Solar Energy Technology
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Lecture - 11
Daily (Or Monthly Average Daily) Transmittance - Absorptance Product Analytical Evaluation

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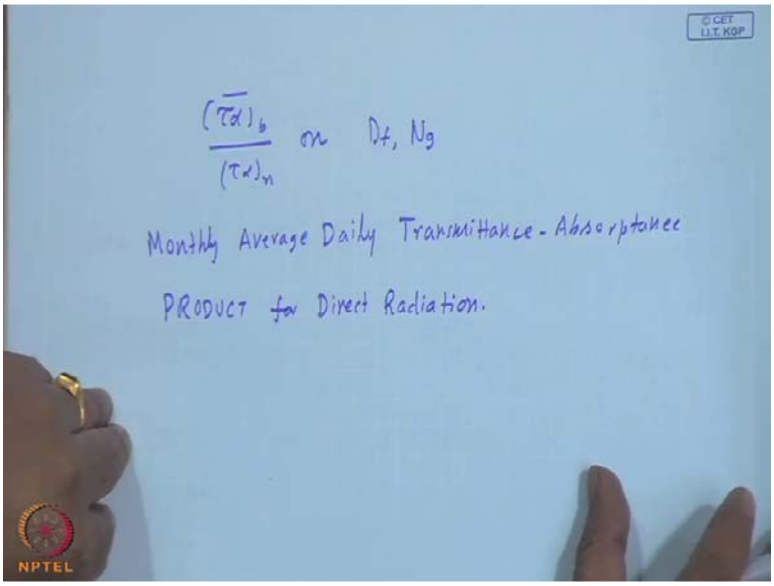

So, before we proceed to examine the dependence of tau alpha bar b upon tau alpha normal on particularly the diffuse fraction, and the number of glass covers. Like we Have done for the monthly average calculation for the direct radiation, How do we get? Monthly average daily transmittance absorptance product for direct radiation.

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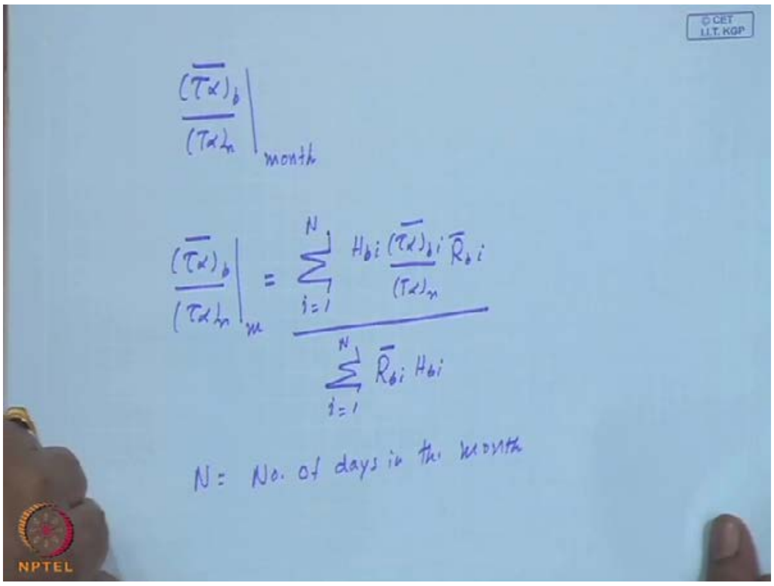

In other words if I may say so we want a tau alpha bar b by tau alpha normal for the month. So, by summation procedure, we can write down tau alpha bar b by tau alpha n for the month should be equal to sigma H b i tau alpha bar b i by tau alpha and R b bar i; i is equal to 1 to N by sigma R b bar i H b i. In other words N is the number of days in the month.

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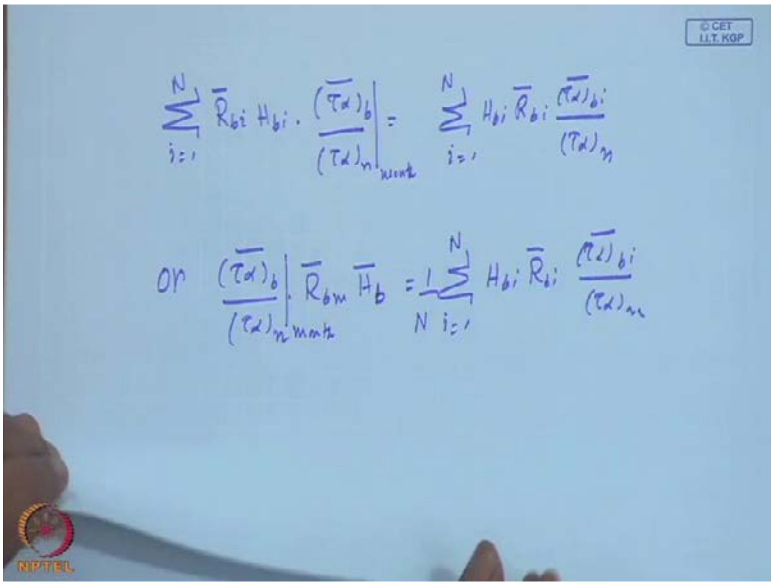

So, if I bring it on to the other side, this simply implies summation over all the days, this should be month or simply this means if I have the monthly average daily radiation direct, and the corresponding the tilted factor R b bar m that multiplied by the effective transmittance of certain product for the month should be equal to the average of the summation of all the 30 or 31 days over the month.

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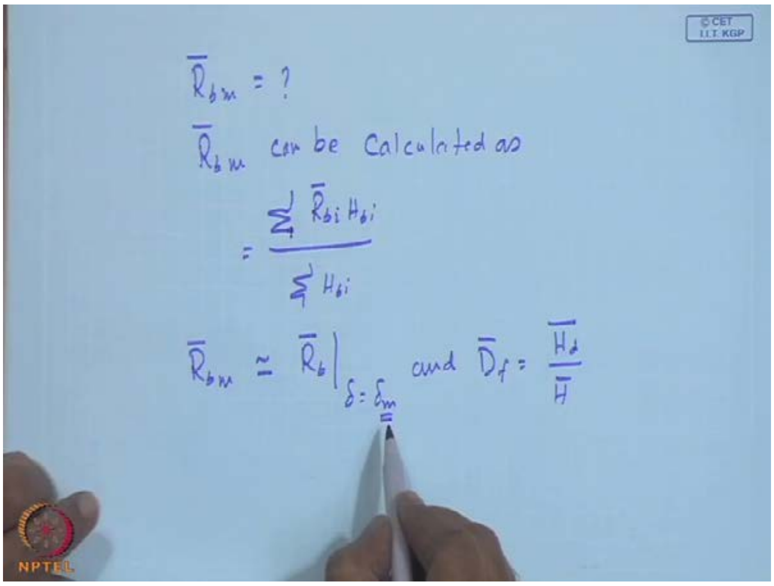

How did you calculate R b bar m; simply we said R b bar m can be calculated exactly summation over all the days, but that should be equal to calculated on the day with the mean declination and corresponding D f bar equal to H d bar by H bar. We use the monthly average daily diffuse fraction, if this calculation has being done under terrestrial conditions or for the overall H t bar, that is the difference between R b bar single for a single day with delta is equal to delta m and R b bar for the monthly average value .

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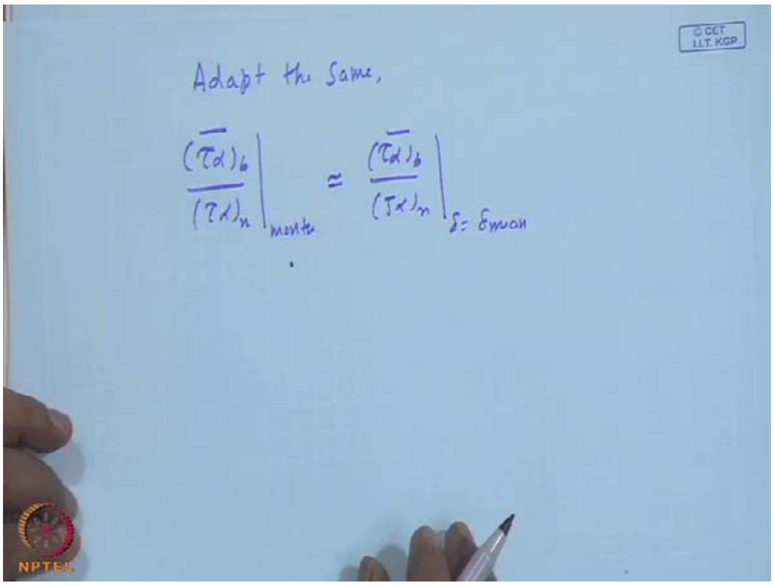

So, we may use adopt the same, and calculate tau alpha bar b by tau alpha n month, this approach also gives a comparable accuracy as the tau R b bar m and R b bar at delta is equal to delta m; obviously these are similar weightages. And in fact tau alpha varies much less over the number of days in the month rather than H b. So, this will be a better approximation then what you have for R b bar m and R b bar.

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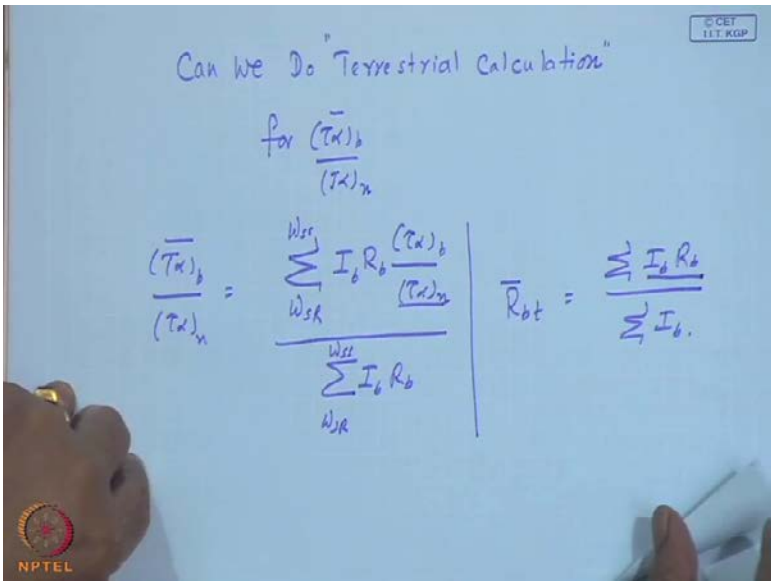

Same question that will be coming to us can we calculate tau alpha bar b upon tau alpha n under terrestrial conditions like we have done R b bar t.

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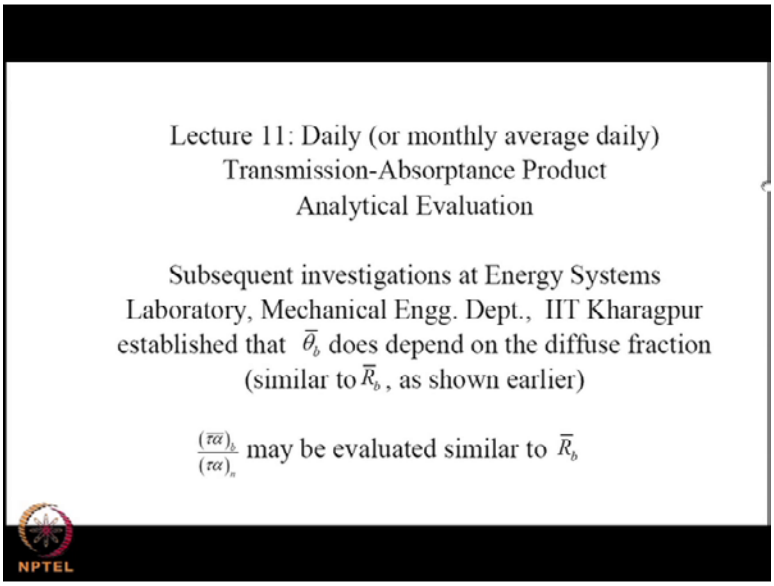

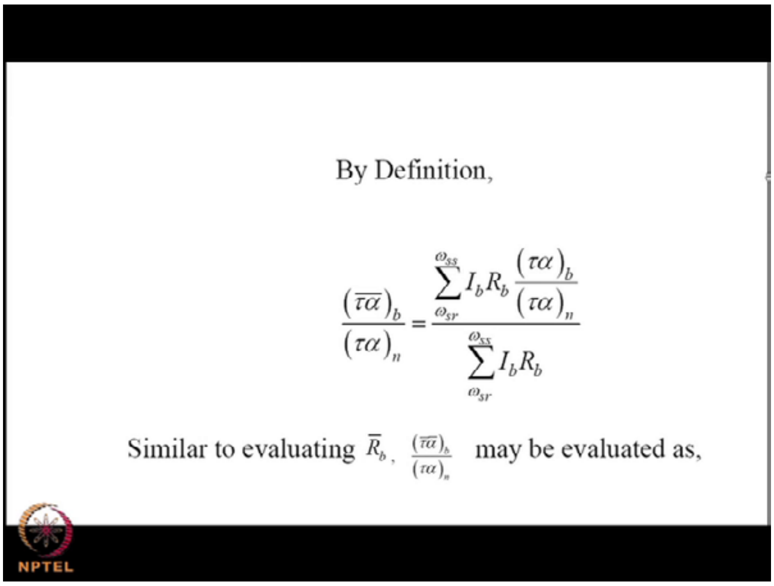

So, the answer is we may (( )) little mathematical difficulties in terms of integration etcetera, but in principle it should be possible by using even your R t and R d a correlations. So, by definition tau alpha bar b by tau alpha n should be equal to for a single day once again. So, we can call it now omega s R omega s s, because this is only direct component of the radiation. So, notice the similarity R b bar t equal to sigma I b R b by sigma I b. So, in addition to the tilted radiation we weighted with tau alpha b r tau alpha normal and the division will be the whole tilted radiation.

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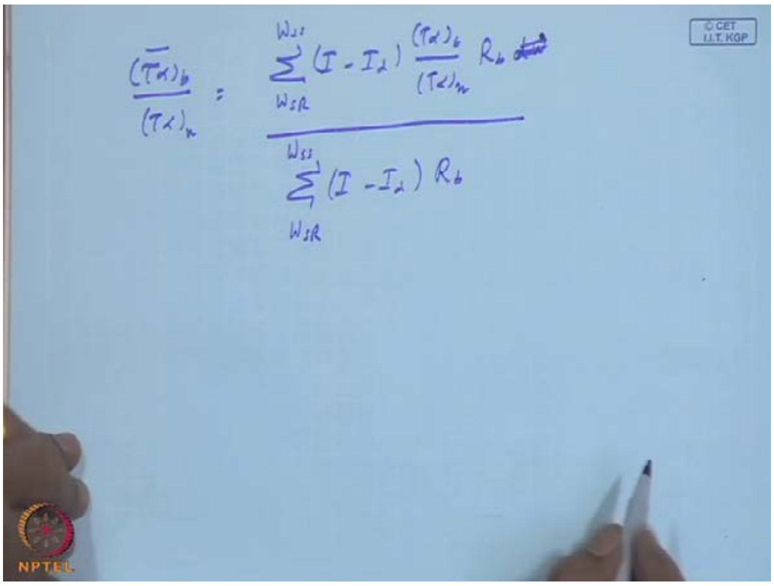

So, this again we can write it in terms of global radiation, and the diffuse radiation. This is not necessary right.

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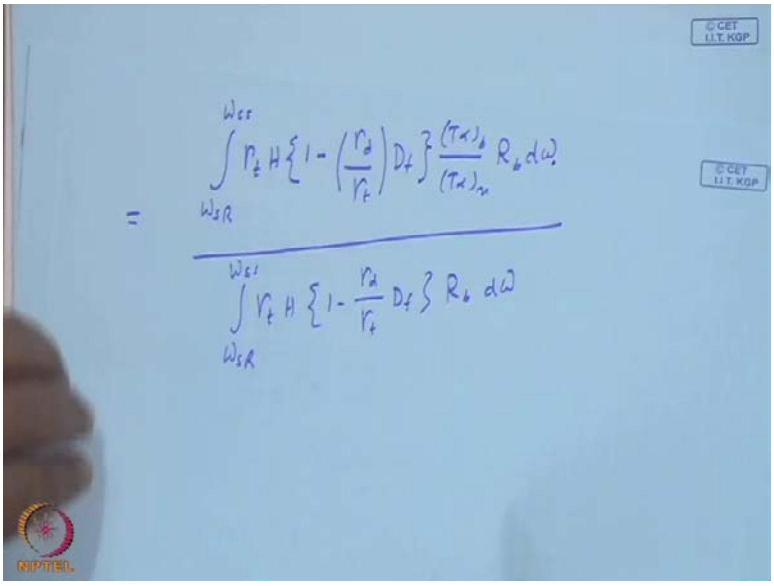

So, now we can transform this into an integral that should be equal to i is r t into H taken out as common. So, I will get one minus r d by r t times D f the daily diffuse fraction multiplied by tau alpha b by tau alpha n R b d omega upon that tilted radiation. Please remember this we are carrying on with tau alpha b by tau alpha n, actually it could have an equally accurate even if you say only tau alpha b R b d omega equal to tau alpha bar

b. However, the relation is for tau alpha b by tau alpha n in terms of the angle of the incidence. So, it is common, it is more convenient to use this particular form rather than only tau alpha b, other than that there is nothing special about multiplying with tau alpha b upon tau alpha normal tau alpha normal is a constant can we pulled out of the integration sign.

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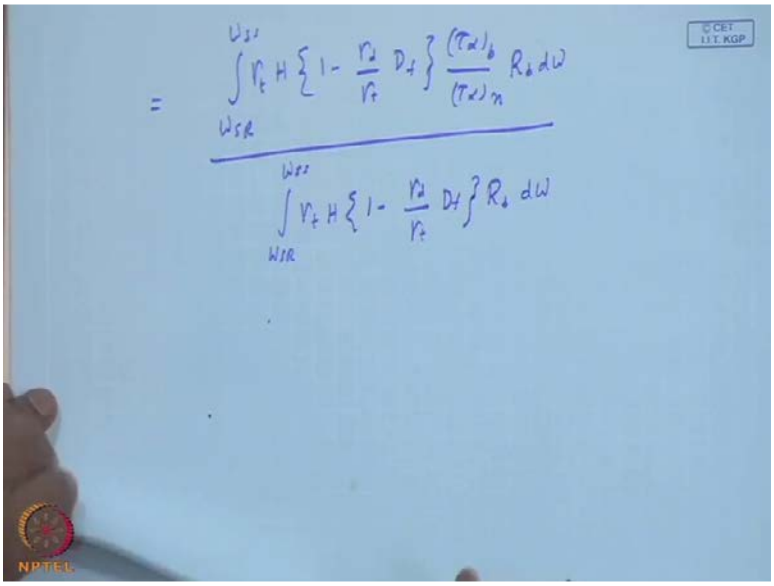

So, this once again simplifies to it does not simplify it is the same relation sorry, this calculation we will not complicate it by having a double sunshine and single sunshine distinction for the collector under question, though we have another complexity here.

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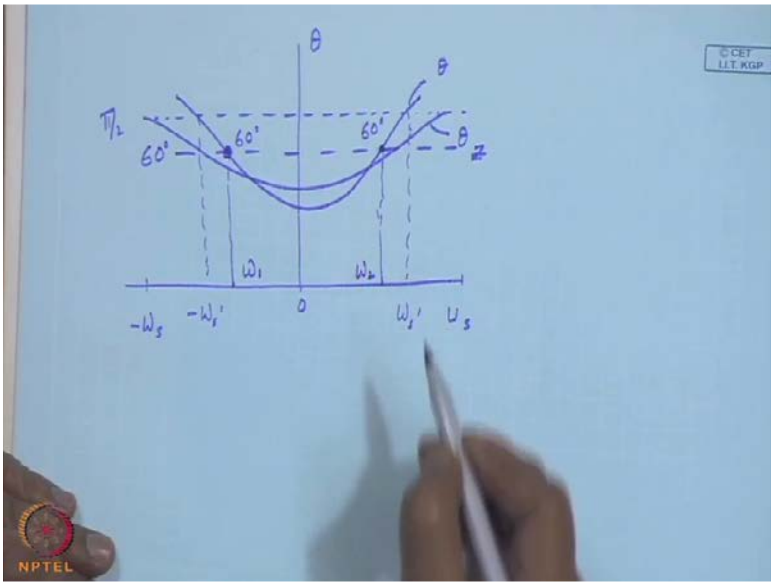

Right, now if you plot for example, a summer month gamma is equal to 0, since we are dealing with a solar collector it is not unfair to consider a south facing surface omega 0 solar noon physical sunrise, and this is physical sun set. Now, this is my behavior of theta, and this will be if it is a summer month, it will be something like this. So, this will be minus omega s dash, this will be plus omega s dashed. So, this is theta z and this is theta. So, now this may be 30 degrees, 40 degrees, this we know is pi by two. So, somewhere here, this will be 60 degrees. So, this point is 60. So, this point is 60 which will be occurring in general at omega one and omega two.

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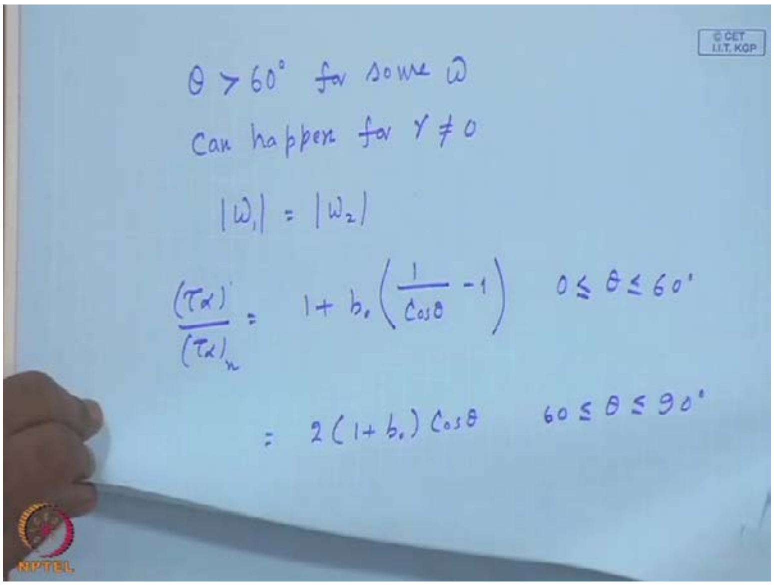

So, in other words the theta can be more than 60 degrees for some omega, this can happen for gamma not equal to zero also, if gamma is 0 there is omega 1 mod should be equal to mod omega two otherwise they define. So, this is where we have the complexity, since tau alpha by tau alpha normal is 1 plus b 0 into 1 by cos theta minus 1 for 0 less than or equal to theta less than or equal to 60 degrees and equal to 2 into 1 plus b 0 cos theta for 60 less than or equal to theta less than or equal to 90 degrees. So, this is piecewise continuous. So, my integration has to be done splitting it into two intervals and omega one and omega two can be identified by setting theta is equal to pi by 3 or 60 degrees.

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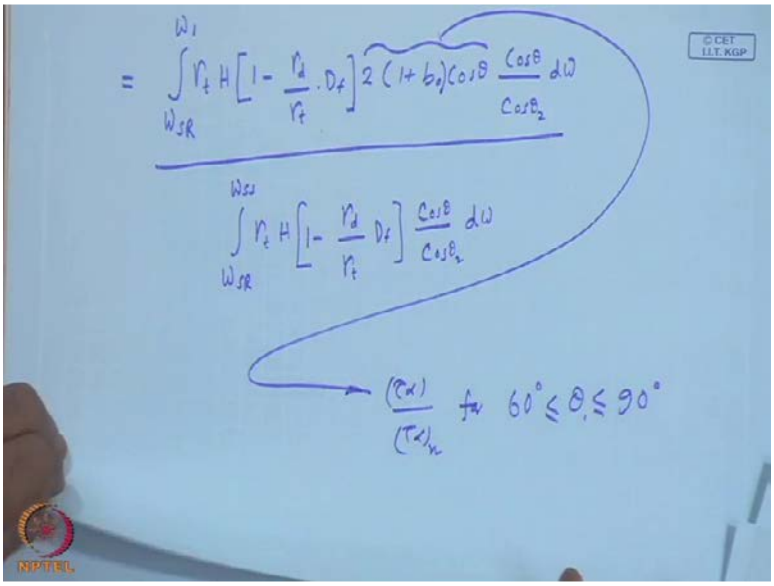

So, when that integral is split I will have these three terms omega S R to omega one in general into r t into H into 1 minus r d by r t into D f times 2 into 1 plus b 0 cos theta times cos theta by cos theta z d omega upon integral omega S R to omega s s r t into H 1 minus r d by r t D f into cos theta by cos theta z d omega. Mind you this is tau alpha by tau alpha normal for 60 to 90 degrees theta this is nothing but the whatever we have in the denominator. Now, omega 1 is the value of the hour angle when theta will be equal to 60, beyond that theta is greater than rather omega S R to omega one theta will be between 60 and 90.

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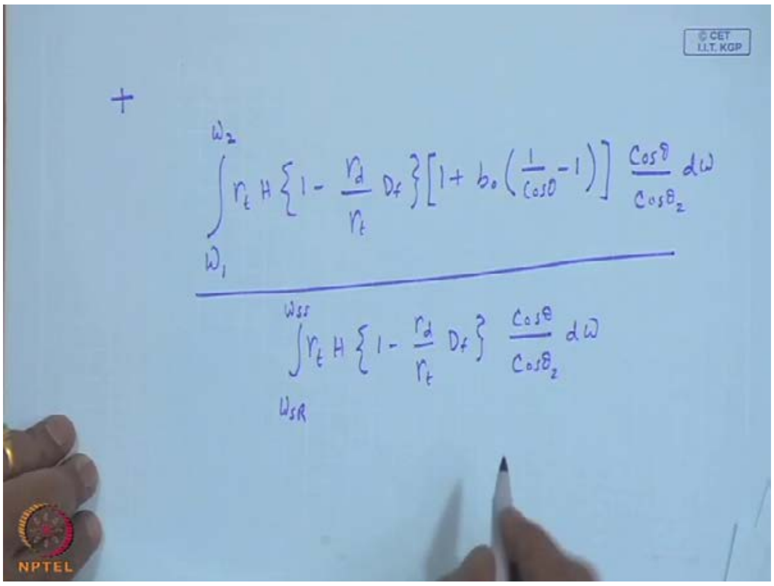

Plus the second term will turn out to be omega 1 to omega 2 r t H 1 minus r d by r t D f 1 plus b 0 into 1 by cos theta minus 1 into cos theta by cos theta z d omega that is written on… This will remain the same.

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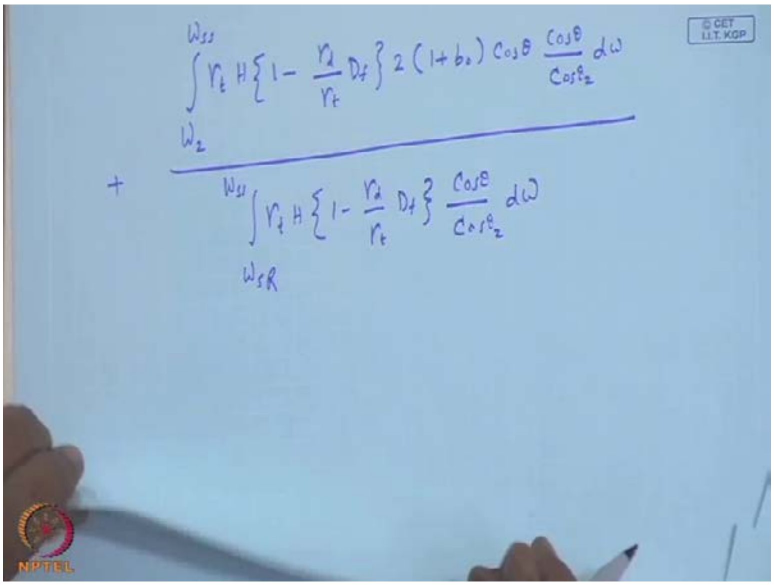

Plus omega 2 to omega s s r t into H 1 minus r d by r t into D f again 2 into 1 plus b 0 into cos theta times cos theta by cos theta z d omega by the same term. So, this is what we get as summation of three terms, where omega one and omega two are the hour angles where theta will be equal to 60 degrees.

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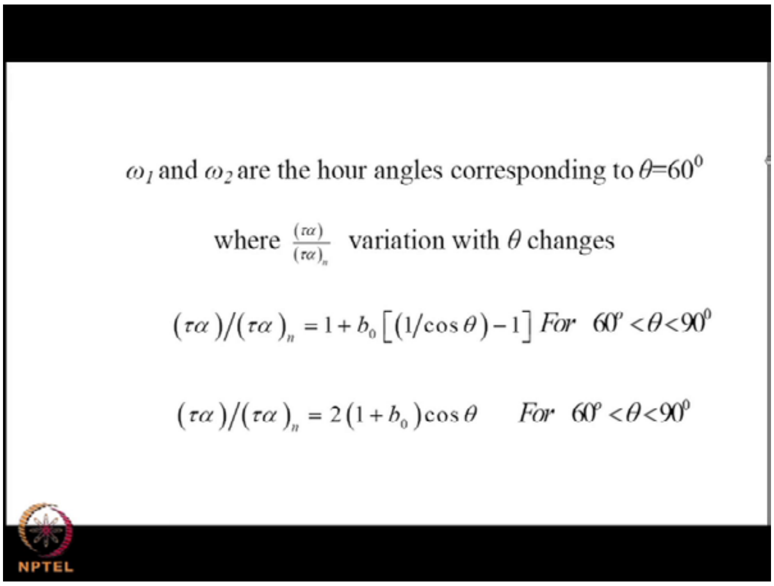

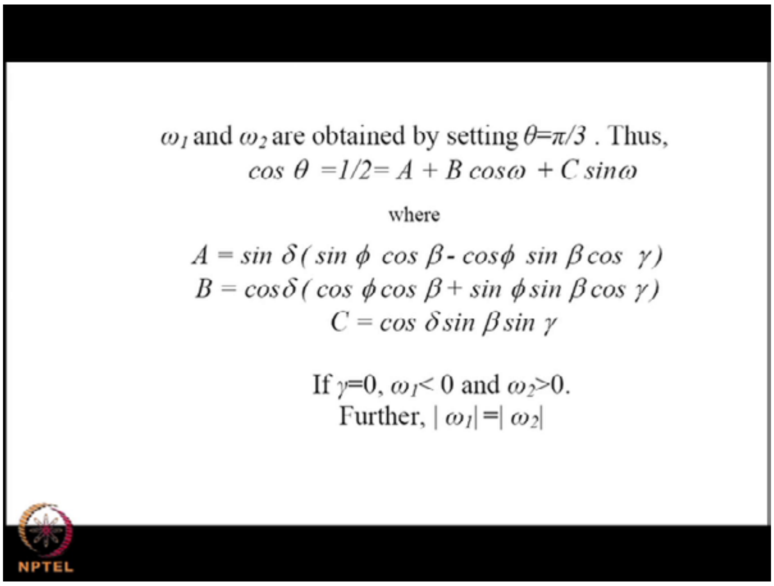

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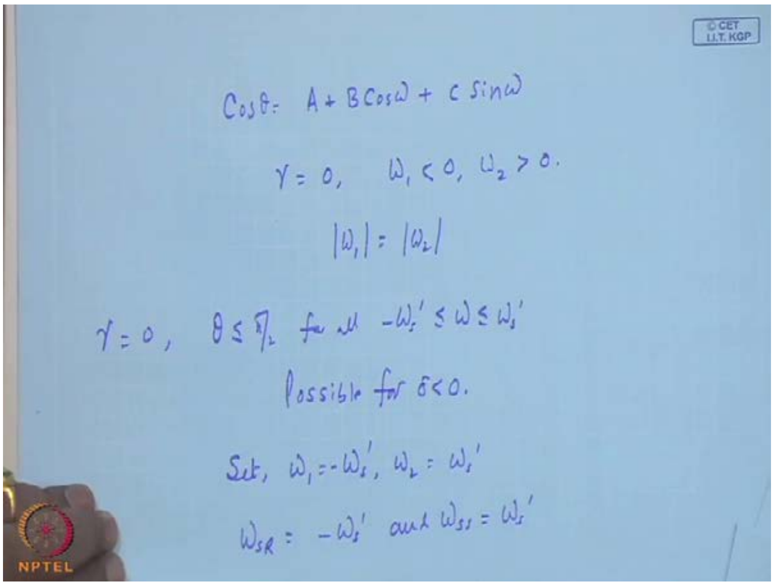

So, omega 1 and omega 2 are obtained by using these relations setting cos theta is equal to half cos theta is equal to cos 60 is equal to half equal our general relation for cos theta is A plus B cos omega plus C sin omega. And we will find which we already pointed out, if it is gamma 0 and you have got omega 1 will be less than zero and omega 2 will be greater than zero, because theta will be a pi by 2 at the sunrise and sunset. So, if it occurs it will should be in the morning time forenoon omega one will be less than 0 and omega two will be greater than 0; further the magnitudes should be equal.

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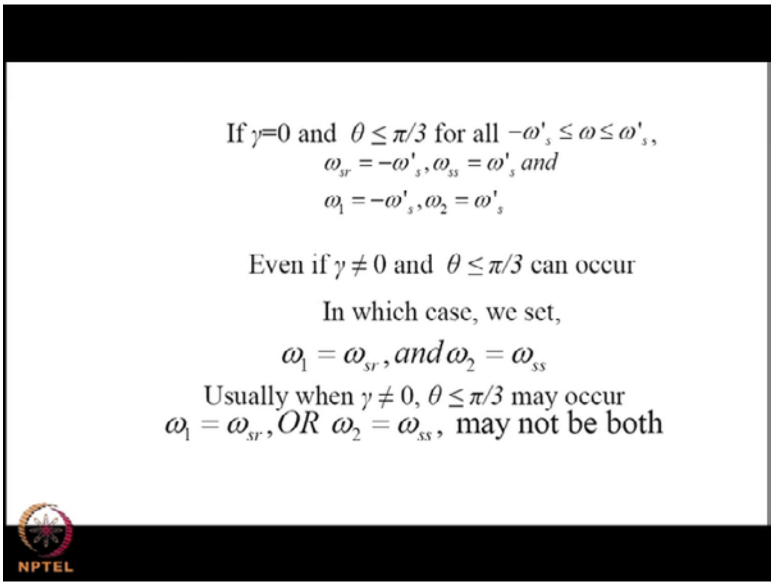

So, now in case for example in summer months or winter months, we may have gamma equal to 0, and theta is less than or equal to pi by 3 for all minus omega as dash plus minus possible negative delta. So, then you set omega 1 equal to omega s dashed and omega 2 will be equal to omega s dashed. So, that only your middle integral remains the other two will become automatically 0. And here of course, because it is gamma is equal to zero you have got your omega S R will be minus omega s dashed and omega s s will be omega s dashed. Please recall this omega s dashed is the sunset hour angle for the tilted surface facing the south.

And even if gamma not equal to zero this can pi theta less than pi by 3 can occur. So, for example if it is true for a south facing surface with some positive delta, it will be also true if small gamma is used. So, in general you cannot rule out the possibility that if gamma is not equal to o, that theta cannot be less than pi by 3. So, again we will set omega 1 is equal to omega S R.

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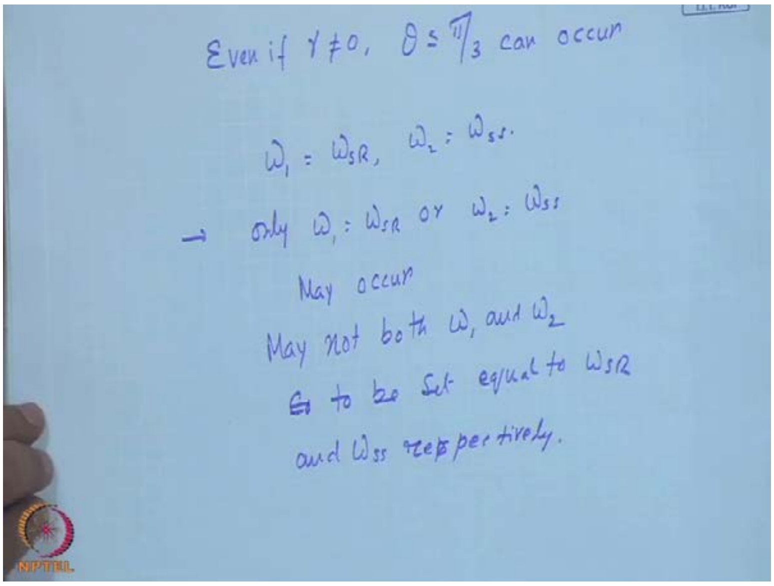

So, we do this and it is equally possible that only omega 1 is equal to omega S R or omega 2 is equal to omega s s, and may occur may not be both. In other words, if it is to west it is possible that theta greater than 60 may occur in the forenoon and may not occur in the afternoon.

So, let me repeat this piecewise integration has become necessary, because of the description for tau alpha by tau alpha normal being set in two interval for the angle of incidence theta, and if you consider a simple south facing surface, in the negative declination case. We know that the collector starts with an angle less than pi by 2 which may be greater than 60 consequently you may encounter a region where there will be theta less than 60 as well as theta greater than 60. Then in which case you have to set omega s dashed magnitude equal to omega 1 or omega 2; of course, the possibility is even more if the declaration is positive where you have got traditionally omega s dashed magnitude is less than the physical sunrise and sunset omega s. Consequently the angle of incidence is bound to be more than 60 for a period of operation during which we have to use one particular law for tau alpha by tau alpha normal, and another law for the second region where theta is less than pi by 3.

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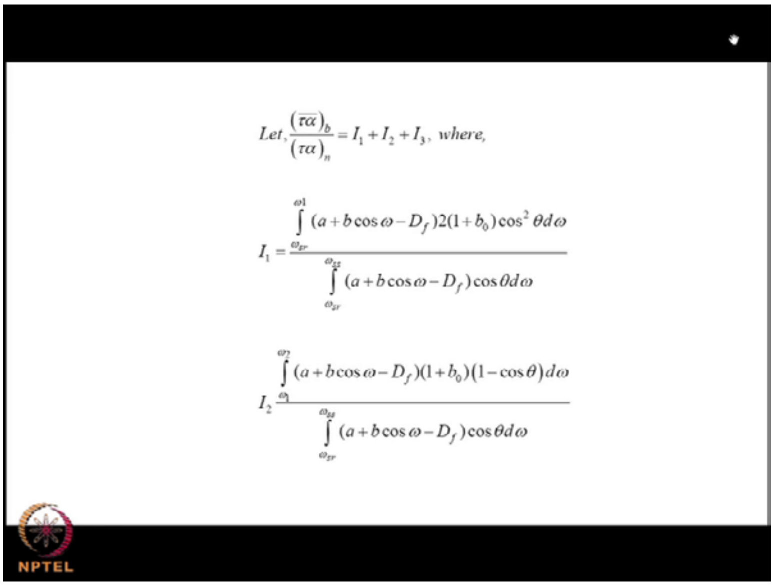

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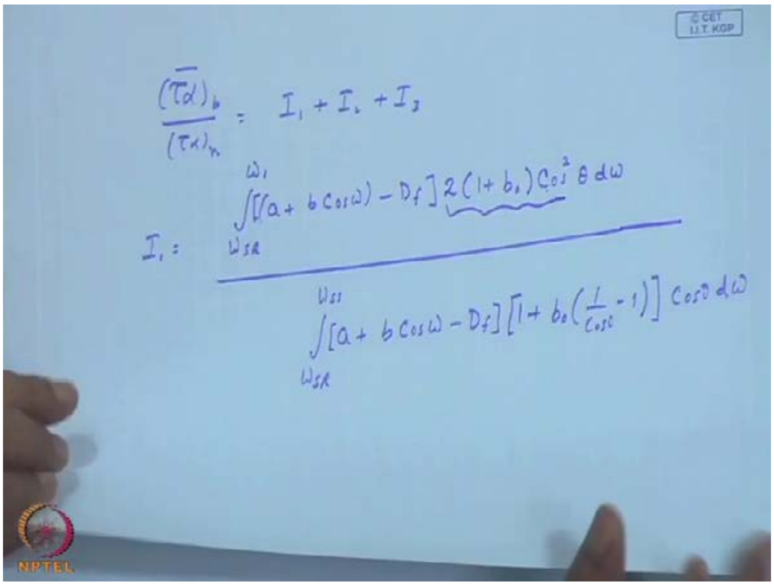

So, now if we recall and use the correlations H is constant in the numerator and denominator, it gets canceled. So, I can now for simplicity right, three integrals where I 1 equal to… We have done similar exercise in calculating R b bar except here we have one more, we have we have to multiply with not only R b, but also R b into tau alpha b. So, I shall briefly explain if you look at the term what I have I shall explain what we got here is the previous term r t is expressed as a plus b cos omega into pi by 24 into cos omega minus cos omega s upon sin omega s minus cos omega s, that can cancelled with the denominator similar term and the cos theta z in R b has been expressed as cos pi cos delta into cos omega minus cos omega s which again gets cancelled with the numerator of the term in r t.

So, you have a pi by 24 get cancelled, and you have a similar expression like a plus b cos omega minus D f into the appropriate law for tau alpha b by tau alpha b n one of the cos thetas is in this cos square theta, and you got the simple tilted radiation in the denominator.

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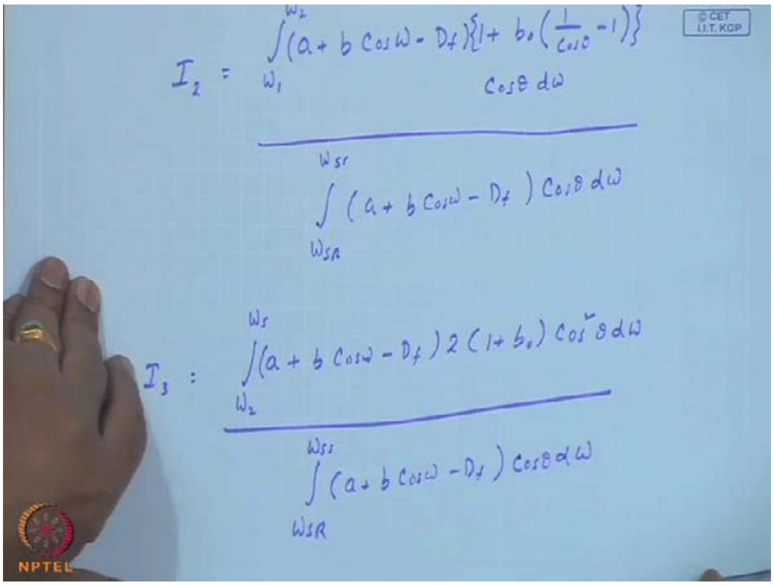

Similarly, I 2 now omega 1 to omega 2 where your theta is less than pi by 3 upon omega S R to omega s s.

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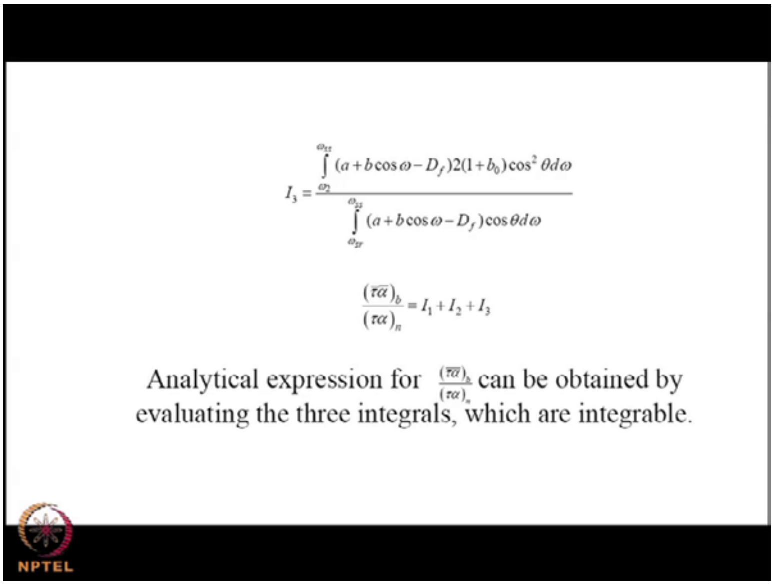

Again you have I 3 the limits of integration are different now omega 2 to omega s a plus b cos omega minus D f times 2 into 1 plus b zero into cos square theta d omega by the tilted radiation. So, now you have got these integrals expressed; these integrals are integrable in the sense it does not require any numerical integration.

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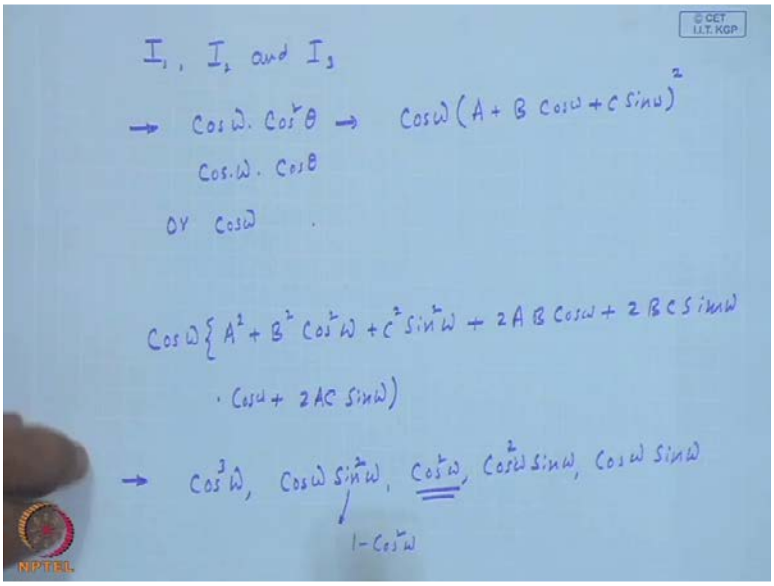

Now, if you look at I 1, I 2, and I 3, the combinations highest combination that can occur is cos omega times cos square theta, and rest of them are lesser cos omega cos theta or cos omega. So, this will lead to cos omega times a plus b cos omega plus c sin omega, I am taking the toughest one which is cos omega into cos square theta. So, that will give me cos omega into A square plus B square cos square omega plus C square sin square omega plus 2 AB cos omega plus 2 BC sin omega into cos omega plus 2 AC sin omega. Out of which it will give a combination of cos cube omega cos omega sin squared omega then a cos squared omega, then cos omega sin omega cos square omega sin omega and cos omega sin omega.

So, if you can integrate cos cube omega, you can integrate everything else this we have already done this can be rewritten as nothing but 1 minus cos squared omega which will give a cos cubed omega, and again this can be written as 1 minus sin squared omega. So, that will turn out to be a sin cube omega which will be of same complexity of cos cube omega.

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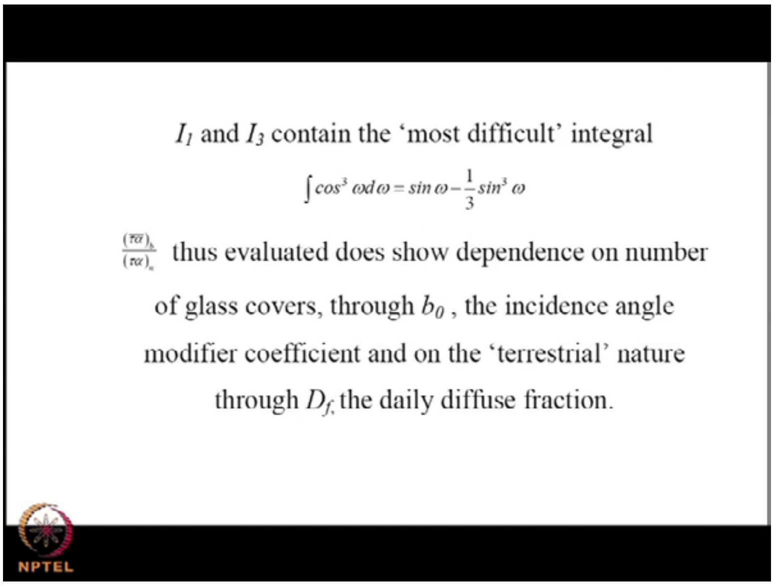

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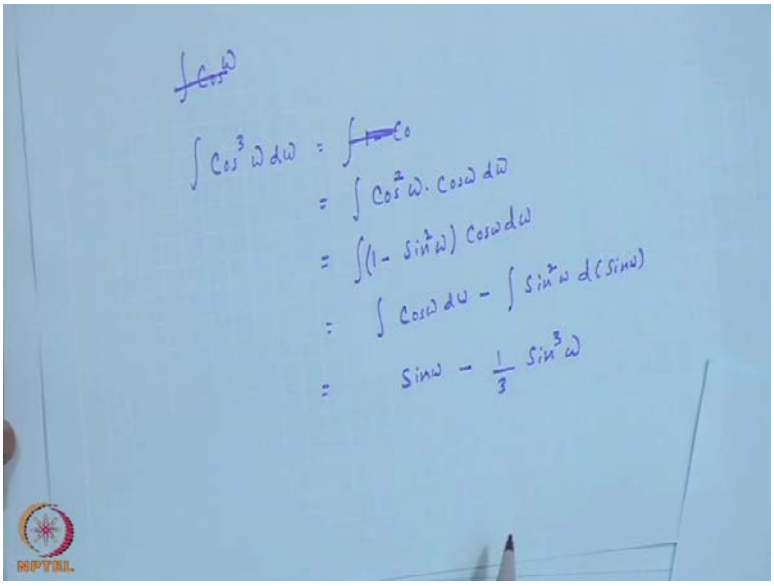

So, if you look at this. So, cos cube omega d omega it can be written as cos squared omega sorry. So, you have 1 minus sin squared omega cos omega d omega that will be integral cos omega d omega minus integral sin squared omega d sin omega, this is nothing but sin omega minus one third sin cube omega. So, it is not at all a difficult to evaluate this integral except that it will be a very lengthy expression that you have got.

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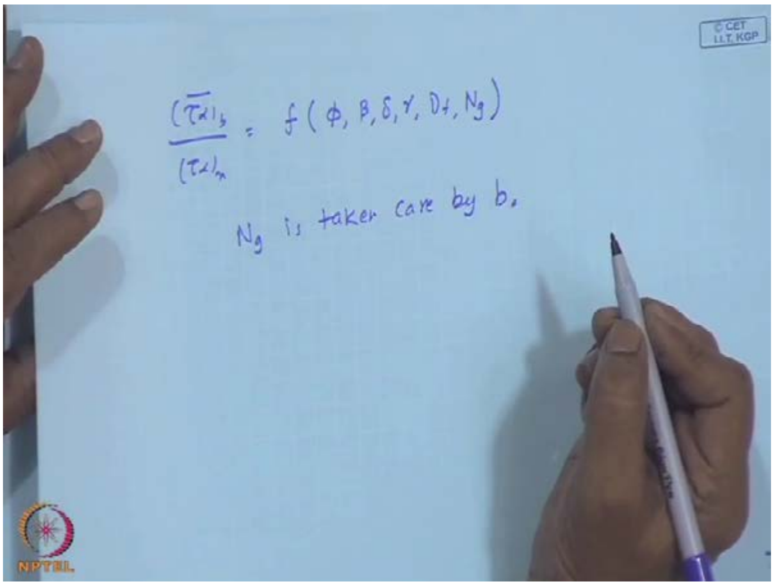

So, now we have got tau alpha bar by tau alpha n will be a function of course, phi, beta, delta, gamma, D f, and N g; number of glass covers. So, D f is the diffuse fraction which will take into the account the climate and N g is the number of glass covers N g is taken care b 0, the incident angle modifier co efficient which really use as point minus point 1 or minus 0.17 depending upon whether it is one glass cover or two glass covers.

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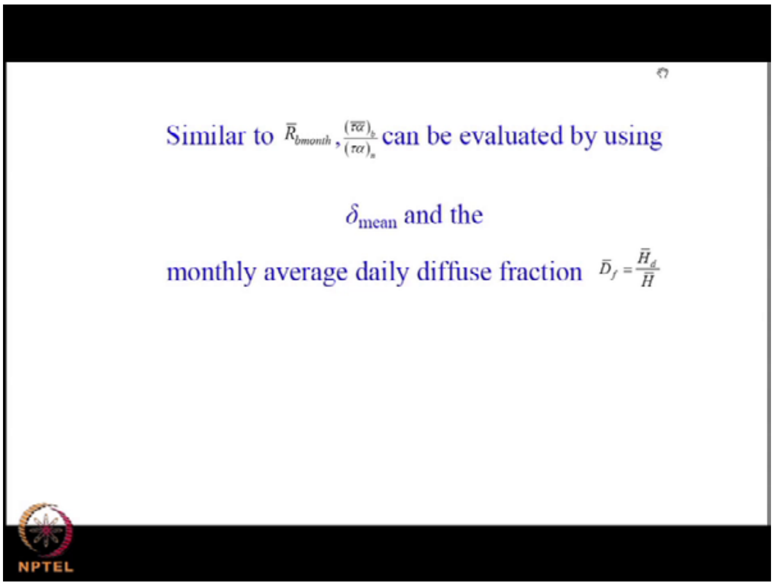

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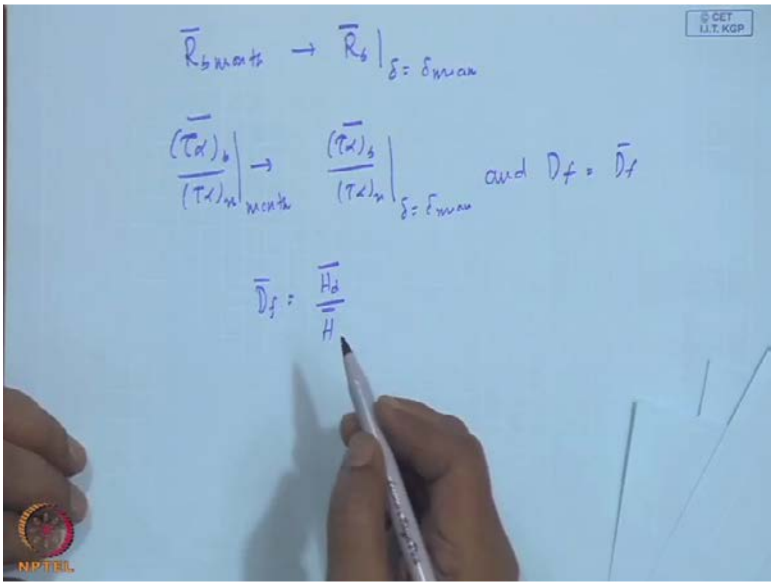

So, this is what? We have this R b bar month we have calculated as R b bar with delta is equal to delta mean. So, tau alpha bar b upon tau alpha n also can be calculated for the month with delta is equal to delta mu, and now the diffuse fraction will be D f bar; D f bar is H d bar upon H bar. So, if you use the monthly average daily diffuse fraction, you will get the monthly average or transmitter absorptance product for direct radiation. So, this is what we could achieve.

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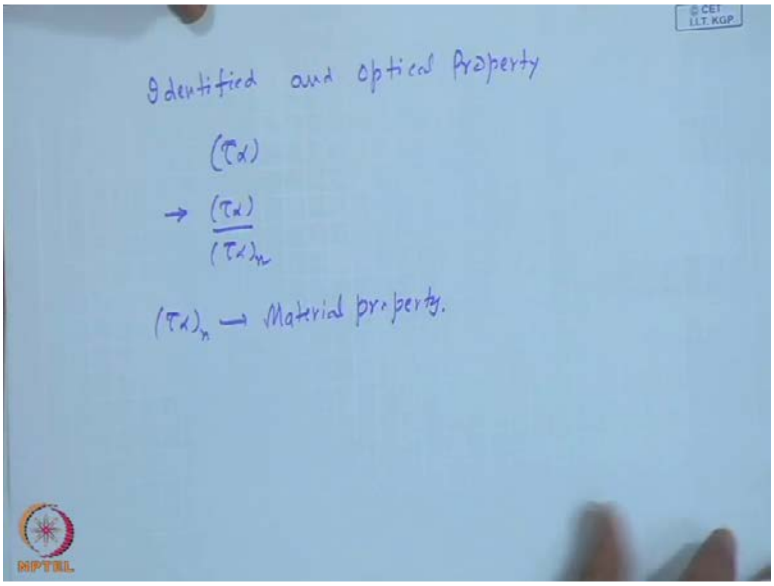

So, I shall spend just, because the algebra is too long, I will spend a few minutes first we identified an optical property tau alpha normalized quantity will be tau alpha by tau alpha normal; tau alpha normal is a material property.

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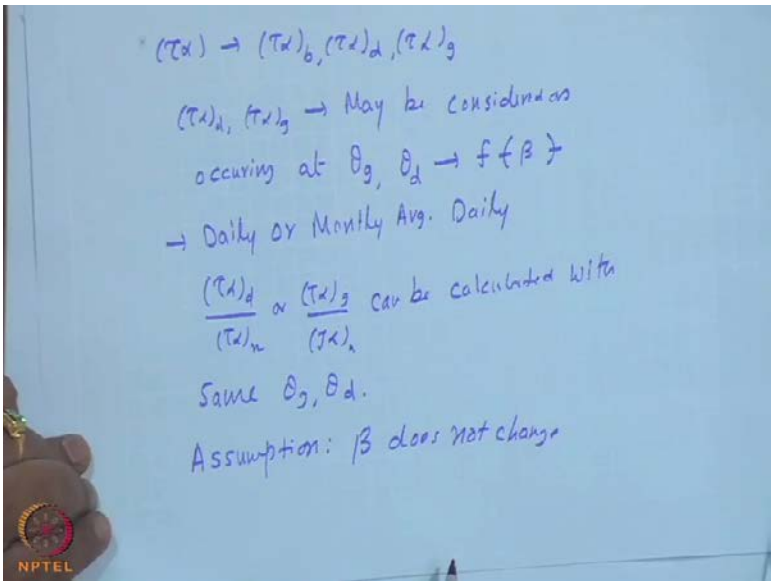

Then we realized tau alpha to be comprising of component for the direct radiation, component for the sky diffused radiation, and a component for the ground reflected radiation. And tau alpha d and tau alpha g may be considered as occurring at effective angles for the ground reflected radiation, and the sky diffused radiation only functions of beta. So, the daily or monthly average daily tau alpha d by tau alpha n or tau alpha g by tau alpha n can be calculated with same theta g and theta d. Of course, the assumption is beta does not change, if the slope of the collector is changing every day or every hour then my theta g and theta d will be changing, then they also have to be evaluated a some sort of weighted averages.

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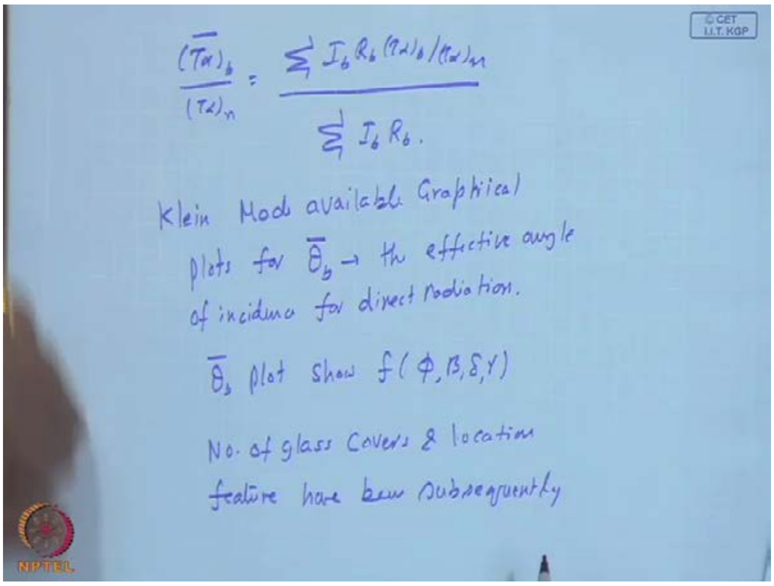

And technically tau alpha bar b by tau alpha n is sigma I b R b tau alpha b by tau alpha normal by sigma I b R b. So, claim made available graphical plots for theta B bar, the effective angle of incidence for direct radiation, and these theta b bar plots show function of beta, delta, and gamma; number of glass covers and location feature have been subsequently examined.

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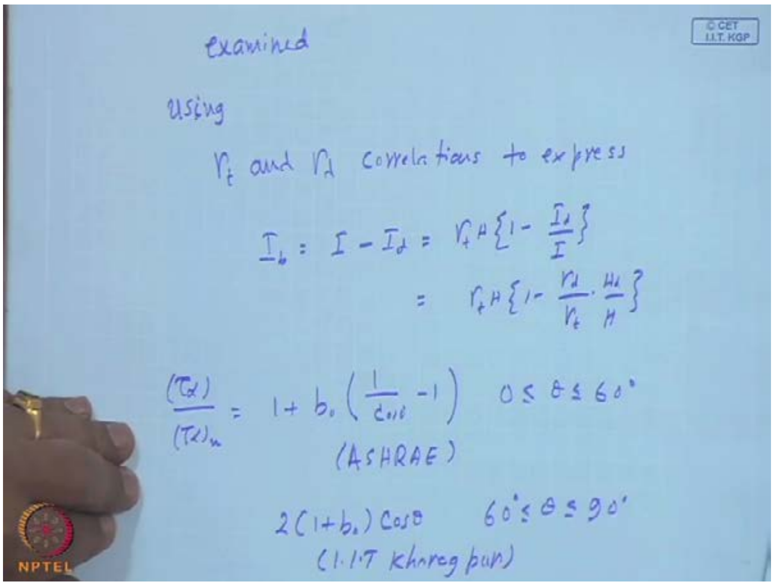

So, using correlations of (( )) Jordan to express I b equal to I minus I d equal to r t into H into 1 minus I d by I, which is r t into H 1 minus r d by r t into H d by H. Then the incidence angle modifier relation, you have got tau alpha by tau alpha n is 1 plus b 0 into 1 by cos theta minus 1 for zero less than theta 60, which is ASHRAE recommendation and 2 into 1 plus b 0 into cos theta for 60 less than theta less than or equal to 90 degrees this proposed at IIT, kharagpur. So, in an additional we have got the preliminary preparations, if I can call preliminary preparations that is how do you process the solar radiation falling on a in general a tilted surface and solar collector in particular, and then how do you calculate the associated transmittance absorptance product for a flat plate collector having one or two glass dots .

So, that can be calculated under terrestrial conditions or use the graphical plots available made available by claim, and the computer implementation or somebody has to either read the coordinates or the values are to be given. However, the subsequent analytical expression though lengthy can be easily implemented on the computer, and when once you put it on the computer it will calculate any number of times. And this is one way of taking care of the location feature without actually making use of the detailed data. So, next time we shall consider the theory of flat plate collectors in detail having the knowledge of how to estimate the solar radiation and the transmittance of certain product.