inside is also absorbed. So, there is emission and every location of the surface it is just absorbed in all other locations as well that is what you mean by total internal reflection right. So, in the same way here whatever little is emitted only very small quantity is actually intersected by these object. It is very similar to the pinhole example that we had before.