Conduction and Radiation

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Lecture No. # 18
Problems on Reflectivity and Transmissivity

So, we looked at in yesterday's class. So, there can be surfaces or media, which are non-opaque, which allows some radiation to pass through; and now, when radiation passes through such non-opaque media, generally, they participatory in nature, because there can be emission, because of the temperature of the medium being greater than 0 Kelvin, according to (( )) law; it can also absorb, it can also scatter; scatter is, scattering is basically reflection, but scattering is from the volume. So, scattering is of two types, there is in-scattering, that is reflected inside, and out-scattering is that which is going out. So, the net will be scattered, whatever is scattered out minus whatever is scattered in. So, this scattering could be function of wavelength; in the scattering, should be of, can be also be a function of the angle; if it is not isotropic. So, if you have anisotropic spectral spectral scattering and all that, and so, the, what will determine the scattering? Scattering will depend on, scattering will depend on what, apart from angle and this thing.

For example, surface (( )) volume, for example, in the atmosphere it it should depend on the size of the particle. So, the scattering by a dust particle will be different from scattering by a water molecule, which will be different from scattering from ice, and these ice can be of different shapes, we need not always assume that it will be spherical; if it is oblate and if it is non-spherical, then the scattering theory becomes very very involved. So, radiation heat-transfer people, as well as, optics people and physicists have worked out extensive theories to handle scattering. So, this called Mie scattering theory, Rayleigh scattering theory and so on. So, there are algorithms which have been developed, we call the t-matrix algorithm and all that, which can handle scattering. So, scattering is very involved, if you are doing such kind of calculations, you are in the forefront of radiative heat transfer research, you are able to handle scattering in molecules, scattering in the atmosphere, and all that.

Now, we look at some simple problems. So, that whatever concepts we have learned in yesterday's class and whatever definitions, we have learned, essentially, they are reinforced. Problem number 15, please take down this spectral distribution of alpha, as well as, rho. So, only one wavelength is given, that is 1.5 micrometer, alpha lambda and rho lambda are given.

Once you are through, you tell me, we will, I will start dictating the problem. Problem number 15, the spectral absorptivity alpha lambda, the spectral absorptivity alpha lambda, the spectral absorptivity alpha lambda and the spectral reflectivity rho lambda, and the spectral reflectivity rho lambda for a diffuse surface are given in the figure, for a diffuse surface are given in the figure, alpha lambda and rho lambda for a diffuse surface are given in the figure. A) Sketch the spectral transmissivity distribution, a) sketch the spectral transmissivity distribution, a) sketch the spectral transmissivity distribution.

B) If solar radiation, b) if solar radiation with capital G, if solar radiation with G equal to 800 watts per meter square, 800 watts per meter square. So, if solar radiation with G is equals to 800 watts per meter square and spectral distribution, and spectral distribution corresponding, to a blackbody, and spectral distribution corresponding to a blackbody at 6000 Kelvin, blackbody is 6000 Kelvin is incident on the material. Determine the fractions of the, determine the fractions of the radiation, determine the fractions of the radiation, determine the fractions of the radiation that are absorbed, reflected and transmitted by the material, that are absorbed comma reflected and transmitted by the material. So, this is basically a fundamental problem, where we move from one property to another property, and this is for the first time, you will be calculating tau from tau lambda, in this class, in this course. Please start.

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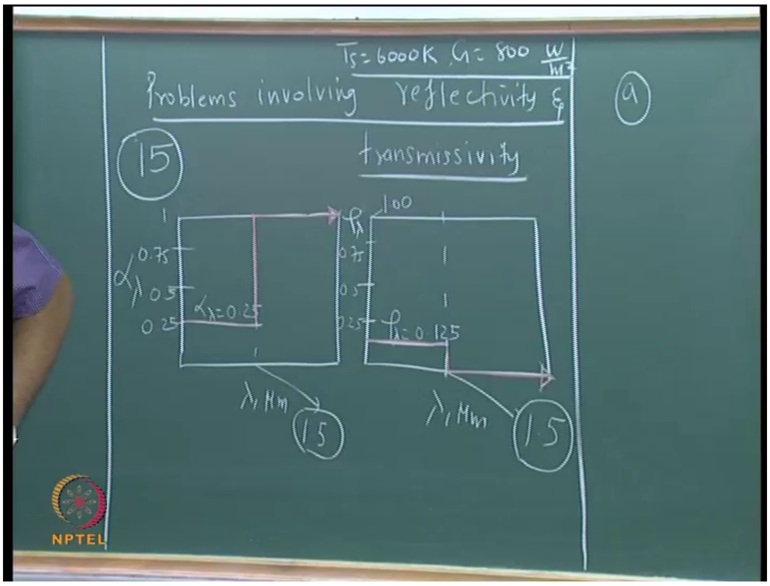

So, for benefit of people who came late, for a surface, I have given alpha lambda and rho lambda. So, solar radiation is falling on it, the people who came late, alpha lambda and rho lambda are given, incident radiation 800 watts per meter square irradiation, sun temperature, 6000 Kelvin, you can take; sketch tau lambda and get alpha, tau and rho and hence find out the fractions. ah

Student: (( )).

Ah.

Student: (( )).

No, alpha lambda plus rho.

Student: And alpha lambda (( )).

Which one?

Student: (( ))

Total will be also equal to 1, that can be proved from the derivation itself .

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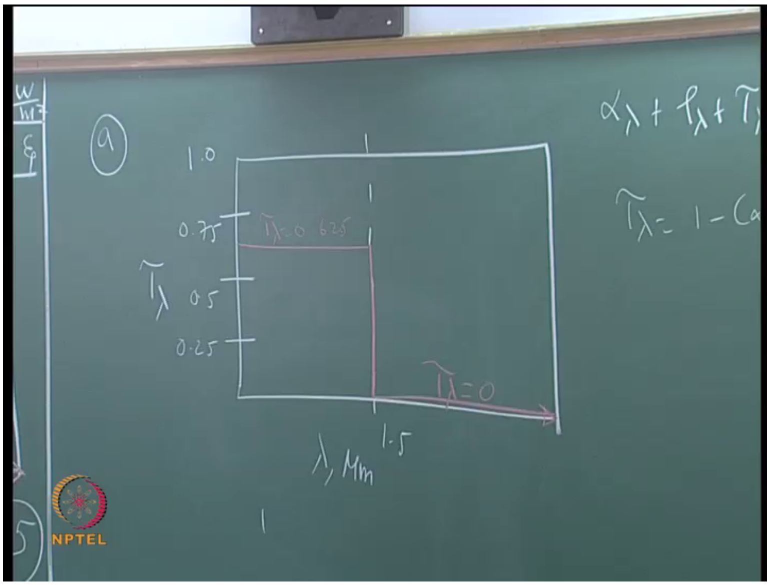

So, the first part of the question is, the first part of the question is, from these two distributions, we have to get the distribution for tau lambda. So, the basic equation use is, this comes from energy balance; this is with regard to the incident radiation, do not worry about the emission, do not get confused, emission is a separate story, tau lambda . So, up to lambda equal to 1.5, from 0 to 1.5 what is the story? This is 0.25, this is 0.125, 0.375, will be the sum, 1 minus 0.375 is?

Student: (( ))

0.625. So, where will that fellow come? Here, after that E is already 1, this 0, therefore this, got it? We do not have to determine the transmissivity, but at least two properties must be known.

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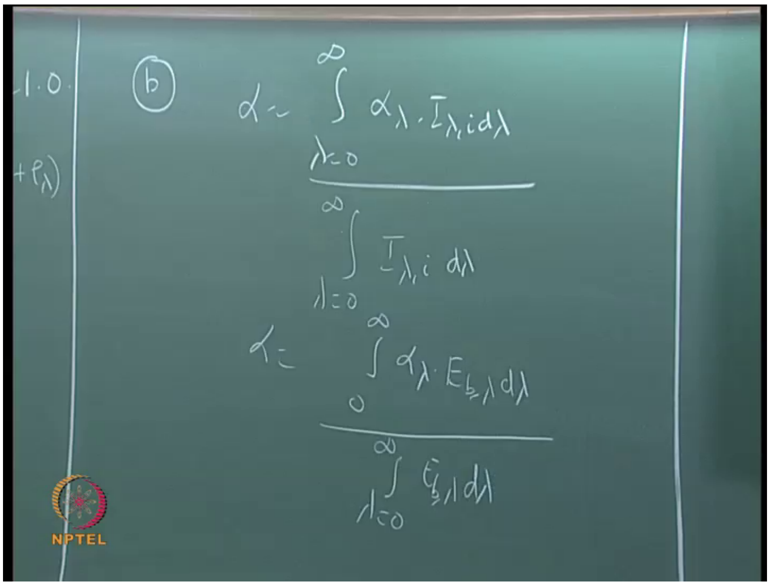

Now, we will go to part b. What is part b? We have to get the individual properties. So, I have to get alpha, I have to get at least two of the three properties. So, I just cannot get rho and say that, tau equals to 0 and; but I know the F function, from the F functions charts, if I apply it once, I can calculate two properties. So, first, we will write the formula for alpha. I can also write this as…

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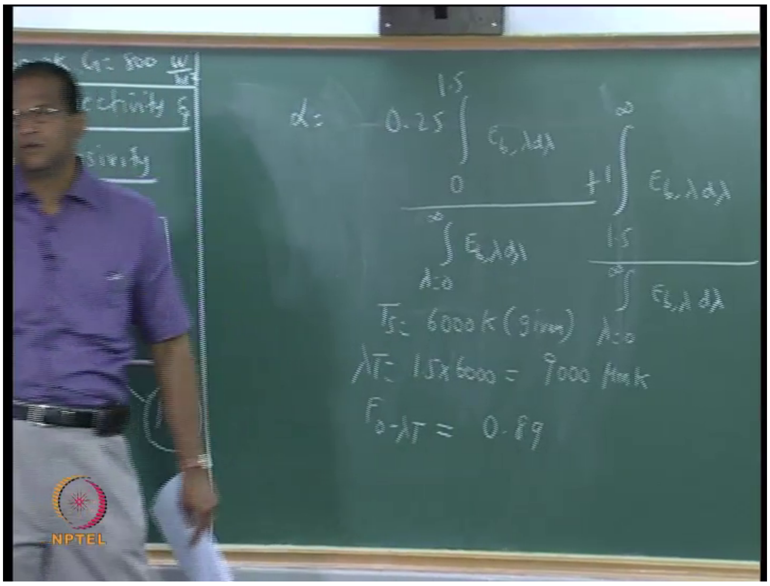

Now, we will keep this. I will start erasing from here. So… Now, to get this 0 to 1.5 divided by 0 to infinity, what do you use? I use F charts, or F function chart. So, T is already given, but T equal to 6000 Kelvin, what is this?

Student: (( ))

0.89

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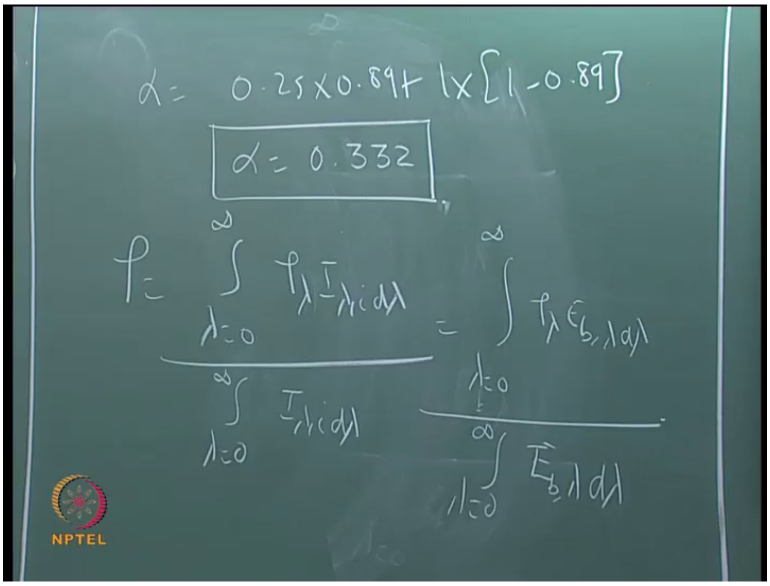

Once you have this; so, alpha, is it correct 0.332. So, the absorptivity of the surface is 0.332, what absorptivity is this? Solar absorptivity. If it is absorbing radiation, let G be 800 watts per meter square, but if it is coming from some from source at some other temperature, it will change; because, it has got spectral characteristic, that is why, we are able to employ, what are called, selective surfaces. What is a selective surface? A selective surface is one which will have poor emission in the infrared and high absorptivity in the solar part of the spectrum. For what for what application, do we want the surface like that?

Student: (( ))

For a flatbed flatbed collector, we want high solar absorptivity and poor emission. It is possible to have some surfaces like this; but if it is a sun control film, in this room and those windows, you want to put a sun control film, or in your car, you want to reduce the radiation and all, then it is a transmittance, we are transmissivity that we are talking about. By the way, we have introduced a quantity as reflectivity, absorptivity and transmissivity. Some authors, if you look at some books, they will say reflectance, transmittance, and absorptance; it is essentially, the same; it is basically a nomenclature, there is no difference with. So, the transmissivity of this glass, what happens is the transmissivity cannot be changed, the sun control film, we will see in the next problem; but the range of the wavelength range a band in which it will transmit is different; it will cut out certain wavelength, it acts like a pass filter. Therefore, overall you will get of the solar radiation, certain portion, certain portion is cut; they claim know, 40 percent cut, 50 percent cut and all that; but that you can see that actually this thing is coming down, but from inside you can see outside, but from outside you cannot see inside.

Now, we have calculated the alpha. Similarly, rho… Do not quickly declare that rho is equal to 1 minus alpha, then you are doomed. There is transmissivity in this problem.

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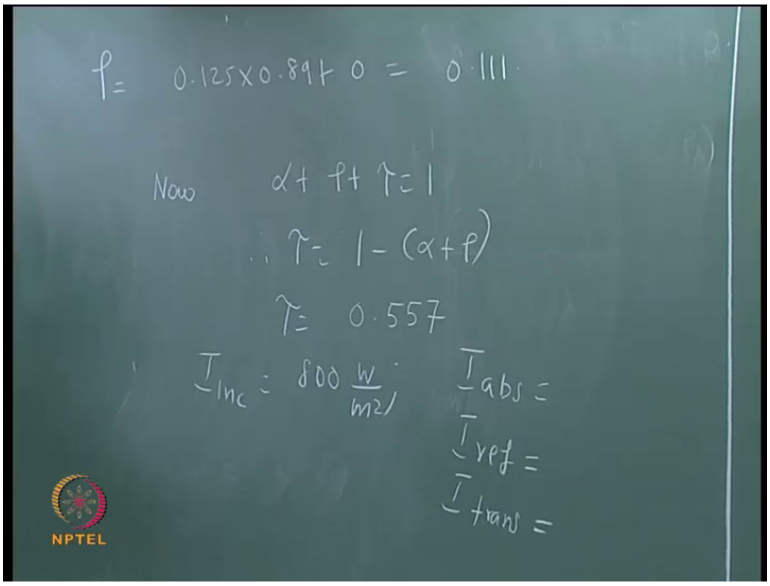

So, rho, what was rho here? Is it correct? How much was it?

Student: (( )).

So, can u fill up this? In fact, I called it as G, I asked you only the fraction, but it is good to put everything in terms of watts per meter square, nothing wrong in doing that; because, already by determining alpha, rho and tau, we got the fractions; if you want, you rework the problem. Vikram, you finished? What is a I absorb?

Student: (( ))

I reflector.

Student: (( ))

88.8? And I transmitted?

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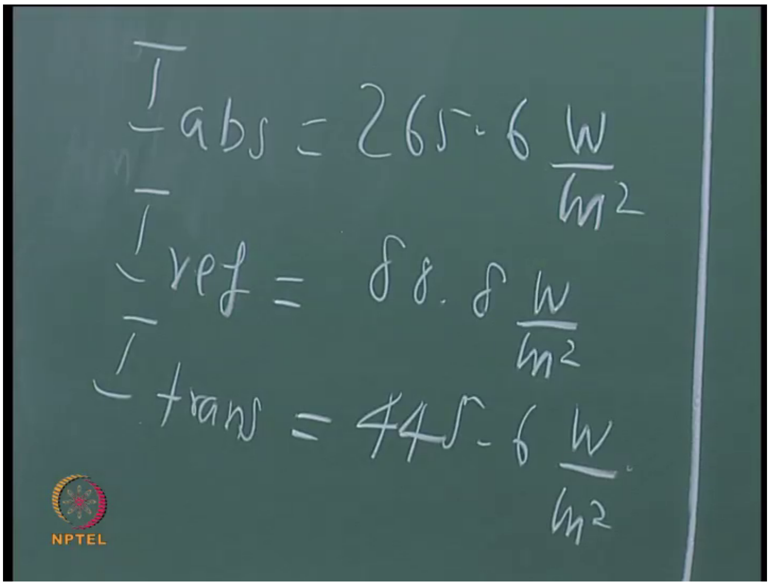

So, I can develop the problem further and all that, but I will leave it here, I can say part c, if the surface, if the surface is at a temperature of 325 Kelvin, what is the emissivity of the surface? Part c; part d, what is the net radiation heat transfer on the surface? We can keep on developing the problem. But now, it is sufficient for us, because we know how to calculate tau. Now, we will solve the problem where we consider two surfaces, plain glass and tinted glass. So that you are able to appreciate, you are, you are able to evaluate whether there is any benefit of using tinted glass; they are also claiming no (( )) glasses also you have tinted glass photo chromatic and all that right. Let us see, whether there is any benefit in doing that, is is this problem, is this clear?

Student: (( )).

G 800 and which is equivalent to this thing; in case that, how else you want to do?

Student: (( )).

You are thinking that, apart from this, something is there. No, even if I tell blackbody at 6000 Kelvin, how will you actually calculate? How will you actually calculate? You want to integrate from 0 to infinity? That is 1353 watts per meter square, that is coming from the this thing and then it calls into the atmosphere and this thing, so many stories are there, for that. That does not exactly reach, blackbody weight 6000 Kelvin, then from there, you can calculate the solar constant, from there atmosphere, so many things are there. He always ask, he is having a very important doubt, many of you should have got this doubt and it must have made you uneasy and all that; but luckily, somebody has opened it up. Basically, there is nothing wrong in our, first of all there is nothing wrong in that question, but it is my responsibility to clarify, we are not saying that it is actually the radiation actually from a blackbody at 6000 Kelvin; the nature is corresponding to the blackbody at 6000 Kelvin, if I know 800 watts per meter square, that the variation the variation is like that, since I am using only the F function chart, I am using it in the numerator and the denominator to find out what is the band between lambda 1 to lambda 2, what is the fraction.

So, to the to the limited extent that using this information I will be using the F function chart this I am it is for okay me to consider this source to be a blackbody at 5800 Kelvin, but it is quite different from actually the irradiation coming from blackbody at, the nature of the distribution is like that, qualitatively with lambda the irradiation varies like this. So, it helps me only to calculate alpha, rho and all that; but if you want to know, how much is reflected, how much is transmitted and so on, I need to know, how many watts per meter square is incident, are you getting the point? We judge the information that there is a blackbody at 6000 Kelvin, I am it will lead to erroneous answers; I may get 1353 or something, for that I require other information; what else do I require? The diameter of the sun, the diameter of the earth, the distance between, so many things I require; why do you want to get into all these? If I do all these, you will get that 1353 that is a solar constant, but that 1353 is just which is entering outside the atmosphere then so many things are happening because of carbon dioxide, water vapor and so many things. And same thing with the transmissivity also, this blackbody story helps us to use the F function chart and get the property.

Now, we will solve another interesting problem; problem number sixteen, the spectral transmissivity, the spectral transmissivity of plain and tinted glass, the spectral transmissivity of plain and tinted glass can be approximated as follows.

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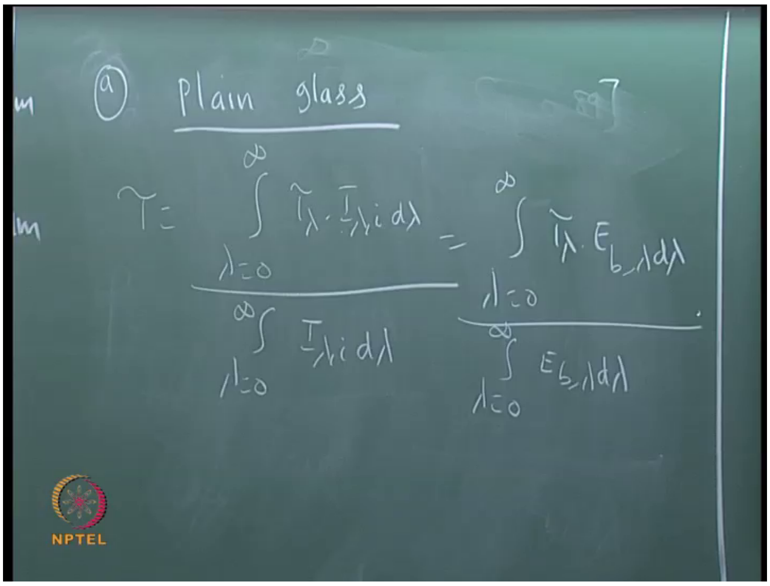

Plain glass, it has transmissivity of 0.9, in the band 0.3 to 0.25 micrometer. What about this tinted glass? Same thing. So, tinted glass is also 0.9. What is the big deal? Why everybody is trying to sell the tinted glass? Why is a tinted glass more, more expensive?

Student: (( )).

The range must be more or less transmitted, it should, it should have a same Transmissivity over a narrow spectrum narrow band. In fact, it has only between 0.5 to 2. So, the spectral transmissivity of plain and tinted glass can be approximated as given on the blackboard; outside the specified wavelength ranges, outside the specified wavelength ranges the spectral transmissivity is 0 for both the glasses; outside the specified wavelength ranges the spectral transmissivity 0 for both the glasses. A) compare the solar energy that could be transmitted; A) compare the solar energy that could be transmitted through the two glasses, do not get confused, though it is not one after the other; compare the solar energy that could be transmitted through the or through the glasses, hang on; B) with solar radiation incident on the glasses; with solar radiation incident on the glasses, compare the visible radiant energy; compare the visible radiant energy that could be transmitted; compare the visible radiant energy that could be transmitted by the two glasses; there are four parts to this problem; because, part a two calculations one for plain and tinted part b two calculations for plain and tinted. So, please start solving, I will take attendance and we will complete this problem, and with that story of the property is over. Shall we start solving?

So, first a plain glass. So, tau, correct, but I have, I do not know, I how I lambda i varies with lambda, but I have equivalent information, what is that information?

Student: (( )).

I lambda i is qualitatively is equal to that irradiation from a blackbody at 5800 Kelvin, that is the suns temperature.

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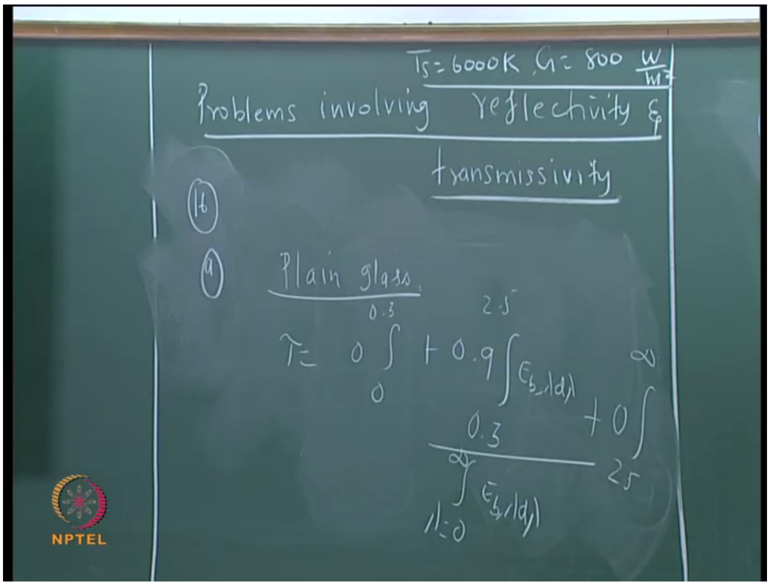

Therefore now, I can take, I can get rid of this. So, 0 to 0.3, I do not have to worry about that the integral and all that. Now, to do this... So, why did we take T as? I have taken 5800, we will take, everybody, how many of you have taken 6000?

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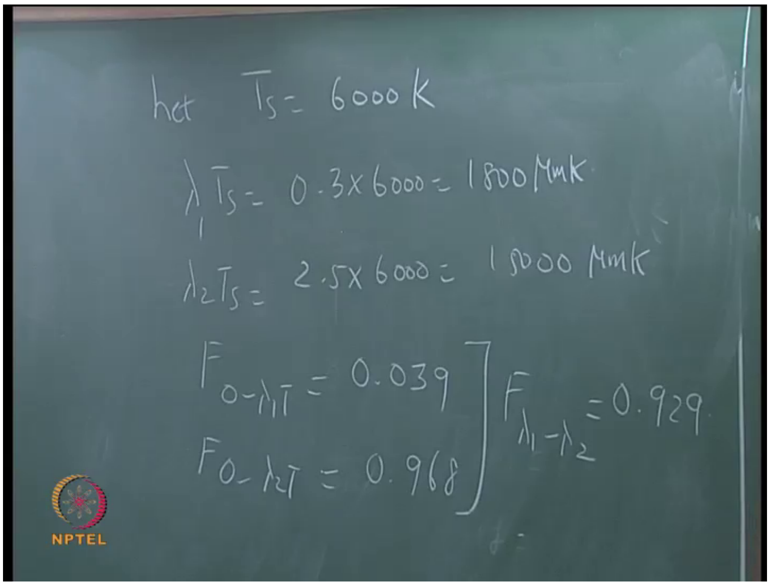

So, 6000 is easier no? But the correct temperature is only 5800. Let T s be, we have to get 0.3 lambda 1, right? **0** to lambda 1. Sampath, how much is it? 0.03. Therefore, 0 to lambda 2, 929? 9 to lambda 1 to lambda 2? 929. So, what is tau? 0.84 or 86?

Student: 84.

84.

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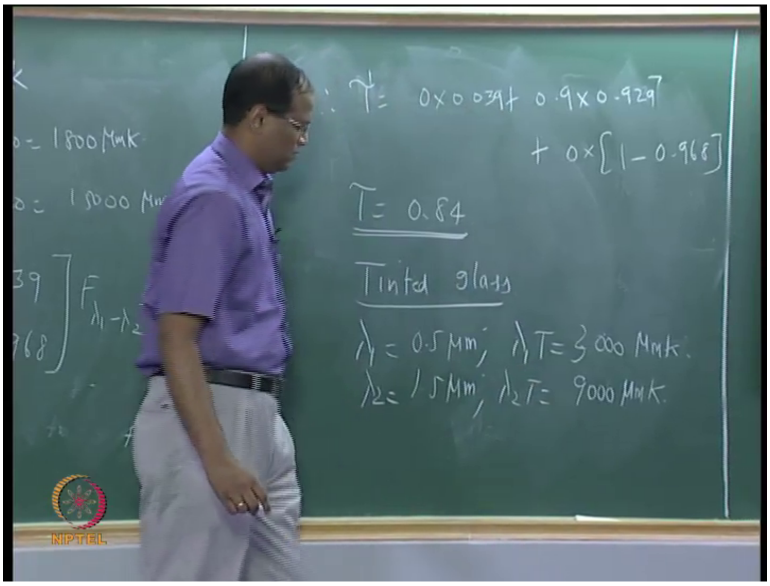

I wrote it with the purpose so that you would not get confused. 1 minus into 0 and all that, I made it complete; second time alone is important. So, tau equal to 0.86.

Student: 5.56, this one 0.8, 0.84.

So, plain glass, how much of incident energy is transmitted? 84 percent is a lot, too much; that is why inside the glass surface, they say glass house and all that, you put a glass and they can grow plants, even in cold places, glass is terrific transmitter, that you can see, right? Because you you you you can feel it, right? Now, what is a story? The tinted glass, I know that, because that the wavelength range in which it permits radiations to be transmitted is smaller, narrower compared to this, I expect it to behave better. So, let us say, tinted glass. Now, lambda 1 is what, for tinted glass?

Student: (( )).

No no no no, lambda 1? lambda 2? 1.5.

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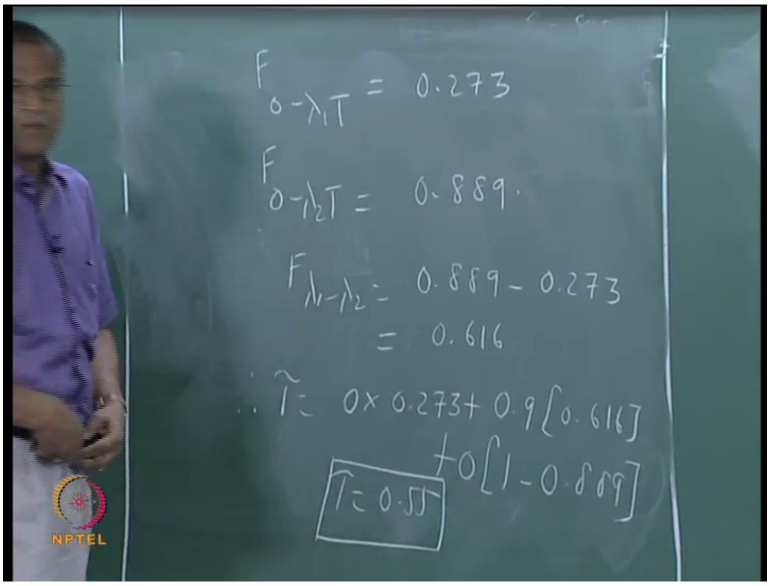

How much is it? 0.273.

Student: (( )).

I am writing writing the formula in full; so that we do not, so that we know that, we are not making any mistake. Now, tau is 5 5? So, the incident radiation is 800 watts per meter square;

for example, the incident radiation, let us say incident radiation is 1000 watts per meter square, the plain glass will allow 800 and 840 watts per meter square to pass through; this fellow will allow only 550 watts per meter square to pass through; out of every 1000, 290 watts per meter square are stopped. So, there is an advantage of 30 percent, that is clear 85 55. So, it cuts out the radiation by?

Student: (( ))

30 percent. It depends on which way you look at, but rough calculation is out of incident is 30 percent, 30 percent it will cut, that is why here 3 m, 3 m sun control film barware, sun control film and all that, they set **30** percent, 40 percent and all that. If you paste it some 30 percent, you will, you will get some benefit, right? This is increasingly relevant because now, the current trend is to have glass and steel structure everywhere. We are copying the west, we are raping the west, that concrete and this thing, wood anyways out, wood, aluminum, these things slowly, it is only glass and steel everything. So, it is very easy to stone out a building now. So, because of, because of this no, it happens no. So, all these Bangalore people are always worried, whenever there is something happening in Bangalore, all these software companies are all having glass and steel structure, they are not very secure, very easy, few only few stones are required. So, therefore, if you want to reduce air conditioning load, you have to look at some energy solutions like this. It is only the first part of the story.

Let us do the second part, (( )) the solar, what about the visible part of the spectrum? Even the city buses, all these Volvo buses, there is so much of glass. So, much of glass in the bus. Nowadays, we see the front fully, side, everywhere there, it is glass. So, air conditioning load and all that, you have to work out, work all these out.

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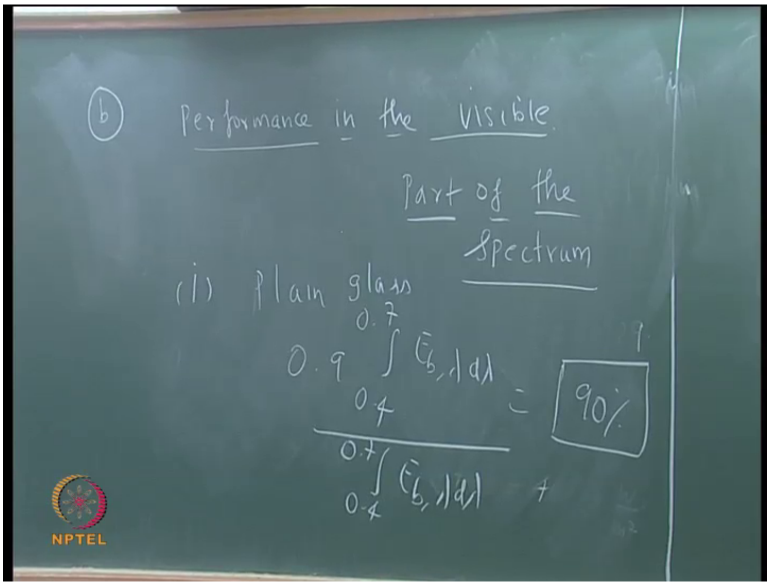

Now, part b. So, performance in the visible part of the spectrum. So, that is something we have to see. So, visible part of the spectrum is 0.4 to 0.7. So, for part a, it is very easy; part a, it is very easy. How much is transmitted?

Student: (( )).

No, for the tinted glass, I am sorry for that. So, no for the plain glass.

Student: (( ))

What 0.84?

Student: (( )).

Ah 90 percent of the visible radiation is transmitted, because within the visible band its tau is 0.9; 0.8 is a total part of the spectrum, are you getting the point? When I write it out, it will become clear. 1) Plain glass. What is the ratio we are looking at? What is a total radiation corresponding to 0.4 to 0.7, that is by denominator? Denominator is not 0 to infinity, if it is 0 to infinity, you already solved man, first part; if you consider only the, if you consider only the visible part of the spectrum, denominator is also 0.4 to 0.7, numerator is 0.4 to 0.7; but fortunately for us, there is one value 0.7; therefore, 90 percent. So, the visible part. So, it does not cut out any this thing, if there is lot of day light outside, there is day light inside, also 90 percent of the lighting available outside is there in inside; but the second fellow does a lot better, can you work out the value for second one?

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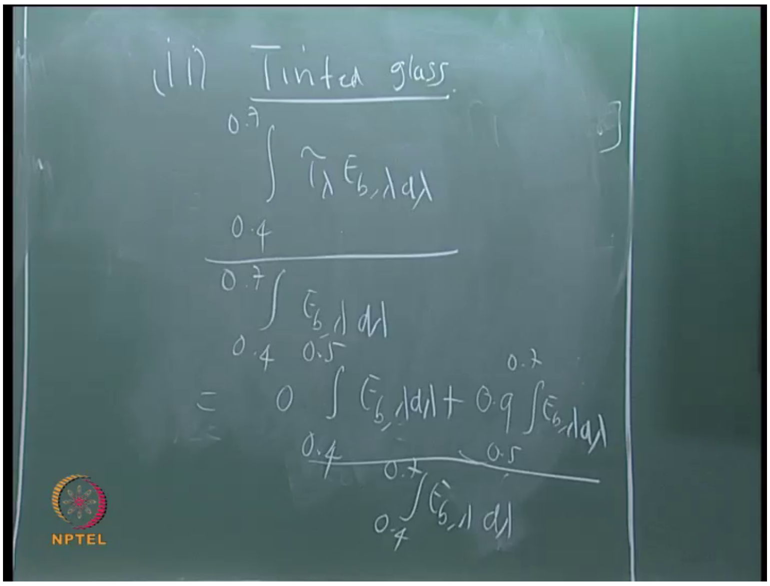

So, samarjit thinking hard? Is it okay? But the beauty is the numerator from 0.4 to 0.5 tau, tau lambda equal to 0. So, some blue light, it is cutting out. What is the 0.4 to 0.5? Blue, right? Violet, blue and all that. So, that violet, blue, those colors, that part of radiation this fellow is cutting out; therefore, that is why they will look different, your dress will look different, in a in a tinted glass, it would not be it will be surreal color, it would not be the real color, it will be something different. Now, that is why some times, it is, you can have better surfaces which will cut out lot of radiations, because such that at visible part of the spectrum so that, we cannot, from outside, we cannot see inside; that is why, in many cities, the polices is now prohibiting people from using dark sun control films in the cars, it is not allowed, you know. Anyway, in the front portion, in the windscreen you will not use, because you want to drive, you do not want to get killed, right? So, that nobody uses, only the first, if you people who are having cars will know, the first 4 inches alone we will close, after that it is open, but the side and back we will use; but now, there are certain sun control films which are banned by the police. Because that you can see instead of 50 percent, it will become 30 or 40 percent, it will be very dark inside, you will not see even somebody is sitting around with arms and these things, having assault rifle, and all that, we do not know. Lot of such things happen in Delhi and all, isn't it? Every day, we are hearing story, somebody they take a gun and shoot, it is not only in the US, it is happening in our NCR - national capital region. So, the police people are said, remove all these, only certain types of sun control films is are permitted.

Now, if you do this, then what was this? Is it correct? 0.9 Into, divided by ... So, what is that ratio?

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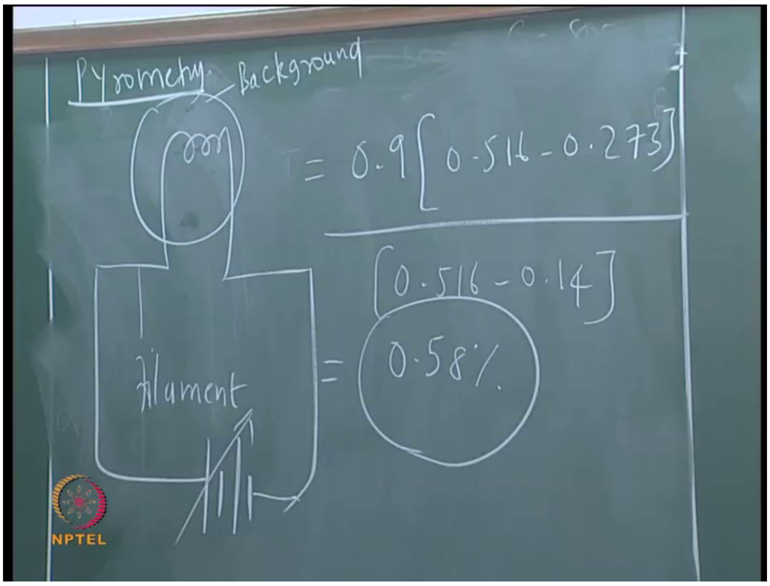

How much? 0.9 Into, 0.49 minus 0.25, is it? How do you do that?

Student: Point.

516.

Student: (( )).

0.2.

Student: (( )).

Divided by.

Student: (( )).

Is it 0.5? 516 minus.

Student: Point (( )).

So, from 90 percent we brought it down to 60 percent. So, it cuts out the visible part by 40 percent, you get an advantage of 40 percent. So, this then you can extend concept and all this; for example, based on the emission, based on the emission, you can also device instruments to measure the temperature, for example, for the temperature of a surface. So, if you, that is the basis of an optical pyrometer. So, suppose the surfaces in the background, the surfaces in the background, what happens is, you can device a system of lenses, you can focus on that and focus on the radiation coming from the background; then you have a filament. This background is at a particular temperature, this filaments temperature can be controlled because the filament is connected to some, you keep on increasing the voltage such that this temperature increases, then depending on the Planck distribution, this things will also characteristics also change, right?

You can change the setting such that, at a particular point, this filament has the same temperature as a background, then what will happen is, since this merges with this, then this filament will disappear, from here field of you. So, at that point in time, at that point in time the temperature of the filament is the same as the temperature of the background; therefore, this a way of inferring the background temperature remotely, this is pyrometer. Optical pyrometer, like that basically. So, based on Planck's law, based on radiation also you can device an equipment to sense temperature remotely; based on infrared radiation emitted from the objects, we can calculate the, we can infer the temperature; that is what they do in the airports and all that know, swine flu you pass through that, suddenly your all these portions, the color is different; then they will say quarantine, and then go to that hospital, and get yourself checked. So, that means, there is a calibration. So, what they will do is, for a for a known temperature, you will first calibrate and you will calibrate that color, that hue there at, suppose there are 256 colors, each color corresponds to what temperature you will calibrate, then accordingly, you will say blue color is this 40 to 42 degrees, red color is this, and all that, and that is basically from the color, you infer the temperature. So, if you look at all the equipment, all the equipment which are coming across in heat transfer, their design, if you want to measure something, it based on some particular law, particular law in the subject, after that you will have to validate it with some reference; the reference with which you validate must be more accurate than the… So that, it can be trusted. This is how science and technology has improved in all the disciplines, right? So, this one example, where you use basic radiation laws to measure temperatures remotely.

So, we will stop here and the next class onwards, we will, we will look at the geometric orientation between surfaces, it is a very critical in the study of heat variation. So, this is known as shape factor or view factor. So, we will look at view factor, lot of solid geometry. We will, we work out lots of problems, lots of algebra will be involved and so on, fine.