Energy Efficiency, Acoustics & Daylighting in building

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Lecture – 54
Design Sky Models

So, what I was saying is that we talked about Indian design sky and if you recollect that it was B theta is equals to B Z cosec theta; theta greater than 0 no not 0 phi by 12 to you know phi by 12 to theta greater than pi by 12 to pi by 2 greater than equals to pi by 2 and equals to B Z cosec pi by 2 pi by 12 for theta greater than 0 to pi by 12.

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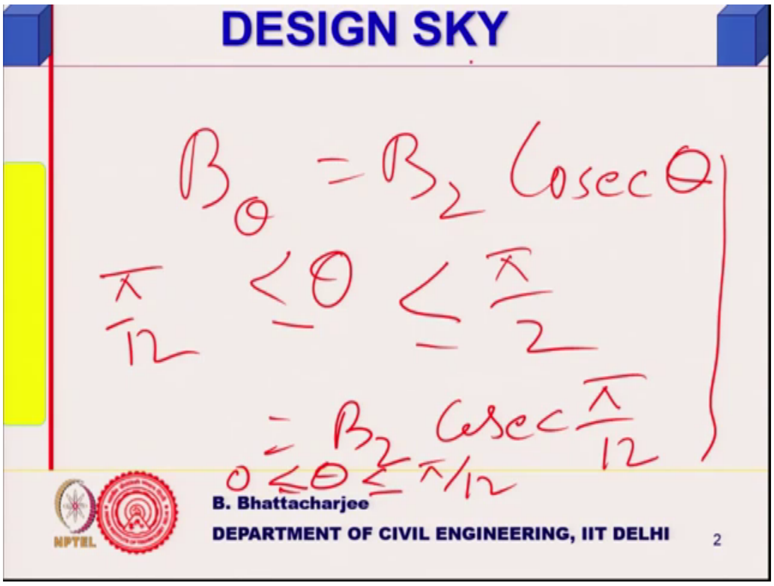

So, this was this was you know they assumed a sky which is very you know, it is it is it is brightness is very high near the horizon some measurements must have been done, but then this is this was Indian design sky and that is what you find in the code and that is what we talked about earlier. But there, as I said there are a lot of changes actually and possibly Indian code would also need a change because, there has been a lot of experiment global experiments; but largely they were in the not you know not on tropical climate, but even some measurements were done in India as a part of a global program.

So, from those kind of global program the first 1 then you know we look into different types of skies one of the non uniform sky which was proposed somewhere around 1996 looked like this B.

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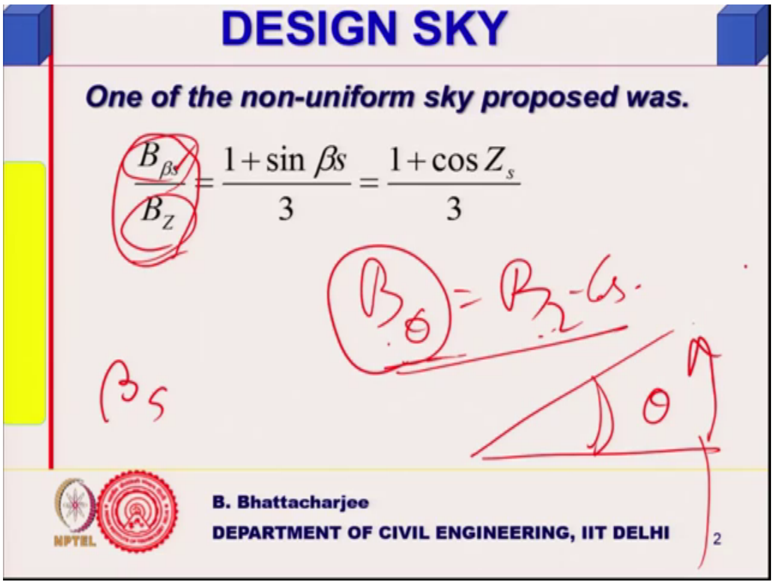

So, this they started you know even there if you seen earlier we talked in terms of B theta was equals to B Z cosec theta right B Z cosec theta. So, you actually you actually relate this brightness of the sky, in this at earlier case only we are doing it at a design point.

So, therefore it corresponded to a specific time and specific part of the skies horizon, if you remember it we were talking about this horizon or the quadrant which is opposite to the sun opposite to the sun. So, at a specific time which means we are fixing up according to a particular you know this theta is essentially theta is essentially the altitude of the point or altitude the point in the sky where I am interested in brightness.

Now, that is defined here in terms of beta Bs I am calling it with beta Bs because, code uses theta. So, we are using that notation theta beta s stands for the elevation angle if I may call, so elevation angle of a particular point in the sky horizon right that is why s.

So, I choose any point in the sky a small element and it is this angle is B beta s and divided by B z. So, here also see it was all ratio B theta by B Z s cosec theta very simple function, it was used for a non uniform sky sometimes people propose something of this kind that a for a for the illumination at any point in a sky element. So, let me draw it like this let me let me draw it like this.

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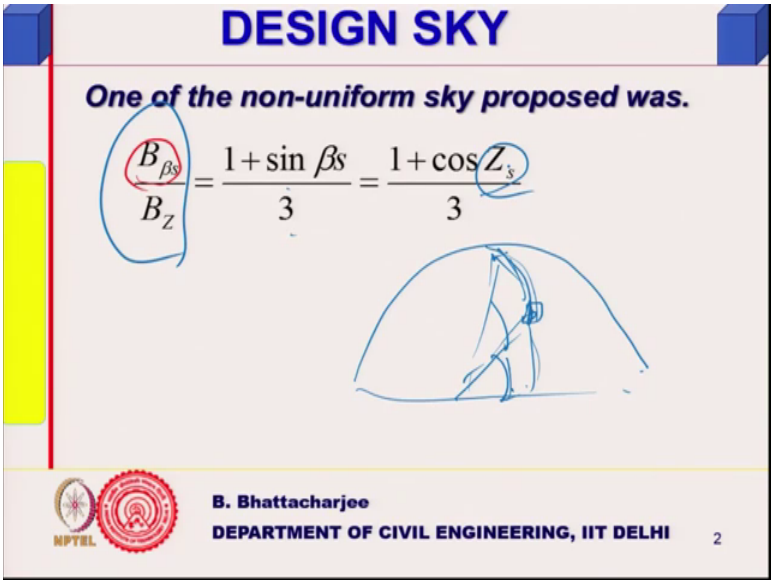

Let me draw it like this so that is my sky right that is my sky and consider some element somewhere some element somewhere right and somewhere and this is this is it is angle with the angle with the this angle I am calling as beta s beta s stands, s stands for sky element. You know I am using notation consistent with whatever we have used earlier, since beta is the notation we use for altitude angle to separate it from altitude angle of the sun.

I put in here beta s, s stands for sky element right or beta sky one could have called so ratio of this is given and this is written as 1 plus sign , earlier it was cosec 1 plus sign plus. Now this would correspond to a zenith angle because, zenith angle of this element in the sky zenith angle of the sky element. So, if I know the zenith from there this is as anything so that is we are calling as Z s.

So, sin beta s is nothing but cos beta cos Z s, Z s is the zenith angle the angle this point makes with the 90 degree minus beta s 90 degree minus beta s 90 degree minus beta s. So, this was 1 of the sky proposed earlier sky is proposed earlier right.

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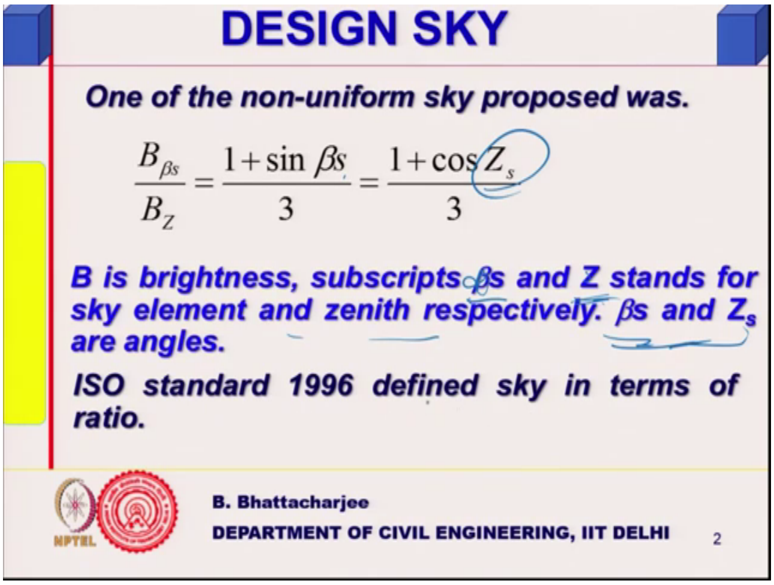

So, B is a brightness subscript beta subscript beta s and Z stands for sky element and they are zenith respectively right. So, this is a sun Z will be sun's zenith Z will stands for suns zenith and for sky element the you know subscript this subscript s not this, B is a brightness subscript s stands for j beta stands for altitude elevation angle, Z stands for sky element angles zenith of the sky element angle and s and you know these are the these are the angles basically Z s stands for the zenith go.

So, we will we will make a diagram and show it. So, then Indians international standard organization defines sky in terms of these ratios this ratios right this ratios. So, this diagram that I was talking about look something like this, you see this is your horizontal plane this is the sky element and this is the sun right this is sky element this is the sun.

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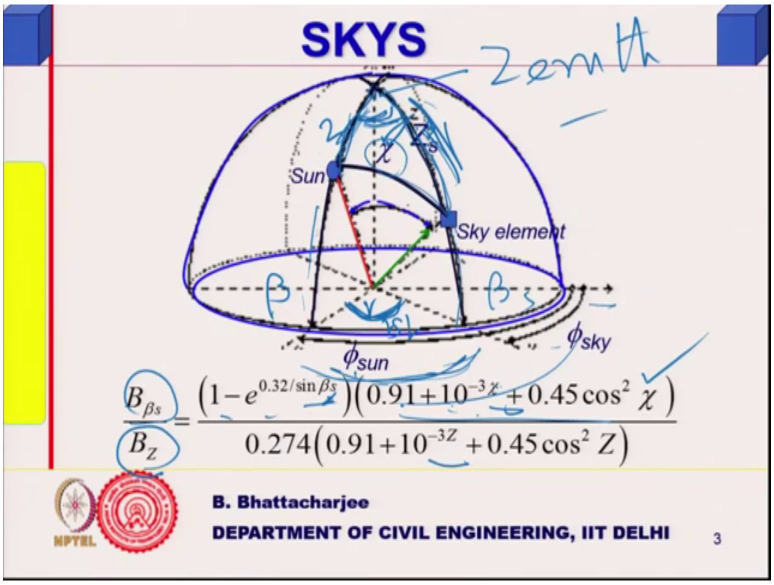

So, this is my and this is the zenith point this is zenith point zenith. So, this is a zenith point you know it is kind of a showing to trying to show in 3D. So, this angle I call as Z this angle will be sky element makes a Z s, you know this I am calling as so this is this I will come to this later on this is Z s and this is your beta s that is how I am defining beta s sky element and this is our normal Z is here zenith angle of the sun that is what we have used so far.

So, I did not want to put a subscript here and this is what is this is beta altitude angle of the sun that is what we have used. So, far altitude angle of the sun is beta and the angle between this 2 angle between this 2 I am calling is you know I will I will just define 1 minute because ok.

Now, sun's position I define by 2 angles 1 is at altitudes angle beta, other is a azimuth angle from north. So, if this is north in the horizon you know. So, this is this is this is azimuth angle of the sun azimuth angle of the sun is like this. Similarly, azimuth angle of the point that I of my interest or sky element is theta sky. So, it has been made now more general you can find out the brightness at any point in the sky, as a you know sky in terms of the zenith brightness in terms of the zenith brightness that was a that is how the functions are expressed.

So, this 2 are this 2 element so this is Z s and this angle we are calling it this what is this notation chi actually I think sky or whatever it is, so this is this is what is used standard use so this is the angle. Now you can see there is a spherical triangle, what is a spherical triangle this is the spherical triangle this is a spherical triangle right and this is 1 arc this another arc the side arc actually and this is a third arc and this is a angle between this 2 arc.

So, I can actually find out the difference in the azimuth angles because, that is something like wall solar azimuth the difference between these 2 is something similar to wall solar azimuth we talked about. So, this angle which is the included angle between these 2 arcs or 2 sides that can be related in terms of this arc angle this angle and this angle right. So, this is what is done anyway I will come to that angle later on, but just before that.

So, you know 1 of those I s o sky suggested was something like this B beta s divided by B Z is 1 minus exponential sin beta s plus point some constant 10 to power minus 3 into to the power k and cos square. So, we can see that there is a function involving this ratio is a function involving this, how much it is away from the sun how much it is away from the sun right. So, that is more it is away this angles is nothing but the arc distance more it is away.

So, it is 10 to the power minus 3 chi this one which means that more this is this will be this value will be smaller this value will be smaller and cos of this angle against cos is cos angle is anyway a fraction, so square it up and so on. So, this will be related to this will be related to this angle brightness would change depending upon the distance from the sun right.

So, if it is opposite quadrant actually you can find out that would be essentially exactly opposite means 180 degree it would make right, 180 degree should make completely opposite 180 degrees should make because, this is 2 pi.

So, pi angle it will make exactly opposite quadrant exactly at the opposite point and then this is so this is function of this angle. Then there is a function of this Z z angles zenith function of zenith angle and there is a constant. So, also this function of this beat beta s is nothing but cos Z s.

So, it is a function of zenith angle of the point zenith angle of the sun sorry this is Z s yeah function of Z s sin beta s is nothing but cos Z z s sin beta s is nothing but cos Z s. So, it is a function of this angle function of this as well and also a function of this angle.

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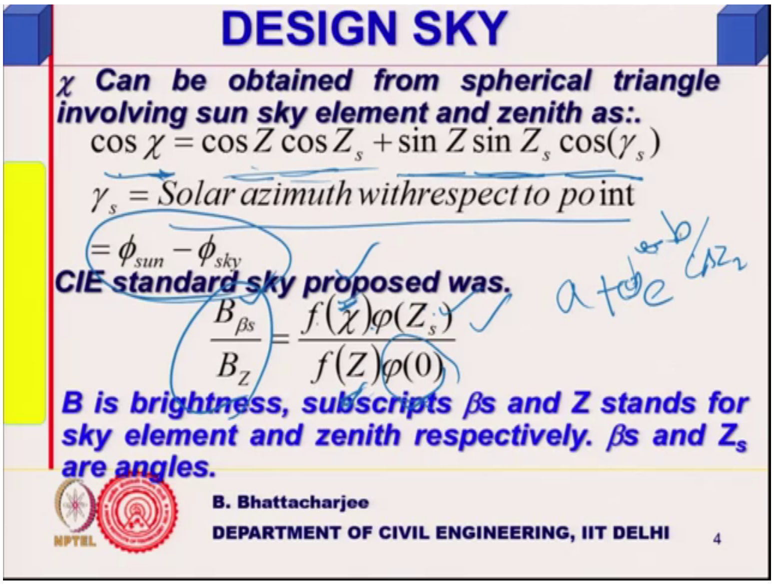

So, this angle first let us look at from the spherical triangle can this can be obtained, from spherical triangle as cause of this remembering the same formula that we have used earlier sin of Z sin of Z s that is what will come sin of Z and sin of Z s and included angle is cos of difference between these 2 angle right, because included angle is nothing but this angle you know this angle included angle is this angle. So, this angle is phi sun phi sky where phi is a azimuth angle this is the same convention we used earlier and phi of the sky element.

So, this I am calling it as gamma sky gamma sky, so this angle I am calling it as gamma sky. So, included angle is gamma sky right and if I write this formula included angle is gamma sky that was cos and remember this was sin Z sin Z s you know because this was this was sin Z and sin Z s, because we took cross product sin Z and sin Z s into cos of this included angle must be equals to cos of those 2 angles must be equals to cos of this , this minus remember this minus cos of this cos of the third angle minus cos of this are the 2 angle. So, if I take it on the other side this is what either get the formula this is solar azimuth with respect to the point which is phi sun.

So, this angle I can find out any point it is related to it is related to the zenith angle of the sun and distance of the you know it is related to distance azimuth angle or wall solar azimuth take point solar azimuth, if I can call it or solar azimuth with respect to the point. So, it is related to all this so that is how I can find out this 1 and my brightness is a function of this my brightness is a function of this right. So, CIE standard sky proposed is this ratio that is brightness at any point in the sky is given a function of this like in a similar manner function of Z s function of Z and this is function of 0. If you put Z as equals to 0; that means, is Z zenith this is Z z is equals to 0 means this is Z zenith.

So, if you know the phi value at 0 you know this function value at 0 and phi Z is given, so this is remember this was the form of the curve I will come back to this is the form of the curve. So, this involves Z and it involved a constant right Z is the zenith angle of the sun it involved a constant and this involved this function. So, exactly and this is nothing but cos Z s. So, if you see that this is this is how the sky look like you know so it is it is function is something of these kinds.

So, is a 1 was that exponential function of Z s you know sin cos Z s was there and exponential function related to this was related to zenith angle and this is a constant 0.234 or something. So, typically this is our sky is generally now expressed now it is sky is expressed in this manner, now how do you find out f of function this functions let us see. So, be is brightness etcetera etc that we have already said.

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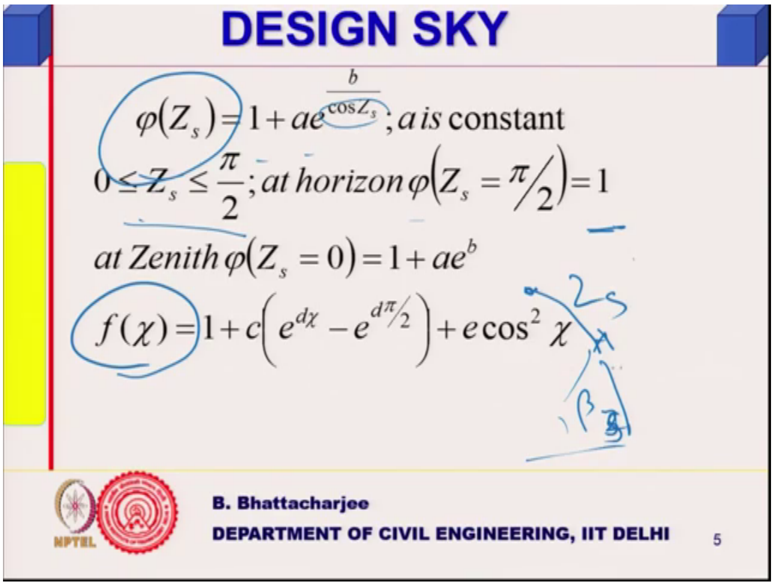

So, this function is given as 1 plus a to the power B by cos Z s, you can see that it is similar almost similar to what was there in that equation it was almost similar to what was there in this equation, it is almost similar to whatever was there in this equations cos

Z s. So, it is a function of Z s you know it is a function of Z s 1 plus a e to the power B divided by cos z.

So, 2 constants we have a is a constant B is also a constant and this is valid you know 0 to pi by 2 because, Z s will varies the locations zenith angle will vary sky from the sky element to the zenith that angle will vary from pi to 0 to pi by 2 0 to. So, corresponding to 0 it is at the zenith itself corresponding to pi by 2 it is at horizon, you know I am talking of this angle this is my sky element this is a zenith.

So, this is Z s I am calling it and this angle is I am calling it as beta yeah beta, beta, beta s I am calling it beta s right I am calling it beta s. So, this is Z s so when Z s equals to 0 that is at zenith and this is 1 plus you know at 1 plus this equal to cos 0 is equals to1. So, a to the a to the b, but what about horizon pi by 2 pi by 2 this is taken as 1 for pi by 2 it is taken as 1 basically this values you know this is this a positive value, so it is actually goes to infinity Z s equals to pi by 2 cos 0 goes to infinity.

So, it is taken as 1 because in not defined so it is a kind of a point singularity or something yeah. So, it actually it is taken as this values is taken as approaching 1 right, approaching 1 as this phi tends to phi by 2 right. So, that otherwise this well would be very large this value would be small it will be very large, so that is that is the point, but taken close to 1 ok. So, constants are defined in that manner and a constants are defined in that manner constants are defined in this manner supposing B is negative, then all this problem is going to get solved , so constants are defined in that manner right these are empirical constant.

Now, this function is defined in this manner this function is defined in this manner 1 plus C e to the power D into this and e to the power D pi by 2 minus. So, there is a similarity there is a similarity here also.

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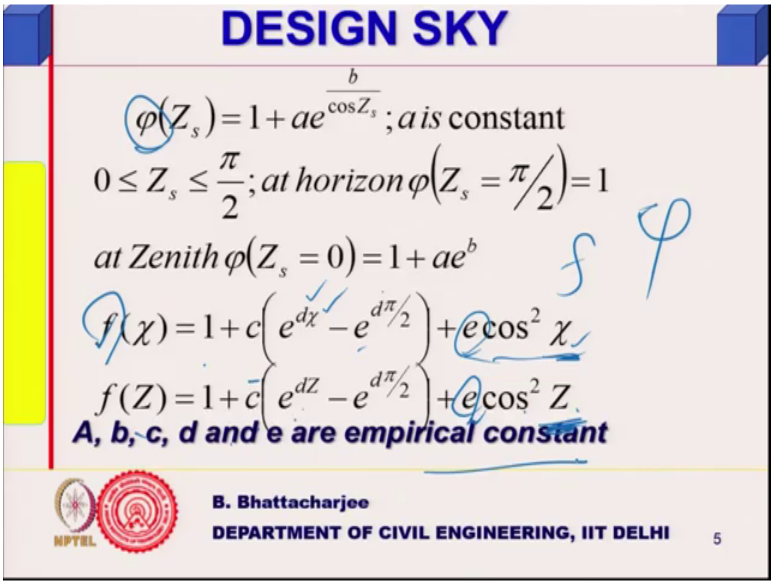

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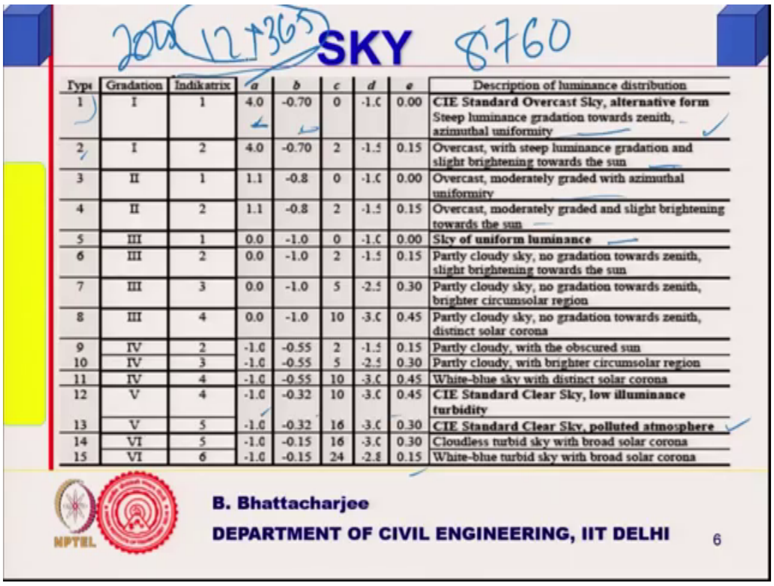

Type	Gradation	Indikatrix	a	b	c	d	e	Description of luminance distribution
1	I	1	4.0	-0.70	0	-1.0	0.00	CIE Standard Overcast Sky, alternative form Steep luminance gradation towards zenith, azimuthal uniformity
2	I	2	4.0	-0.70	2	-1.5	0.15	Overcast, with steep luminance gradation and slight brightening towards the sun
3	II	1	1.1	-0.8	0	-1.0	0.00	Overcast, moderately graded with azimuthal uniformity
4	II	2	1.1	-0.8	2	-1.5	0.15	Overcast, moderately graded and slight brightening towards the sun
5	III	1	0.0	-1.0	0	-1.0	0.00	Sky of uniform luminance
6	III	2	0.0	-1.0	2	-1.5	0.15	Partly cloudy sky, no gradation towards zenith, slight brightening towards the sun
7	III	3	0.0	-1.0	5	-2.5	0.30	Partly cloudy sky, no gradation towards zenith, brighter circumsolar region
8	III	4	0.0	-1.0	10	-3.0	0.45	Partly cloudy sky, no gradation towards zenith, distinct solar corona
9	IV	2	-1.0	-0.55	2	-1.5	0.15	Partly cloudy, with the obscured sun
10	IV	3	-1.0	-0.55	5	-2.5	0.30	Partly cloudy, with brighter circumsolar region
11	IV	4	-1.0	-0.55	10	-3.0	0.45	White-blue sky with distinct solar corona
12	V	4	-1.0	-0.32	10	-3.0	0.45	CIE Standard Clear Sky, low illuminance turbidity
13	V	5	-1.0	-0.32	16	-3.0	0.30	CIE Standard Clear Sky, polluted atmosphere
14	VI	5	-1.0	-0.15	16	-3.0	0.30	Cloudless turbid sky with broad solar corona
15	VI	6	-1.0	-0.15	24	-2.8	0.15	White-blue turbid sky with broad solar corona

This e is constant this e is not exponential this constant this is constant not exponential e cos square this. So, for f Z it is the same function because it is a f function there are 2 function f and other 1 is the there are 2 functions, I am using 1 is this another is f f is 1 plus C e to the power D Z e to the power D minus pi by 2 e is a constant cos square corresponding angle.

So, this is for sun solar you know solar zenith angle, this is for the element the angle it makes the element and A B C D are C D E are constant depending upon the sky type A B

C D E are constant depending upon the sky type A B C D E are dependent constant depending upon sky take.

So, therefore these values have been actually proposed these values have been actually proposed right, these values have been proposed and these are empirical constant. So, this has to be determined from experimental wall. So, what they did was they had measurements done in various places particularly in North America US and also somewhat in Japan data's are data's were available, sky brightness data's are available they measure them and 1 or 2 might be also mostly in Berkeley and places like that you know some in Canada and 1 or 2 might be in places like phoenix some of those 1 or 2.

But largely it is in non tropical, but however there was a global program from where they finally, also came out with the constants are not available for Indian scenario some or other we have not been able to trace that data in published literature or also on the source. So, whatever it is so this is how you know the skies are defined.

Now, what are how this A B C D E varies you see their 15 skies defined 15 skies have been defined right face 15 skies have been defined; for example, type 1 type 2 to type fifteen etcetera etcetera. Now this is standard sky this is standard sky right there are alternative forms, so the form this is for example, this is CIE standard sky alternative form steep luminance gradation toward zenith and azimuthal uniformity. So, if there is a it does not vary the azimuth right. So, this is how it has been described and A is 4 B is point minus 0.7.

So, that that makes sense you know B will be always negative otherwise if B is not negative then it will not go to 1 right. So, it is 1 at the that is how the B has been fixed for C stands C is what is C for the for the you know standard overcast sky, which is overcast sky is by enlarge luminance you know gradation toward zenith and it is uniform all over the azimuth; that means, you take in 1 quadrant of the other quadrant it will be same for the overcast sky right and it earlier this was taken to be completely uniform, but now it is not taken to is uniform it is taken like this.

So, let us seize the values of is equals to 0 values of e is equals to 0, so this term is not there this term is not there and this is negative 0.7 or something C is also equals to 0 C is also equals to 0 D is minus 1 0 D is minus 1 right, so this would right. So, this as you increase as the distance increases from the sun as the distance increases from the sun right. So, this angle increases which means that this will be lesser and lesser, but if C is 0 anyway this term is equal to 0 C 0 this term is equals to 0 that is if we go back to this formula you know C is equals to. So, this is simply coming as a constant this is simply because, C is 0 D has got a value D has got a value so, but this whole term will go to 0 e is 0.

So, I have got actually this function equals to 1 this is also 1 and, but this will be there because B is negative A as value 4 or something like that. So, if you see this a has a value of 4 B is negative. So, D is 1 but D is not relevant if C is equal to 0 because, in the formula in the formula D comes here if C is 0 effect of D is not there simply, so all that is there is A and B. So, if you go back to the formula something like this you know this value is we said that it will be 1, this will also be 1 in a way and this values phi Z s how it is phi related 1 of them is 1 plus what is phi Z s is 1 plus A to the power B.

So, only this term is there only this term is there only this term is there depending upon , so you know this is because it is not varying with the A zimuth. So, this term is 0 this term is 0 this value is some value is there A is equals to 4 and B is equals to minus 0.7. So, this value be A plus B to the power I mean e to the power minus B over know some terminology B was some cos was it how much cos Z s so cos Z s cos Z s.

So, B is actually negative B is negative e to the power you know 1 plus e to here A e to the power that is what it is 1 plus A e to the power. So, this is negative this term is the position of the sky element from the zenith position of the sky element from the zenith; that means, along this height the brightness is varying, but it does not vary otherwise right and when Z s is small near the horizon when it is equals to pi by 2, this value becomes 1 at pi by 2 this value is 1 and all other values you know when this is equals to 1 this negative, so this will become least.

So, maximum at the zenith and gradually decreases gradually decreases gradually decreases. In fact, steep gradation that is what we are saying steep gradation steep grid luminance gradation towards zenith azimuthal uniformity, because it is not varying with the azimuth therefore those 2 terms are equals to 0. Similarly this is overcast sky with steep luminance gradation slight brightness towards the sun and overcast moderately graded with azimuthal uniformity overcast and then sky with uniform luminance 0 A is equals to 0 B is minus 1 right.

So, you know it is its uniform luminous everything is I C is 0, so every term goes to 0 D is equals to minus 1 and so on. So, sky of uniform luminance everything although it will be simply phi Z, B Z will be same as B beta s will be equals to B Z same all throughout it is same all throughout it is same, because these terms are 0.

So, that is how these coefficients have been determined as I said so CIE standard clear sky polluted atmosphere this values are there and it depends upon the because because it depends upon the you know overcast sky if you see, either there is a total cloud cover or you have something like highly polluted environment what you are seeing right.

Now, similar sort of situation it is highly you know a lot of lot of particles in the system, it is which is diffusing this or it is fully cloud cover. But cloud cover cloudy sky somewhere it is given I think overcast sky is brightness is different than a somewhat you know polluted atmosphere things are totally different , so this is this is how this various skies are defined.

Now, you have to have for a given location you have to have a set of data , in order to find out your A B C D E if you are doing it for 8760 hours; that means 24 into 24 or at least 12 12 into 365, if you want to calculate out how much daylight will be available design is 1 thing, design is done to find out the fenestration area , but you want to compute the energy that is coming in.

So, that how much artificial illumination you are saving then you got to find out for all these days and therefore you know the position of the sun becomes important right, position of the sun becomes important because this will keep on changing from day to day and day to day and time of the day as well.

So, this is you know position of the sun becomes important and therefore if you are the to be used in a software must use appropriate sky because, it will calculate most of them also calculate the energy saving due to the daylight. So, that has to take right kind of sky into account, now to find out this A B C D E either you make some notional assumptions or measurement should be available to find out what your A B C D E are, but there is another way of doing it also that has been also proposed that is when proposed based on you know based on ok, let us lets first I mean I will come to what based on.

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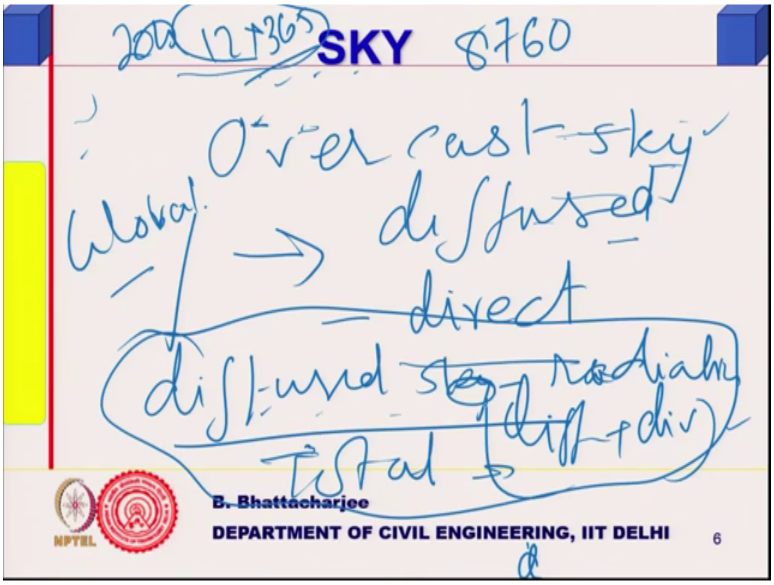

Now, diffused radiation in a in a in a completely overcast sky, the since we have got 2 radius diffuse radiation as direct radiation remember that global radiation was diffused and you know diffused and direct global radiation was diffused in direct in an overcast sky which will be more right. So, what it is done is you can relate diffuse ratio of diffused sky radiation diffused radiation divided by total that is global radiation total, radiation that is diffused plus direct if this is high what does it mean it is more towards overcast right.

It is more toward over overcast or you know cloud covered or or is something like more towards possibly 1 of those skies that we are defining, it would it can be defined with respect to this ratio with respect to this ratio and this data is easily available this data is easily available; you know this radiation data are easily available while brightness data are not so easily available sky brightness data are not so easily available right.

So, diffused radiation divided by total diffuse plus direct radiation diffused plus diffused plus direct radiation, if you take this ratio. So, I might be able to relate or something called sky clearness, clearness of the sky will depend upon this ratio clearness of the sky will depend upon this ratio.

So, I can define clear sky a clear sky will have high amount of direct radiation and diffused radiation will be less on the contrary, if it is overcast or you know like all sorts of covered situation then diffused radiation will be more not so clear sky. So, if I am looking at all the skies the skies can be defined you know this skies standard overcast sky. This skies can be defined or A B C D E can be related to this sort of a ratio right overcast with luminance etcetera etcetera sky partly cloudy partly cloudy partly cloudy and the cloud less turbid sky white blue turbid sky you would blow you know.

So, this is more towards clear sky C I e standard clear sky or something for polluted atmosphere.

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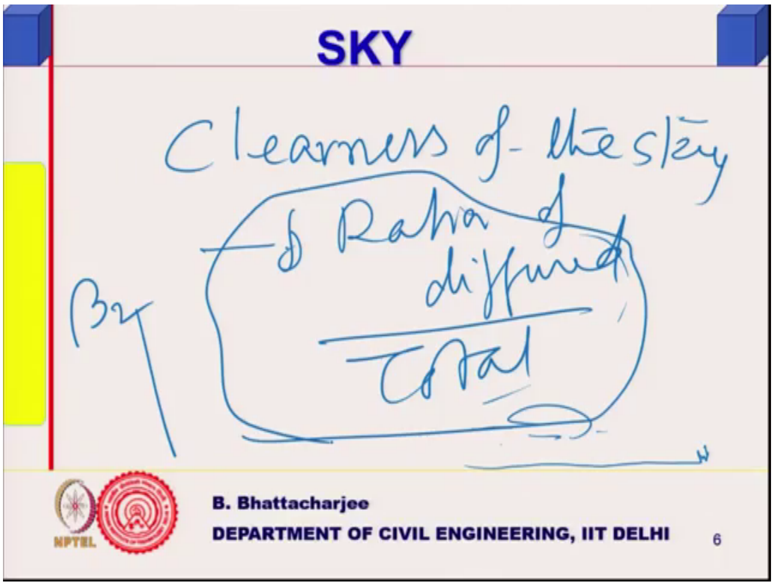

So, clearness of the sky is a function of clearness of the sky clearness of the sky is a function of you know it is depend on the ratio of diffuse to total, so zenith brightness I can relate to this zenith brightness. So, zenith brightness you know what I am calling it B Z I am calling it B Z is my zenith brightness see one of the unknowns there is B Z and A B C D E 1 of the unknown there is B z.

So, B Z and A B C D E I should be able to relate to this term clearness, clearness of the sky and that was has been done that is also has been done and again is validated for only certain locations. In the globe certain location the globe not throughout some as I said some data are were available particularly in tropical countries is not much available, but some data is available, so but one can relate to this 1 can relate.

But validation of this 1 as I said A B C D etc has been done only with respect to certain specific locations, but still this might be more useful one. So, we look into this in the next class and also I did not define clearness index, did I define glamorous index G; G I have defined right what was that glare constant. So, 10 log of sigma GI are defined as glareness glare index and their glare index yes. So, glare index I did not define G I defined did not define. So, I will define that as well and look into a couple of small computations glare constant.

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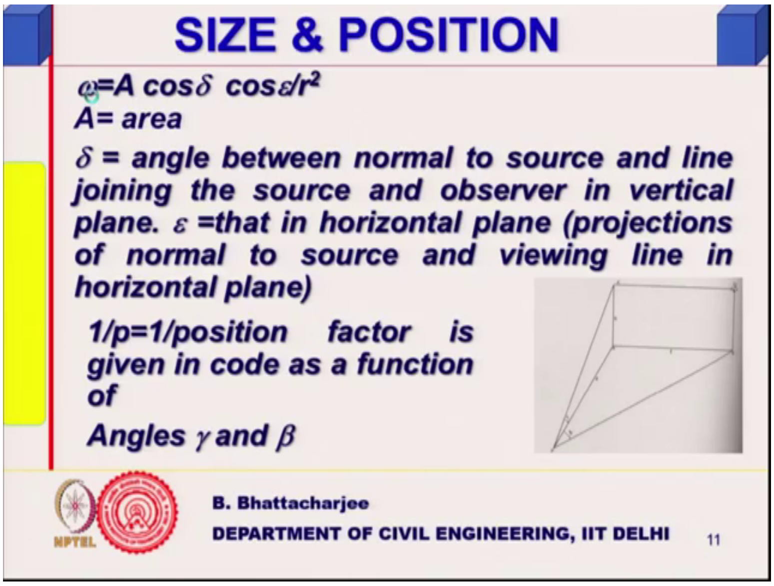

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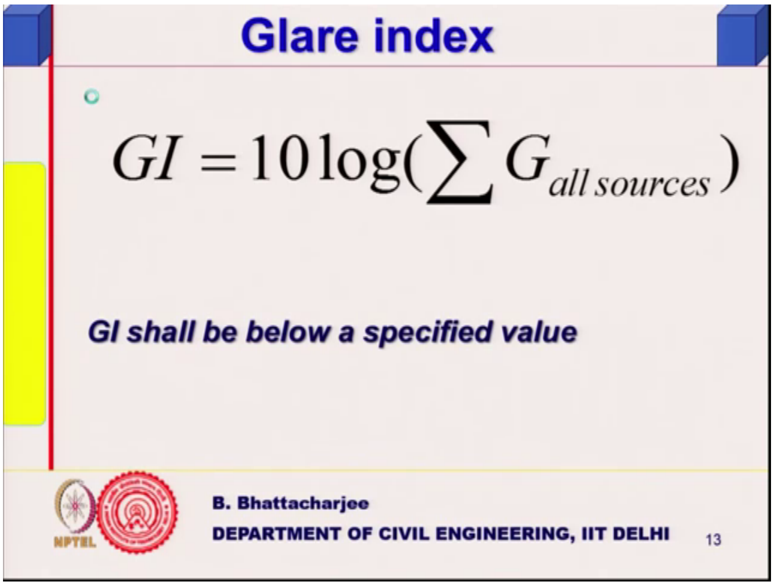

We defined just we are defining the glare index and I think I have told you the size and position factor and all that in the last class some time right and glare index is defined like this 10 block. So, if you can calculate out the glare constant for any source according to the formula, then glare constant you know glare index you get well and this value should be below a specified value order of 1920 etcetera etcetera.

So, if we go back a little bit and look at this you know the this is that is what I said 10 log G. So, let us go back a little bit and look at this look at this situation it was given by 0.24 B 0 1.6 omega to the power 0.8 by B s 1 by point p to the power 1.6.

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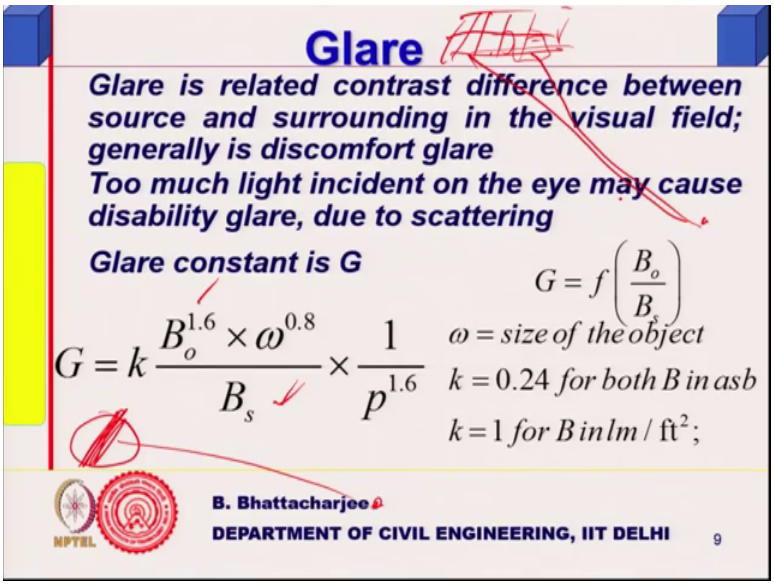

So, this you know the using this formula we can calculate out the glare constant for each individual source. for example you consider a source like supposing I have a spherical source I have a spherical source right; supposing I have a spherical source globe right if a globe let us say a 5 centimetre radius or something whether some such you know says a globe and the observer is somewhere there.

So, if I draw a normal 1 size of the object will be given by pi r square, size of the object will be given by pi r square right and brightness also if you know that if you know the total lumen output that is flux. So, flux into basically you know flux divided by flux divided by 4 pi r square will give you the illumination on the surface lux and 1 lux corresponds to 1 apostil.

So, if you are using this in apostil if you are using this in apostil remember 1 lux brightness corresponds to 1 lux illumination corresponds to 1 apostil otherwise 1 by pi candela per meter square, so you have to have a pie relation. So, now if it is an apostil you can calculate out accordingly.

So, similarly surrounding brightness or surrounding lux is known and reflectivity of the surrounding is known because, they will be you know so reflectivity multiplied by the lux level that will give you the brightness in apostil again. So, this can be calculated in this manner source and the surrounding I mean object and the surrounding you can calculate and position factor has to be taken from a table as I mentioned. So, that is how 1 can calculate all the glare index.

So, for example if it is a flat lamp if it is a flat lamp rectangular lamp no louvers, the size will be full size right size will be full and brightness you can of course, find out from the lumen output of the lamps that are inside and if there are some louvers like this then the effective size will become this much each 1. So, each 1 separately has to be considered and summed up right.

So, that is how that is how it is done, but then angle would change for each 1 of them because, if somebody is viewing from here let us say so this angles are angles are different. So, position factor will actually change a little bit so that is that is how we calculate glare right. So, continue with the sky see this idea of idea of Paris model actually watched on from this.

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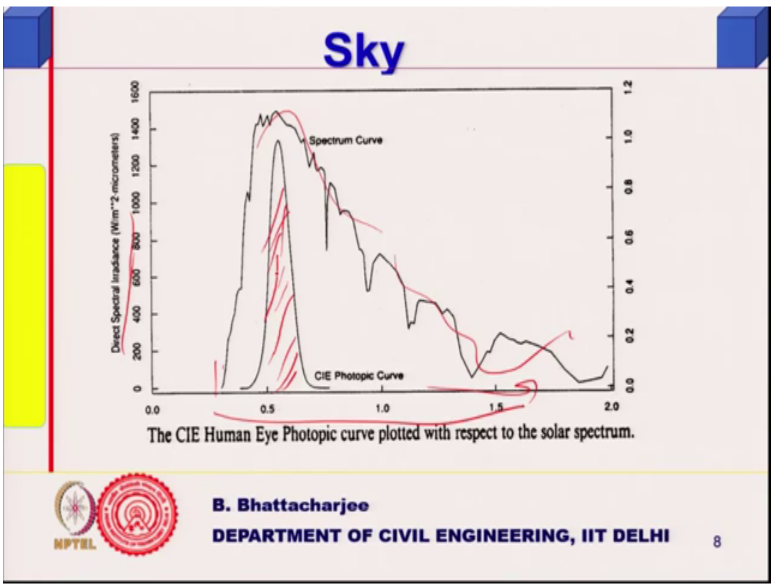

If you see the solar spectrum right, radiation as the function of the radiation of the function of wavelength right; So, only over a small portion in the centre as you can see this is what is our what we see right. So, this is what we see actually this is a nanometre so solar spectrum this isn't you know this is this not nanometre 0.5 this must been I know like this is 55 nanometre. So, 0.5 would be what will be the scale multiplied by multiplied by the corresponding scale sorry multiplied by this corresponding scale.

So, therefore it has something to do this radiation that is received itself, this is the portion sorry this is a this is a portion this is a visible portion this is the direct spectral irradiance this is the wavelength. So, this is the total solar radiation of course, you know a large amount of infrared radiation heat waves are there and this is the visible portion.

So, therefore it depends upon this total irradiance that is the same. So, 1 can relate the amount of light to the total irradiance as well that is the idea that is basically the idea you know that is basically the idea.

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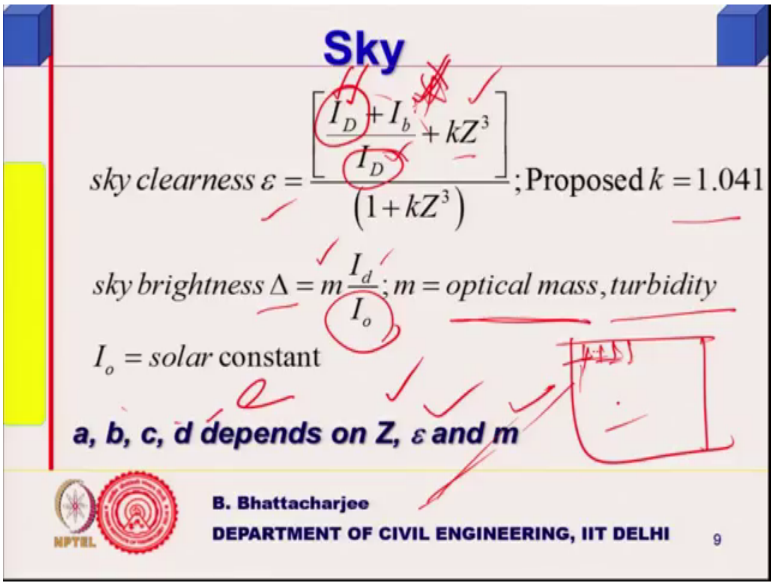

So, that is why Paris moral stands and he defines 3 terms cly sky clearness epsilon which is given as I diffused radiation that is what we have used the notation earlier , I beam radiation divided by I diffused radiation right. So, then some constant of course, this is zenith angle depending upon position of the sun depending upon position of the sun right, this depending upon position of the sun.

So, k is a constant it is been proposed as 1.041 zenith angle of the sun, where the sun is if it is in the horizon. So, it is related to that so that is that is the kind of skies clean and clearness is given which is the ratio of total radiation global radiation divided by diffused radiation. You know relationship between these 2 because as I said if you have higher total radiation you are likely to have I mean you know basically I mean the visible portion is also proportional.

So, that is 1 can relate to the radiation, but clearness is related to more the more the direct radiation, it means what you have more clear sky more the direct radiation you have more clear sky. So, more Ib beam radiation diffused compared to diffused radiation. So, this number will increase with sky clearness this value epsilon will increase because, this ratio is if you know it is 1 plus Ib by Id this part.

So, if by id is large compared to Ib it means it is less clear overcast sky means I have got large Id very little direct beam radiation you just do not see the sun overcast sky you do not see the sun, but still you will see that you know the daylight is still available. So, clearness sky clearness is defined by this right. Then it defines 1 more thing called sky brightness which is m divided by Id by solar constant; this is actually you know solar constant that we talked about how much of it is reached at the diffused radiation, how much of it reached at the ground compared to the solar constant.

Now, it would depend upon turbidity of the atmosphere so m is called optical mass, if you have you know it will depend upon cloud condition as well as level of pollution industrial area, this would be different then less industrial area etcetera etcetera. The particulate matter in this you know atmosphere and so on and this is any a solar constant.

So, in his in the model proposed by Paris where he tries to because, radiation he looked in a data for brightness of the sky may not be available everywhere; but this was validated for as I said only for mostly for subtropical climates not for tropical climates and A B C D E if you remember the e also A B C D E of the model that we talked about earlier clear sky model, they depend on epsilon and m and also the zenith angle.

They depend on epsilon and ion zenith angle and they have actually given some empirical curves or formula related to this. So, that is what that model is Paris model is so I think that is that is it. So, these are related to sky now once you know the form of the sky we have already integrated it and seen that how we can get it how we can compute the illumination sky component at any point you know that you have seen.

But all this all this one point passing through the corner is required only for using the table, supposing you are writing a program of your own today it is not necessary because, you can do numerical integration. For example, the window you can divide into very small areas it is not really FEM, FEM is a method for solving differential equations right.

It is but here, I have no differential equation not minimizing Galerkin's error you know residual or not using any functional minimization or anything that cancer here. But it is you can say it is you know like a numerical scheme. So, you can divide this window into each small component and how much is the illumination coming through that D x D y element, so you know and then contribution of each element you can find out and sum it up.

So, obviously you have to relate this to from the point that you are considering right viewing point from the viewing point. So, numerical integration can easily be done, you know instead of for different or limits of integration you can you can do that. So, that is not, but then and this some of this some of this sky model can be fairly it can even become more complicated to get a kind of a closed form integration.

It may be because A B C D E etc will go into you know remember, we talked about the ratio of brightness at a given point divided by zenith brightness is equals to some function of A B C D E etc, zenith angle and they say this angle itself position of the sun and all that. So, it can become long expressions integrating their you know through closed form solutions manipulate, but numerical integration is possible.

So, I think that that is so all I wanted to tell it about the sky I think all about the sky others we have looked into, if you are interested you can do a numerical modelling one.