Solar Energy Technology
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Lecture - 10
Transmission – Absorptance Product

Last time I gave briefly the operation of solar colector.

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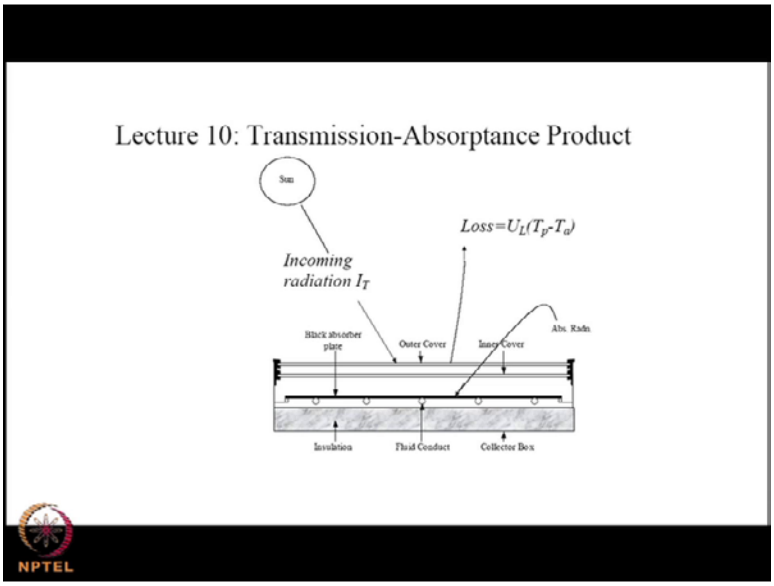

Particularly in order that we bring out the transmittance absorptance product, that would be required in calculating the performance of the solar collector.

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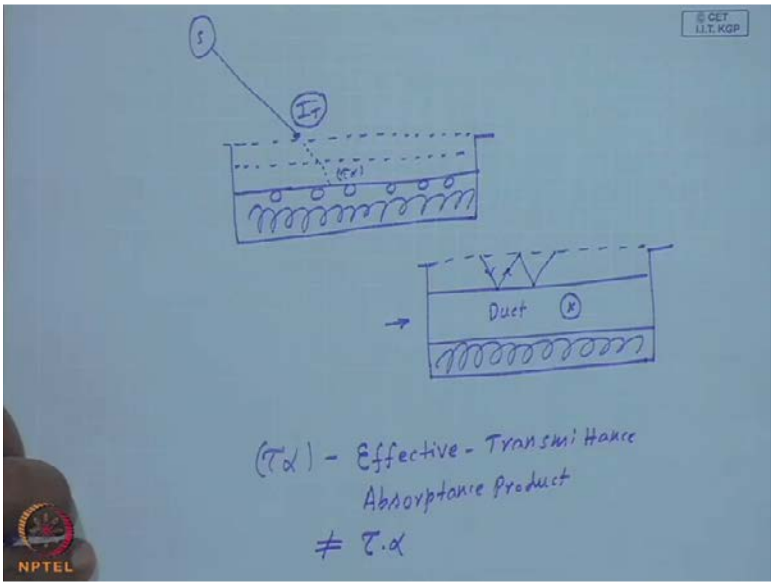

Basically the solar collector consists of an absorber with fluid passages, which are pipes and then host in a box, the bottom of which is insulated, so that the back losses are reduced. And there may be one or two glass covers, so that the convective and radiative transfer loss of feet is reduced. So, the same figure is shown here and here is the sun and the radiation that falls on this is I T and something will get transmitted and absorbed over here, where tau represents a transmittance of the glass covers and alpha is the absorb of the absorber plate.

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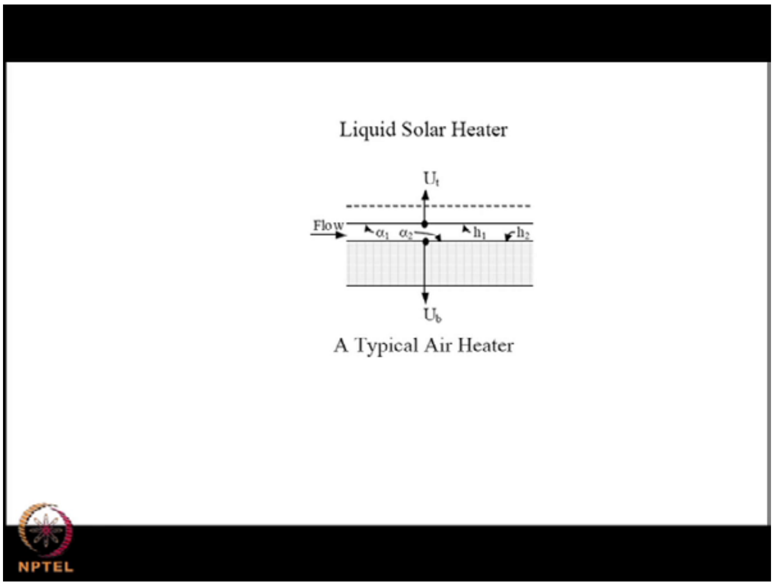

So, I have shown a typical air heater configuration also, where in you need a large flow area, because the volumetric flow way of air will be much larger for a given amount of energy gain compared to that of a liquid or water. Again this will be a duct and perpendicular to this the air flows and it is insulated. This is only to understand that the incoming radiation I T for which we have made elaborate calculations will be transmitted through the glass covers.

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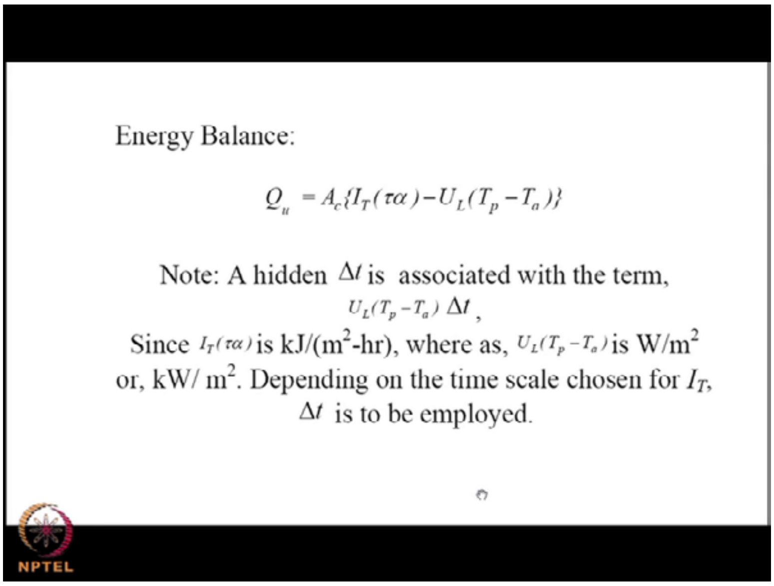

And will be absorbed and there will be several multiple reflections between the glass cover and the observer plate making that tau alpha within brackets, which I shall call the effective transmittance absorptance product, which is not exactly equal to simply the product of tau into alpha.

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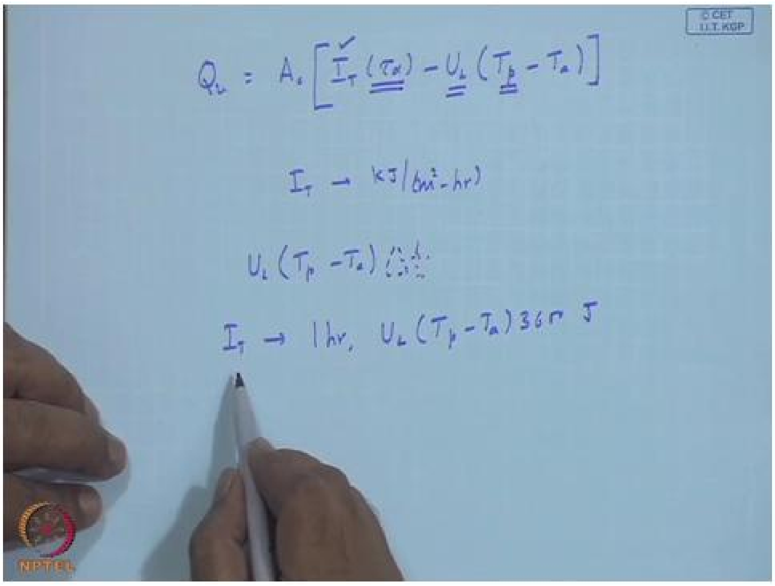

We also have given the energy balance equation for the solar collector, which says that useful energy gain from a collector of area A c is given by the absorber energy I T tau alpha minus losses taking place from the plate temperature T p to the ambient T a. You may note that we represented the entire collector absorber to be at a single temperature T p. And the incoming radiation is multiplied with the effective transmission absorptance product, we know how to calculate I T given the solar radiation on a horizontal plane. We are yet to find out how to calculate U L, T p and T a are weather data or the operating temperature of the collector.

So, now our aim is to calculate this tau alpha, also I pointed out this I T is typically in Kilo Joules per meter square hour, which is typically a short period of time that we consider. So, this U L times T p minus T a, a hidden multiplication factor of a time scale is involving this. If we consider I T is 1 hour then it will be U L into T p minus T a as 3600 this will be in Joules and if it is in Kilo Joules. We can convert it and that same thing has to be used consistent with the time frame that we apply.

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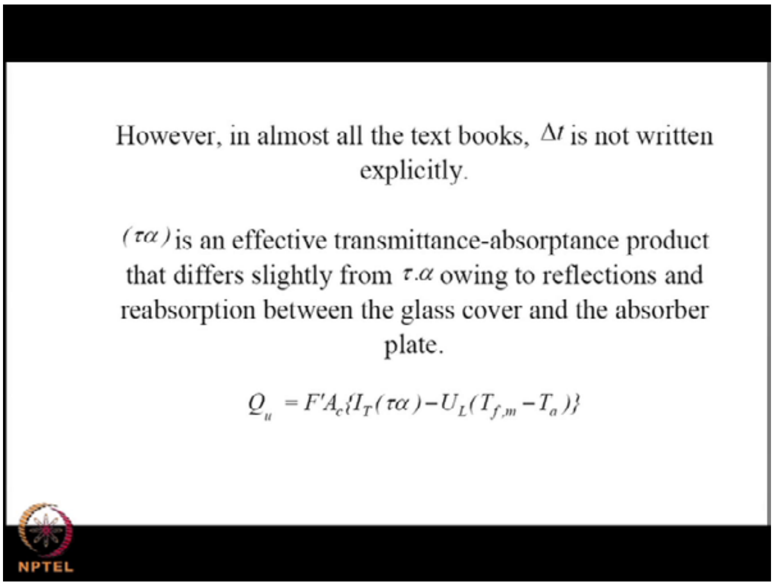

In order that the uncertainty in the play temperature and the associated problems are alleviated.

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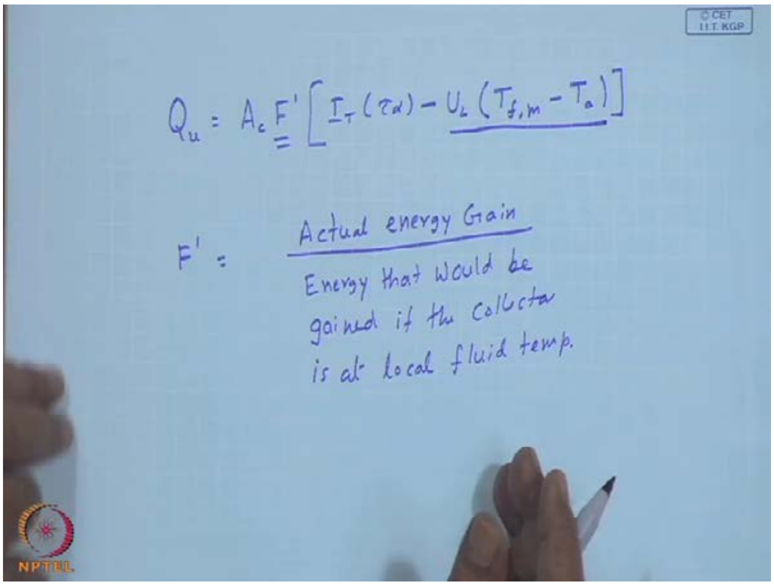

We express this useful energy gain from the character Q u as a product of A c and F dash times, I theta alpha the incoming absorb radiation minus the losses if the entire collector had been at the local fluid temperature mean. So, instead of T p, I represented T f m, so this an under estimate. So, to compensate that this F dash the collector efficiency factor is introduced we shall have definition later.

And further again this T f m, F dash it is actual energy gain by the energy that would be gained if the collector is at local fluid temperature. In other words this represents the energy that would be gain by the solar collector, if the heat transfer coefficients between the fluid and the passage is infinity; to avoid this uncertainty of the mean fluid temperature.

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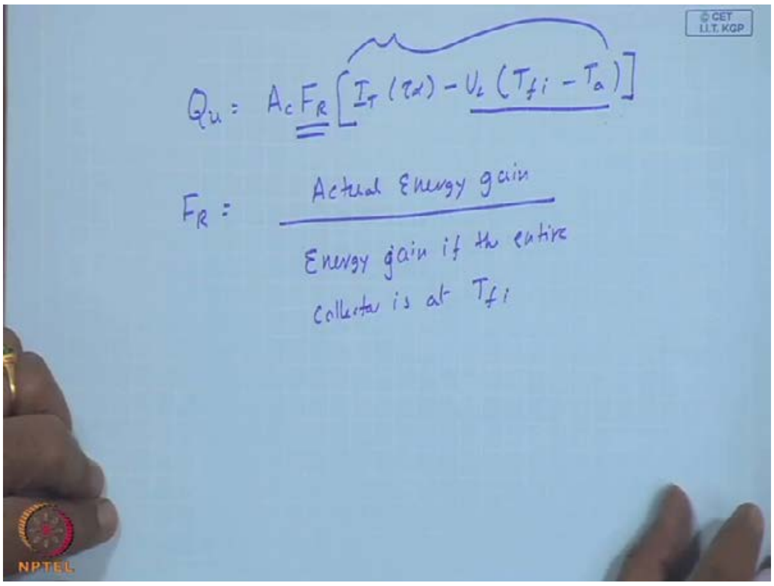

This is further refined as Q u, A c a factor F R instead of F dash times the absorbed energy minus U L into T f at the inlet minus T a. So, T f i is a single point temperature, so there cannot be any uncertainty whether it is the average of the inlet and the outlet or the temperature at the average position, etcetera. So, now F R will be defined as actual energy gain energy gain, if the entire collector is at fluid inlet temperature. So, this is the minimum loss that would be taking place from the collector.

Consequently this the maximum possible energy gain. So, to compensate the underestimation of this loss, we have put the heat removal factor F R, something like effectiveness for a heat exchanger that you are aware in heat transfers studies.

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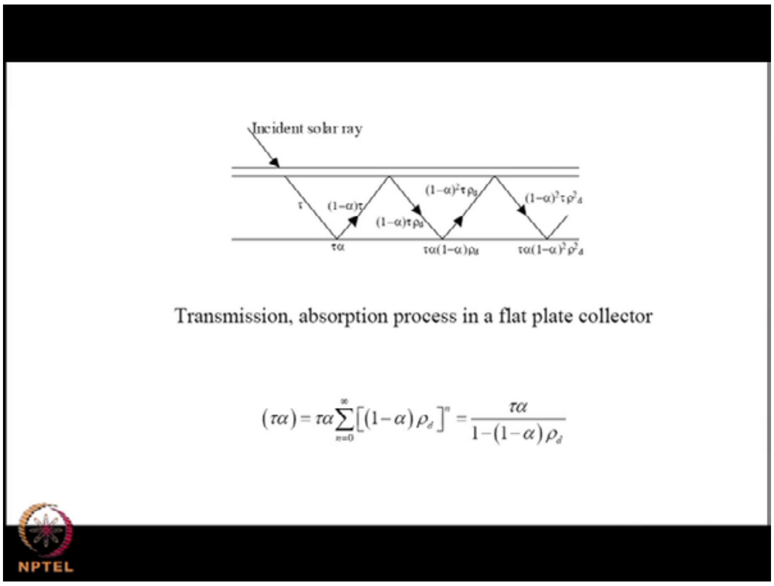

Now, let us examine what is happening to the incoming ray; now we know I T how to calculate.

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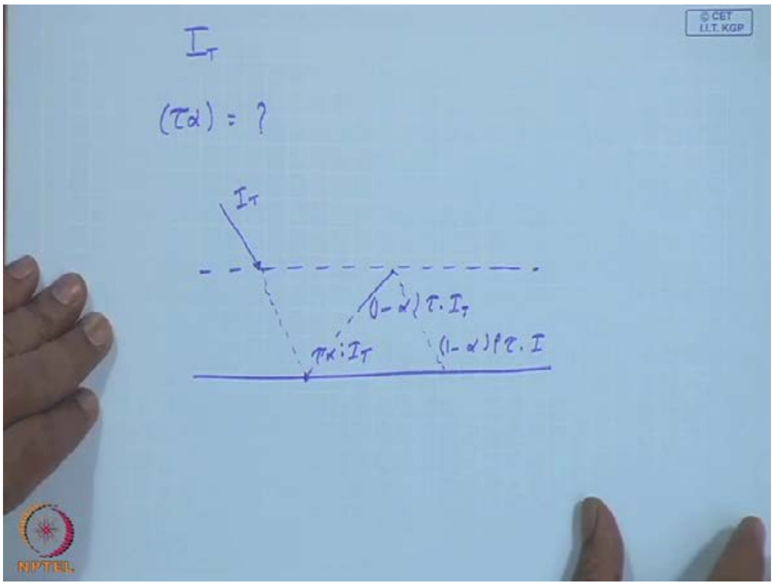

Now, we are set about to calculate tau alpha that is the effective transmittance absorber product. If this is your absorber and this is the glass plate my incidence solar array of I T will be penetrating and if that is a unity this will be tau alpha into I T we will be absorbed. A part of it will be reflected which will be 1 minus alpha into tau into of course, I T; again this process keeps on happening this will be 1 minus alpha into rho tau into I T the reflective of glass surface is rho a part of it will be reflected.

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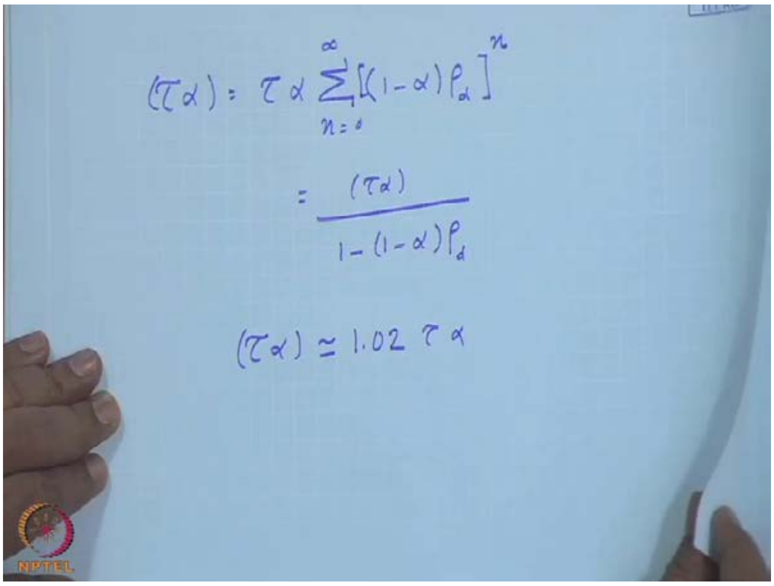

So this continues, and if you some of the total absorbed energy or the effect to transfer to SR product, the product of alpha, this typically summation over infinite number of reflections. This should be equal to tau alpha by binomial explanation 1 minus 1 minus alpha times rho t this is the refuses of the surplus. So, this is the actual formula for the effective transporter the product we tells it should be little higher than the actual tau into alpha. And is a simple thumb rule is effective transmission product is approximately equal to 1.02 times tau into alpha; that means, it is about 2 percent more than the product tau and alpha.

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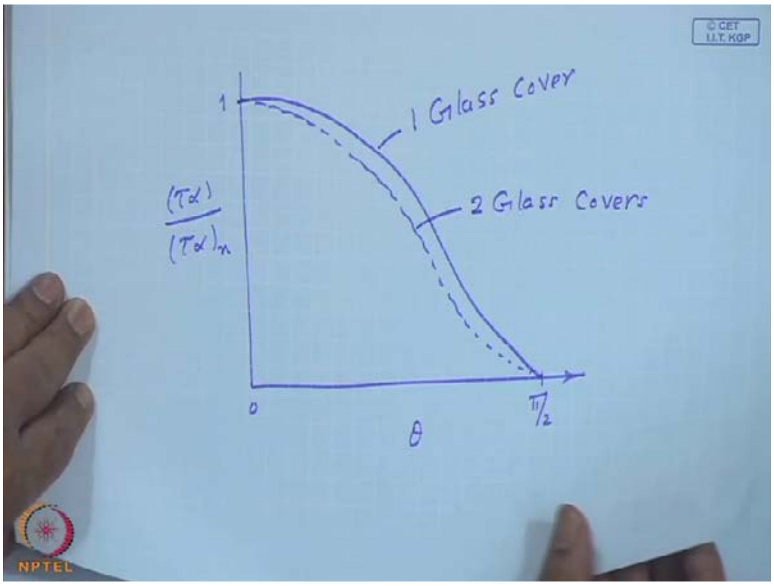

Now, if you plot the variation of transmission absorptance product at any angle of incident theta by the normal transportation absorptance product that theta equal to pi by 2, this will be 1 at theta equal to 0 and this is pi by 2 something like this it will go to 0. This is 1 glass cover, if you have 2 glass covers little bit slightly something like this a simple minded calculation will be tau into tau into alpha, which will be less than tau into alpha consequently the effective transmission of certain product for 2 glass covers will be less than 1 glass cover.

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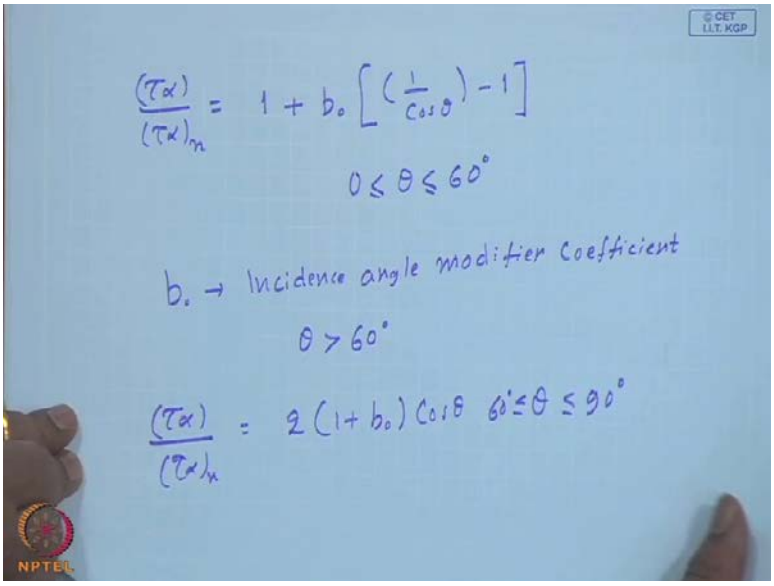

Now, this is describe by hash by know this reference 2 tau alpha n that is the transportation SR product at normal incident is a material property that will be the highest for the given material glass cover and the SR. If the incident is normal then you have the maximum transparence, because the part to traverse will be minimum this is described accurately, adequately rather for 0 less than theta less than 60 degrees equal to.

And this b 0 is call the incidence angle modifier coefficient. In other words this modify transportation product from the value at normal incidence by a certain fashion. However, there is no description for theta greater than theta greater than 60 degrees will proposed at IIT Kharagpur, this can be give by theta less than or equal to 90 less than or equal to 60. This is if you put theta equal to 60 degrees that will be one half, which will be 1 plus b 0 which is same as first one and theta equal to pi by 2 it will be 0. So, it follows the line between 60 and 90 very close to the data values.

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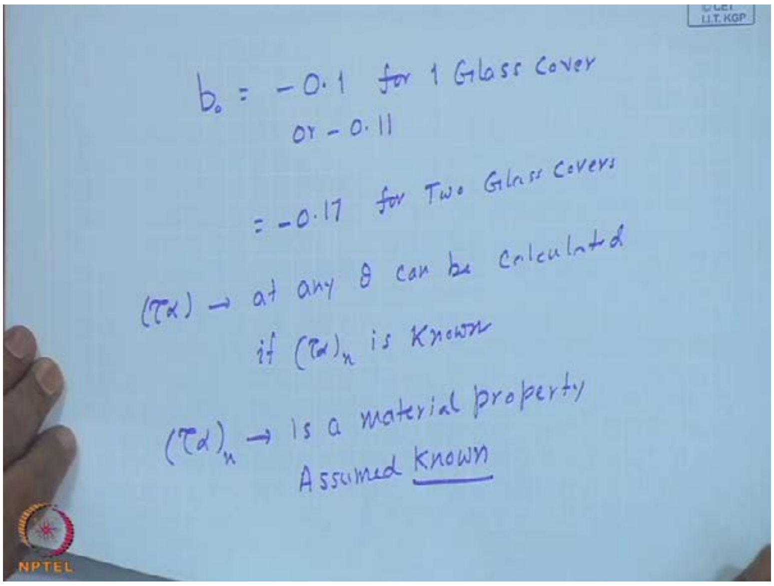

And the typical values for b 0 minus or 0.1 for 1 glass cover or minus 0.11 at times and equal to 0.17 for 2 glass covers. So, what we have now is tau alpha at any theta can be calculated if tau alpha n is known. So, tau alpha n is a material property assumed as known. So, we know the transportation of certain product at normal incidents and we can calculate at any angle of incidence with this law which contents incident angle modified confident b 0 and which will take on the value of minus 0.11 or minus 0.17 depending on 1 glass cover or 2 glass covers.

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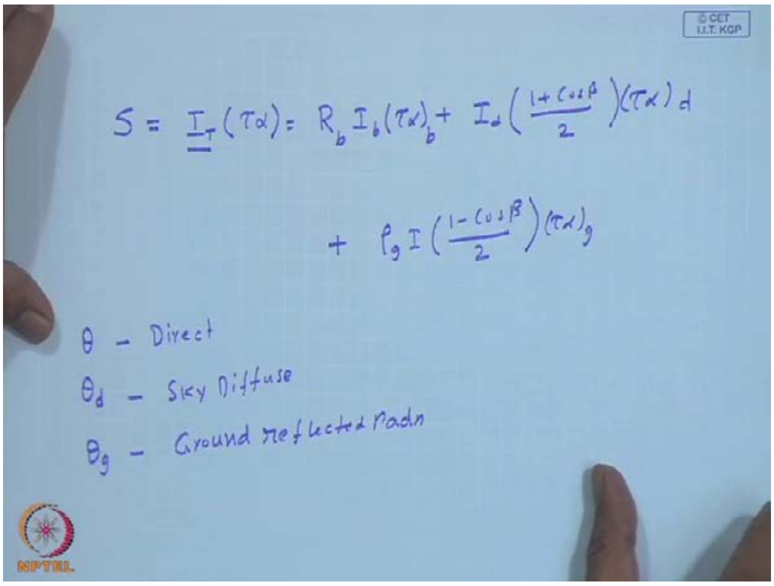

Now, this SR radiation S is given by incident radiation multiplied by effective transpative product. Now, we know that this I T compels of direct radiation and sky diffuse radiation plus ground defected radiation, we can say that the direct radiation strike the surface at the angle of incidence theta.

But the sky diffuse radiation comes in all possible directions we do not know what is the effective angle of incidence for this sky diffuse radiation. This for direct, this is for sky diffuse. Now for the ground fact radiation, similarly is also diffuse radiation this will be effectively stacking the surface at a angle in incidence of theta g. We have no idea of what is theta d and what is theta g, but a given our a day location and orientation recollector we can calculate the angle of incidence at which the direct radiation strikes.

So, to distinguish with theta d theta g I should filling this blanks which tau alpha (( )) with tau alpha b this 1 with tau alpha diffuse and this one with tau alpha ground defected radiation right. So, know my total tau alpha is a summation of three components tau alpha direct, tau alpha sky diffuse and tau alpha ground associated with the corresponding component solar radiation striking the surface.

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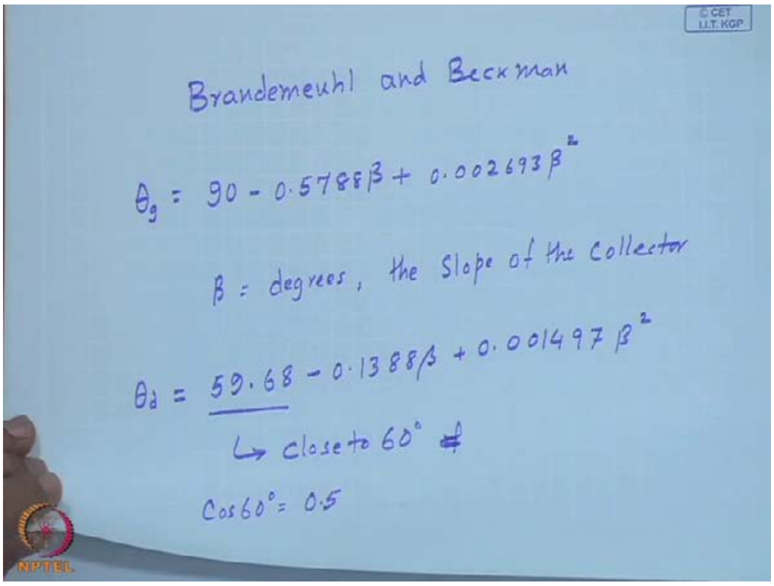

So, Brandemeuhl and Beckman they are correlated theta g the effective angle of incidence for the ground reflected radiation as 90 minus 0.5788 beta plus 0.002693 beta square, where beta is an degrees the slope of the correct. Now, you can use it terminology collected, because this tau alpha deals with the collector instead of a general tilted surface as we have been doing in calculating I T H t etcetera. Similarly the effective angle of incidence for round reflected sorry diffuse radiation is given by 59.68 minus 0.1388 beta plus 0.001497 beta square.

Now, if you see the ground reflected radiation theta g if beta equal to 0 this theta g will be 90 and making the tau alpha g 0; that means, if beta equal to 0 is a horizontal surface. So, there will be known ground reflected radiation falling and also the consequent transmitted subtract of the radiations. Similarly this is close to 60 degrees, if beta is 0 it will be only 59.68 and cos 60 degrees is 0.5. So, if you have a horizontal collector how transmittance of transport product will be corresponding to theta is equal to 60, which is cos 60 a half.

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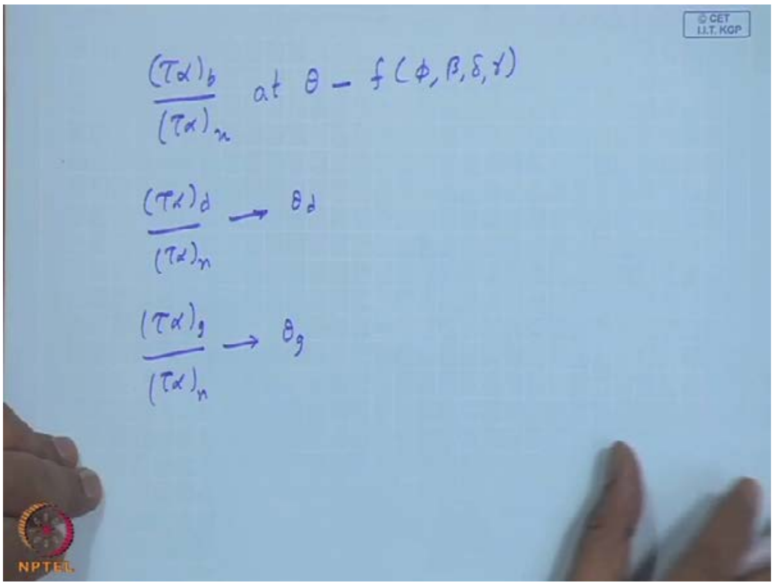

So, now we have to evaluate where in mind at theta a function of phi beta delta and gamma of the direct radiation. And this tau alpha defuse by tau normal at theta d given by the above equation and tau alpha ground by tau alpha normal to be evaluated at theta g as given by the previous equation.

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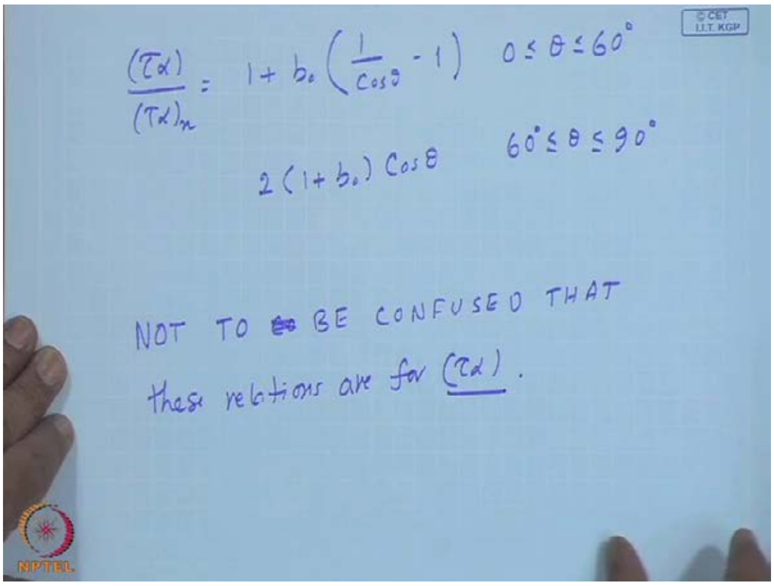

Now, we have to remember one thing the relation which you have to written or this is not to be confused is not just for they overall transmitted absorptance product it is a property how transmitted absorptance product ratio with three transmitted absorptance product at normal incidence.

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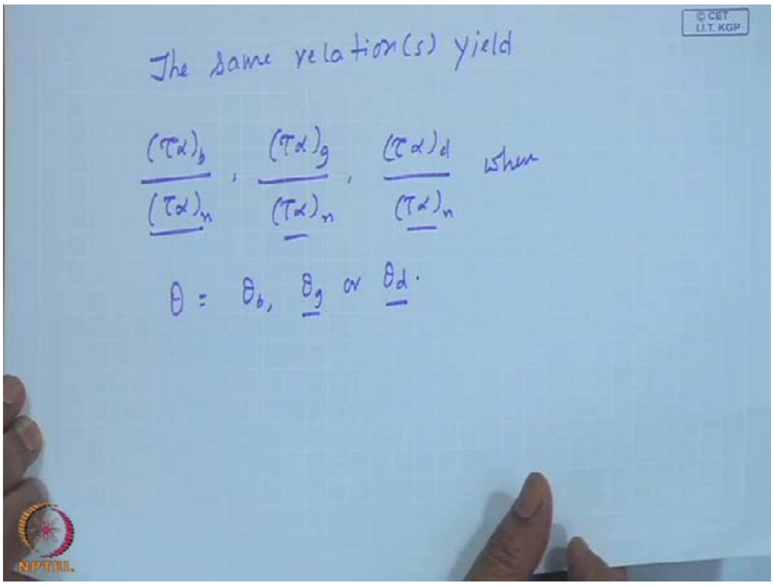

The same relations yield all the ratios of direct transmitted absorptance product tau alpha g upon tau alpha normal, tau alpha d upon tau alpha normal when theta d theta b theta g or theta d. So, you will you see theta b you will get tau alpha b by tau alpha n you will use theta g or theta g you will get this corresponding transmitted substance of product of ratio with respect to the normal incidence value.

So, it is not difficult when once, because theta d and theta g the correlation are available which are when developed by Brandemeuhl and Beckman. So, you can calculate tau alpha at any incidence time of the day are the location of calculating theta d and theta g fortunately they depend only on your slope of the collector beta and nothing else and one can calculate this transmitted absorptance product effective.

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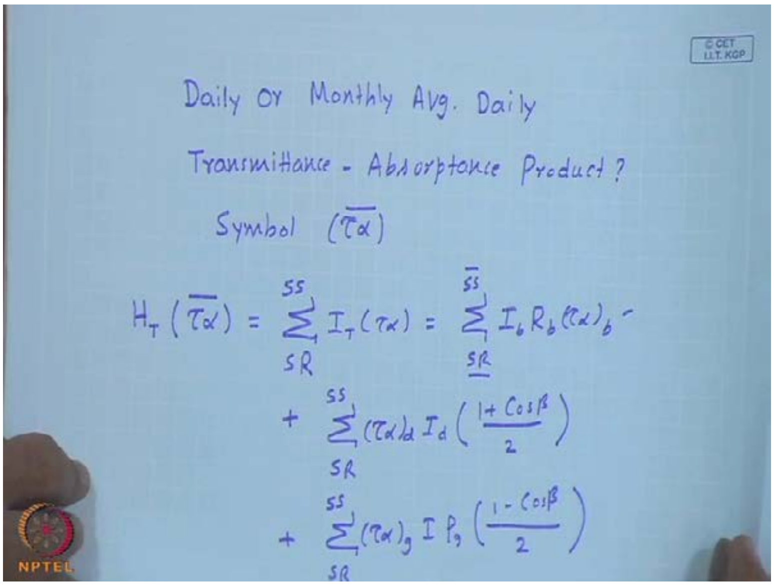

Now, how do we do or calculate daily or monthly average daily transmittance absorptance product. So, if I give a symbol like we had R b bar and r bar if H T is daily radiation falling on the collector surface that multiplied by effective transmitted absorptance production of the day. I should be able to go get it as a summation from sunrise to sunset of I T tau alpha, this should be equal to summation of the direct radiation component.

So, you will notice in all these summations I am only categoryly stating sunrise to sunset. Now, we know that this will be for reference for the appearance sunrise to sunset, whereas these two components will be from physical sunrise to sunset never the less in general we can write them SR and SS.

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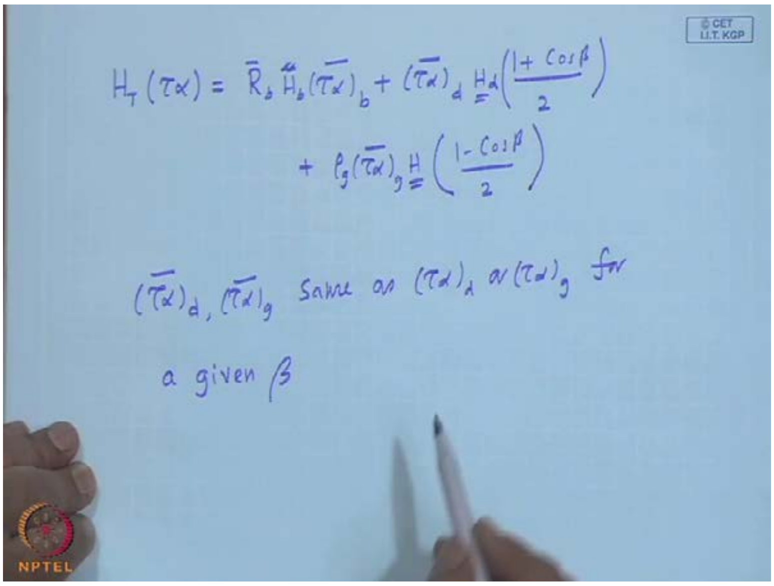

So, if I express like we had done it for R bar are this need not be a bar. Fortunately tau alpha bar d tau alpha bar g same as tau alpha d or tau alpha g for a given beta; since is only a function of slope of the collector it does not change from from hour to hour. So, the average daily transmittance absorber product for the diffuse radiation or for the ground reflector radiation is a single number, which can be put out of my submission sign consequently this submissions will be H and H d over the d.

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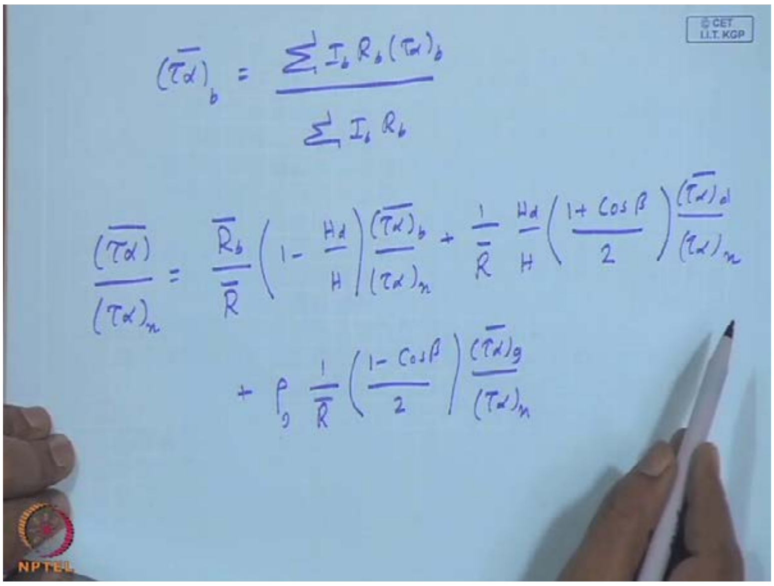

However, since I b changes this tau alpha bar for direct radiation should be defined has a weighted average; this is the absorbed direct radiation by the absorb radiation falling on the collector which will give you the average are transmittance absorber product key for the direct radiation. So, if we define a overall tau alpha bar upon, now I have divided throughout with tau alpha n for normalize this algebra you can do straight forward.

what we have done is are divided throughout with tau alpha normal to make them ratios of tau alpha b bar by tau alpha n tau alpha d bar by tau alpha n and tau alpha bar g by tau alpha bar n. Divided then again H T which will be nothing but, R bar into H, so that and expressing H b as H minus H T like we have done earlier you get this simplification factor. Now, this needs to be evaluated with the data as a weighted average of each hourly value.

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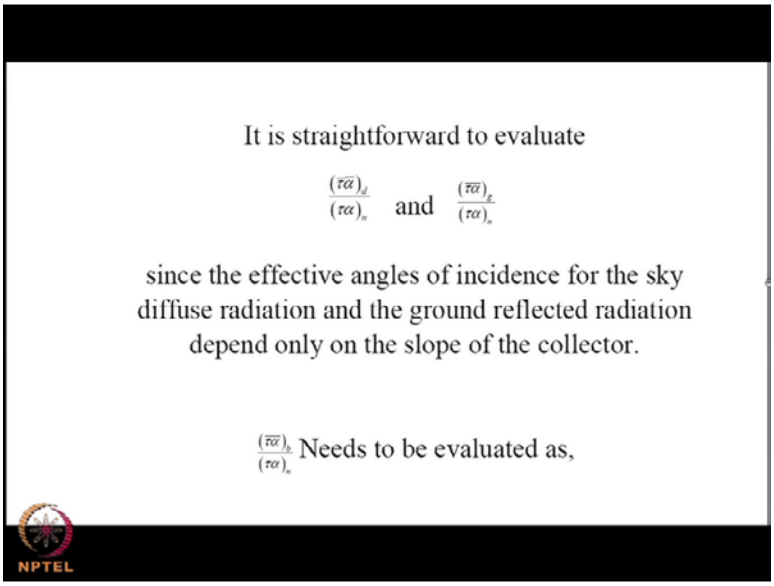

So, this I have already mentioned that alpha bar d and alpha bar g can be evaluated when once you know theta d and theta g which are simple functions of the slope of the collector and this needs to be a weighted average.

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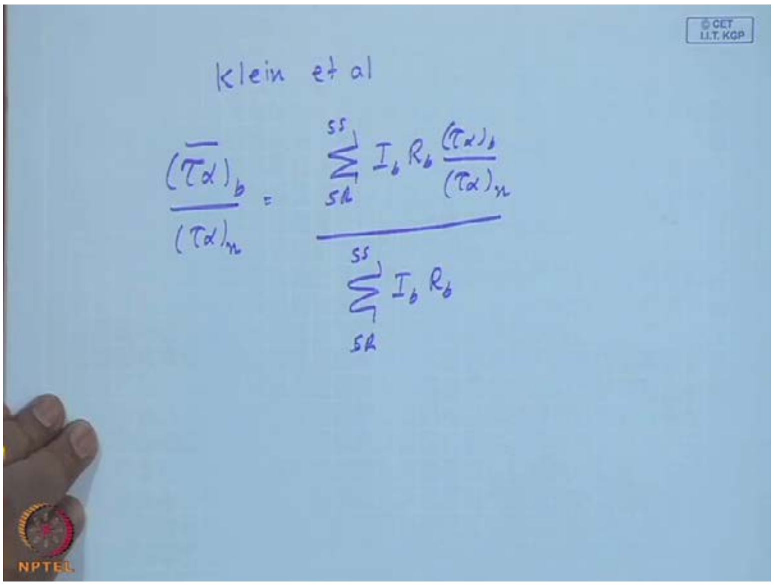

Klein e t al have evaluated this tau alpha bar b by tau alpha n given by sigma I b R b tau alpha b up on tau alpha n again sunrise to sunset appropriate by I b R b sunrise to sunset, what are they approaches the that are value.

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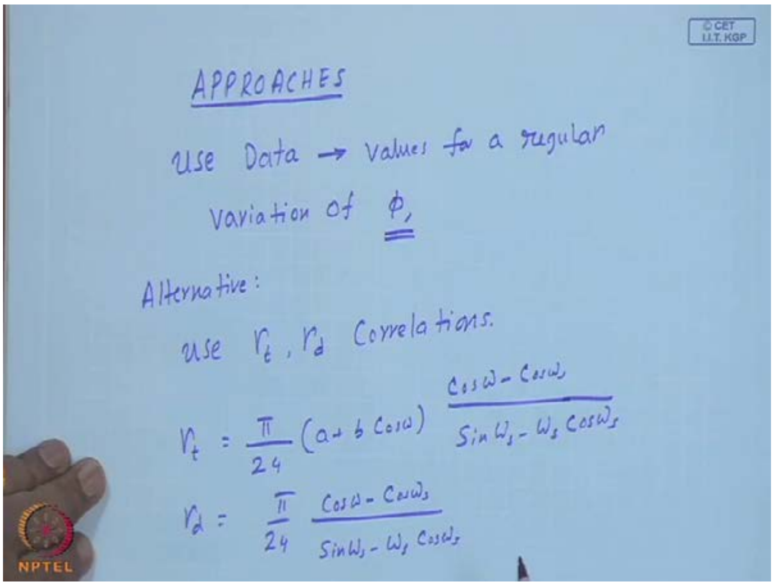

Use data, so you have a large data base like a n by 2, but covers about 25 degrees latitude to 49, 50 degrees latitude may not be covering all the lower latitude search one part. The second thing is one may not be able to have values for a regular variation of phi particularly beta, delta and gamma are in my hands, but not latitude. So, the other alternative is r t and r b correlations can be used right, where we have got r t is pi by 24 a plus b cos omega cos omega minus cos omega s by sin omega s omega s cos omega s you can check the relations. Similarly r d is pi by 24 times cos omega minus cos omega s by sin omega s minus omega s cos omega s.

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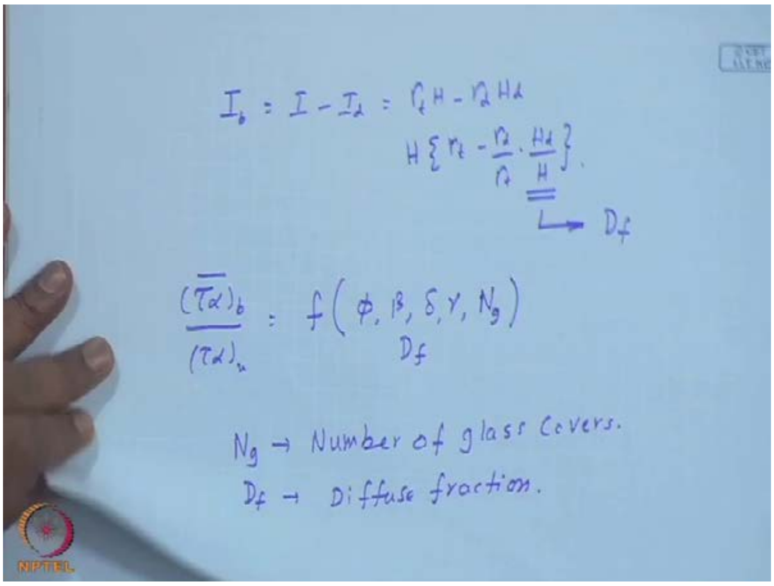

So, I b as we done earlier, I minus I d r t into H minus r d into H d or one might write it H times r t minus r d by r t times the diffuse fraction H d by H. So, now, from this relation this is our standard symbol, which we have been using as D f the diffuse fraction. So, I can except in general tau alpha bar b up on tau alpha normal a function of phi of course, beta, delta, gamma and N g this is what I will call it the number of glass covers, this is in general what except and in addition the diffuse fraction.

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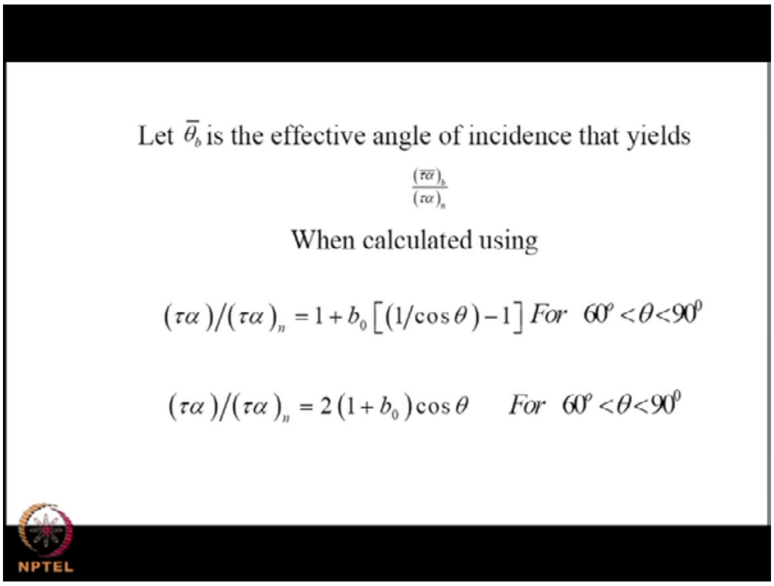

So, having got this tau alpha bar b by 2 alpha n, whether it is calculated using the beta or whether it is calculating r t and r d correlation, they have put back in the relation for 2 alpha bar n by tau alpha normal.

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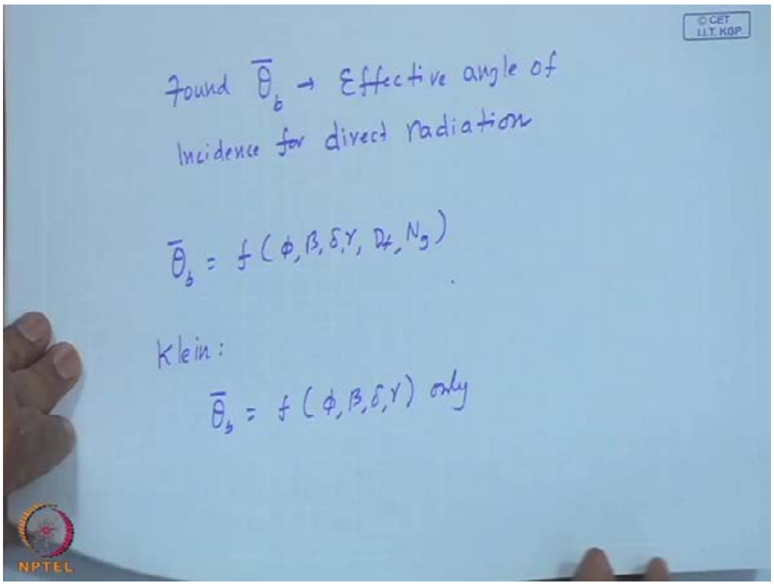

And found theta b, because it is a day this is the theta b bar this so called effective angle of incidence for direct radiation. So, if you have got this, and now as a Klien this should in general be a function of, pi beta, delta, gamma D f and N g.

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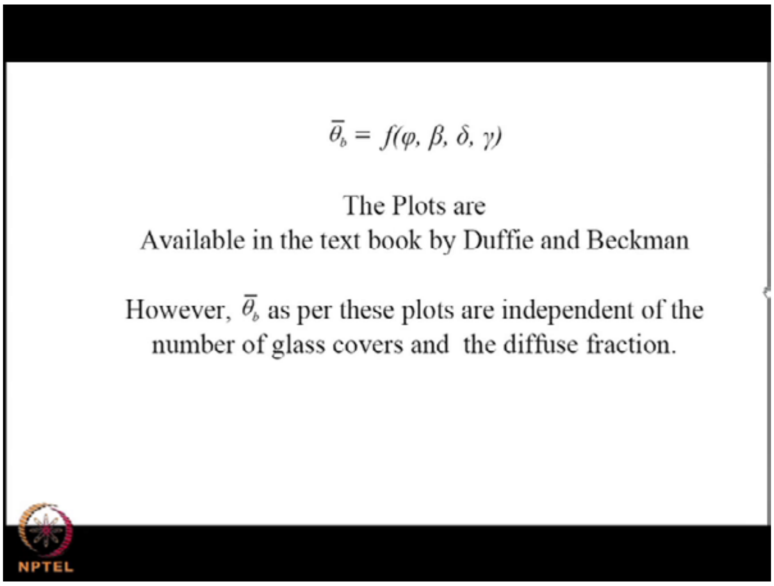

So, they have been given plots for a given as a function of pi beta, delta and gamma only the dependence on the climate are the diffuse fraction are the number of glass covers is not available in this plots.

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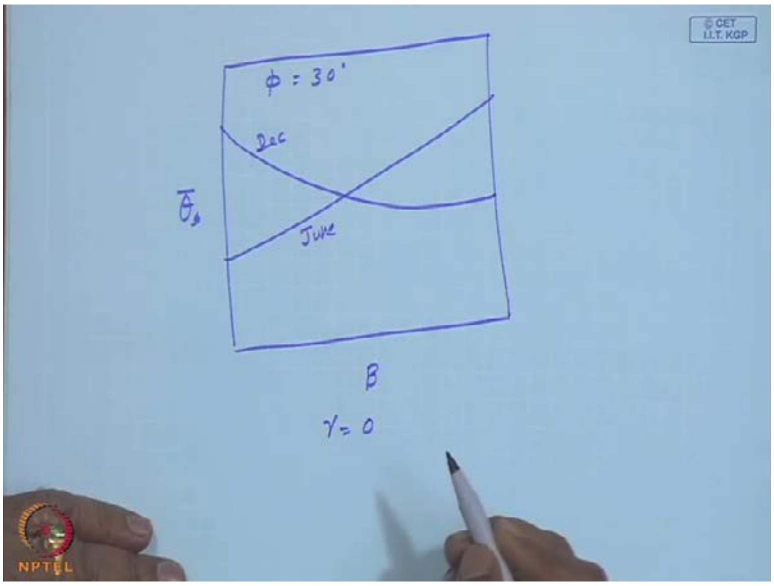

So, they typically look something like this, is with respect to beta and theta b bar this is for latitude of let us a 30 degrees and you may have this is for December, this is for June. So, in between November at (( )) depending up on the decreasing order of magnitude of declination they will be appeared and this is for gamma equal to 0.

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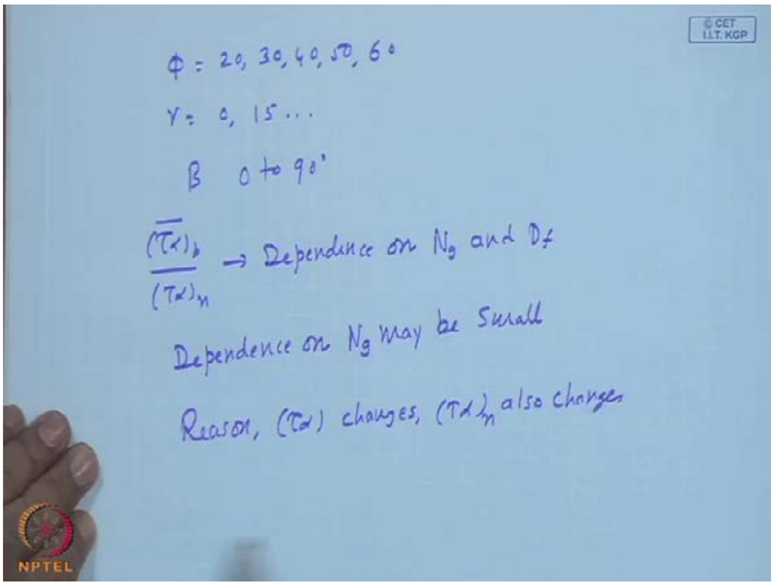

So, you have several plots for pi equal to 20, 30, 40, 50 and per as 60 and see 70 also; similarly gamma equal to 0 15, so on and so forth and the beta 0 to 90 degrees.

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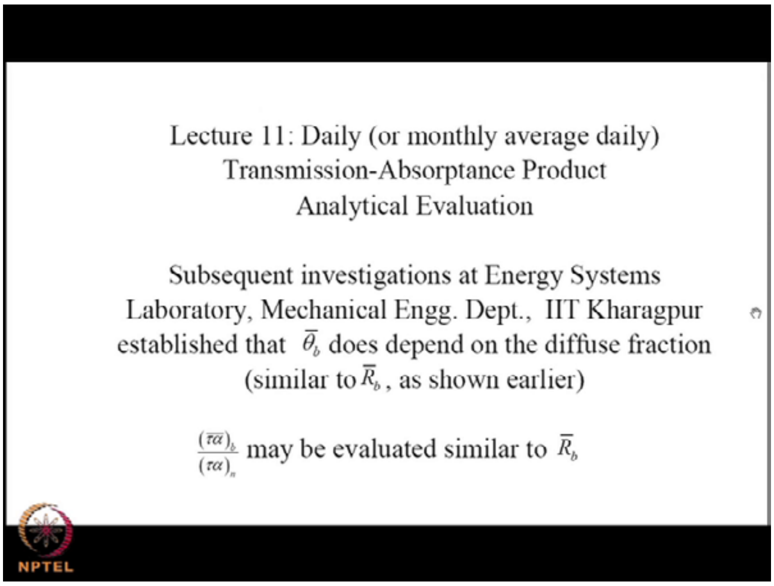

So, this tau alpha bar b by tau alpha n not being dependent, one possibility is dependence on N g may be small reason tau alpha changes tau alpha normal also changes.

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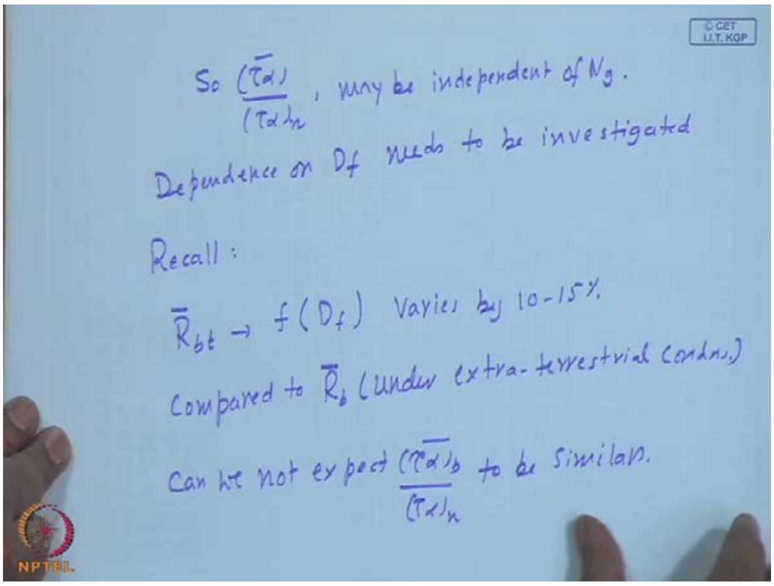

So, tau alpha by tau alpha normal in general, average maybe independent of N g, but dependence on D f needs to be investigate. So, you may recall R b bar T a function of D f and various by 10 to 15 percent compared to R b bar under extra terrestrial conditions, so can we not expect to be similar. So, what we try to do in this lecture is essentially we have given the useful energy gain equation for a solar collector particularly a flat plate solar collector, in that we know how to process the incoming radiation.

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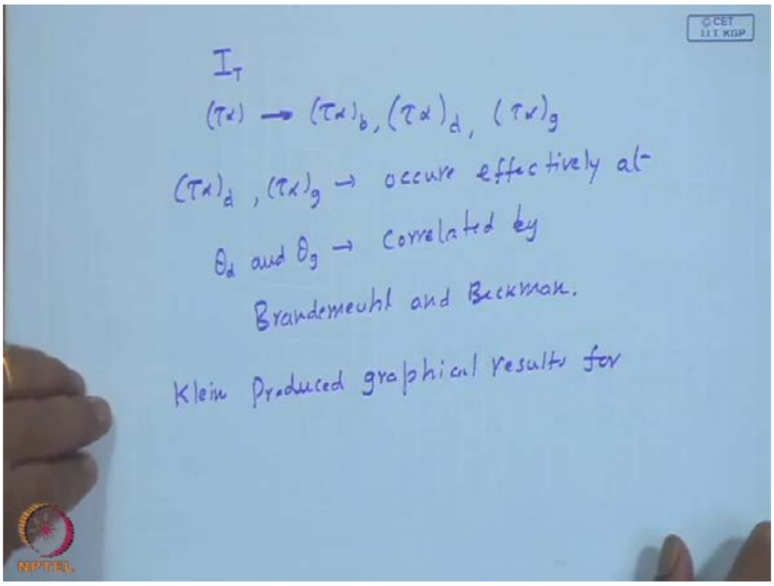

Then we identify that there is a optical property transmittance absorptance product compress of three components for the direct radiation and for the diffuse radiation and the ground reflected radiation. This tau alpha d and tau alpha g occur at effetely at theta d and theta g correlated by Brandemeuhl and Beckman.

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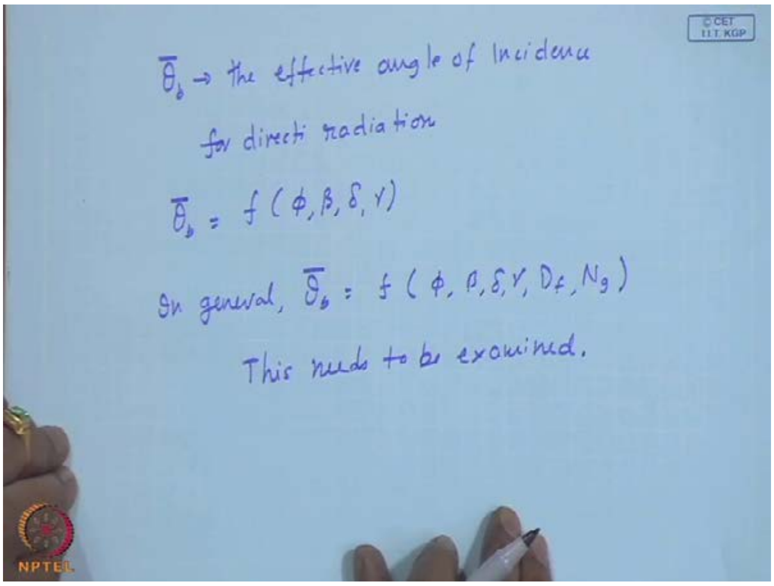

Klein produced graphical results for theta b bar the effective angle of incidence for direct radiation as a function of latitude of the location, slope of the collector the month and the (()). But in general, theta b bar can be expect to be a function of pi, beta, delta, gamma, diffuse fraction and the number of glass covers, this needs to be examined.