Solar Energy Technology
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Lecture - 40
Passive Architecture Overhangs and Wing Walls (Contd.)

So, we were considering the passive architecture and we considered number of devices like solar cooker solar steels etcetera. And then we also were considering the so called overhangs and wing walls.

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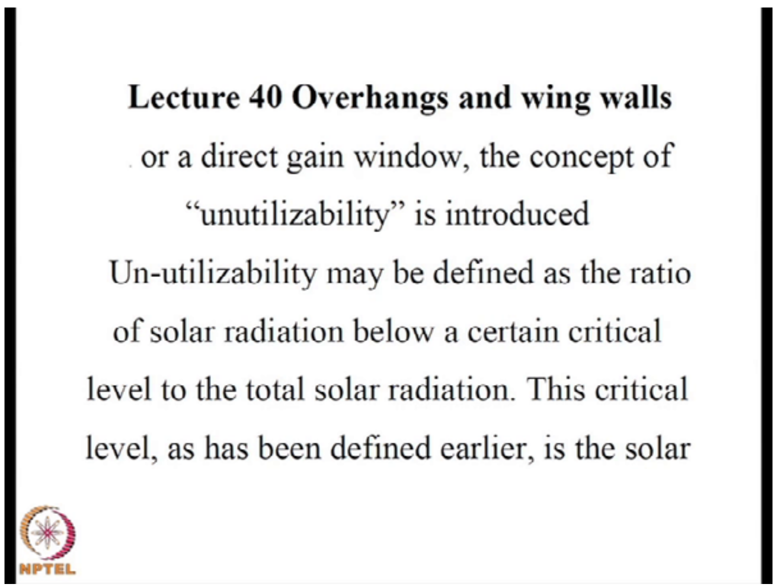

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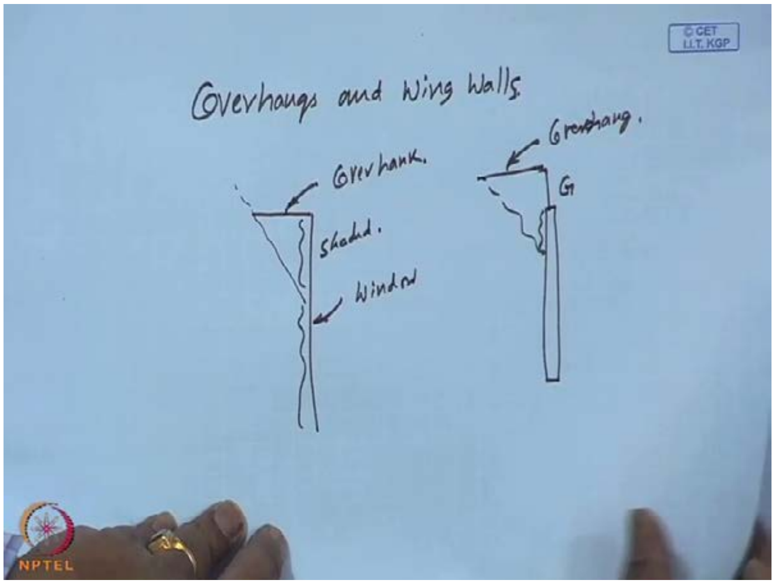

The whole the idea of if you have got a in the end view, this is the window and this is called the overhang. So, this will not let the sun shaded. Over a certain area, the remaining thing can be lit; and of course you may have also have window certain thing, then a wall and your hang maybe after a certain gap G. Still this may cause the shadow over certain part of the window, and consequently this could be useful in summer and particularly in tropical climates in stopping the solar radiation entering the room, and in winter because the sun is pretty low as I have explained in the last lecture, it will allow the sun's rays to enter the room.

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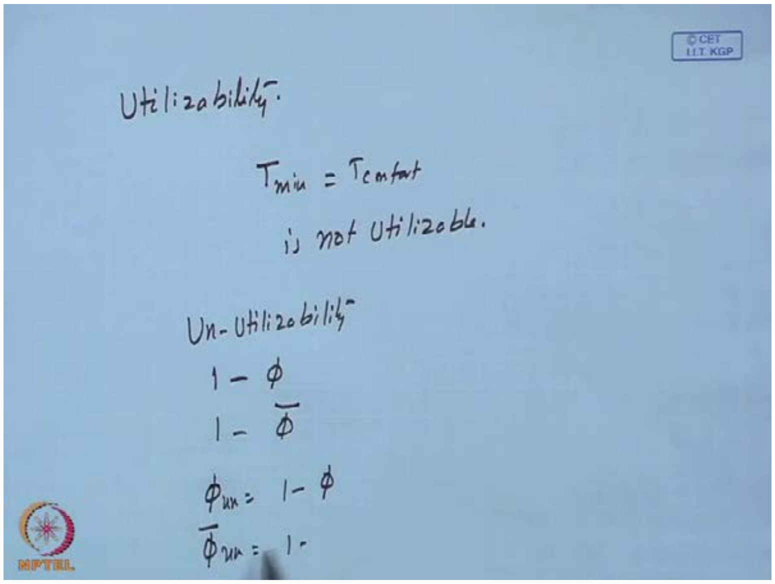

Now in the context of so called utilizability, which we set that the solar radiation intensity above a certain critical level shall be useful for meeting the energy demand above a particular specified minimum temperature. But, in the case of passive heating the solar radiation above a certain level comparable come to the T minimum equal to T comfort is not utilizable in other words

When once the room is at T comfort level any solar radiation above that level shall not be utilized and hence the concept of un-utilizability. So, this sun different times scales will be simply one minus phi or one minus phi bar if you have calculated utilizabilty unutilizability will be simply one minus that utilizability. So, that is what I have put down here phi un equal to one phi or phi bar un equal to one minus phi bar and we know the method to calculate phi or phi bar of a monthly average or daily or a hourly average. So, in that context the solar radiation available to you above a particular critical level shall not be utilizable to heat the room because it over heats beyond the comfort condition. The concept is the same the methodology of calculating phi bar remains the same however that energy is not useful for contributing to heating the room. Because, it over heats

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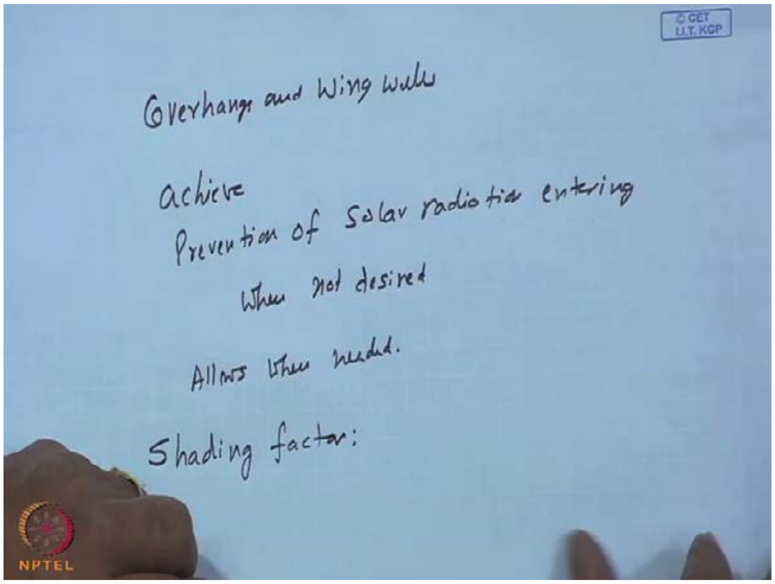

So, these overhangs and wing walls achieve prevention of solar radiation entering when not desired or desired it can be interpret both ways and allows when needed. And there a number of calculations number of concepts and one of the references is 57 which I will give you at the end of these lectures and then 58 our own work contains the method of calculation of what we call the shading factor which will come just now. So, now you have got a what is called a shading factor. When the window is shaded by the overhang or the wing wall a part of it will not receive the direct solar radiation. Consequently the radiation that this likely to enter through the transmittance of the class cover will be impaired by the factor which we call the shading factor since the entire window is not exposed it to sun's radiation.

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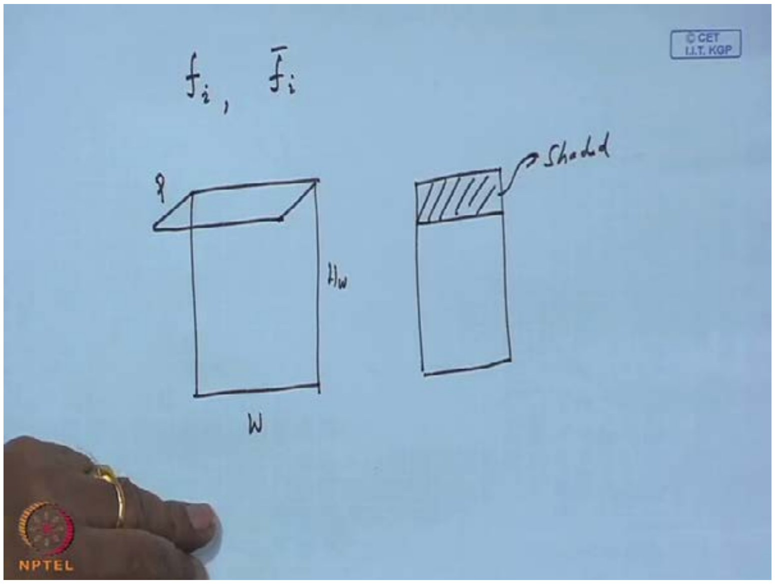

So, now you can have that shading factor just to distinguish between our a solar load fraction and this is actually I stands for illuminated area it can be short term like an hour or a long term over a period of one month or a day. So, we have also described in the last class the types of shadows that can be formed the overhang in general is at least the width of the window where H w is height this could be the projection p. So, this without showing the clumsy way that is a shadow right when the sun is in front of it like this shaded this is only to recapitulate.

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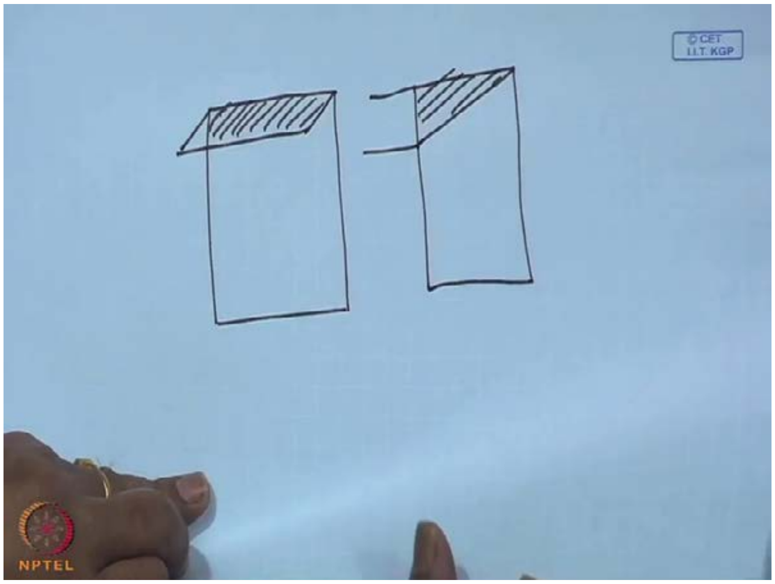

What we did earlier and to more to emphasize the complexity involved in calculating the shading factor though it is very easy to understand that the projection will cast shadow. And it could be like this is the shaded area it is not the overhang but the shadow shape goes beyond the window. And I can have a degenerate case that this line shall be up to here and then proceeds we are not really interested in what happens further. So, this a triangular shape where the end of it edge of it just coincides with the edge of the window.

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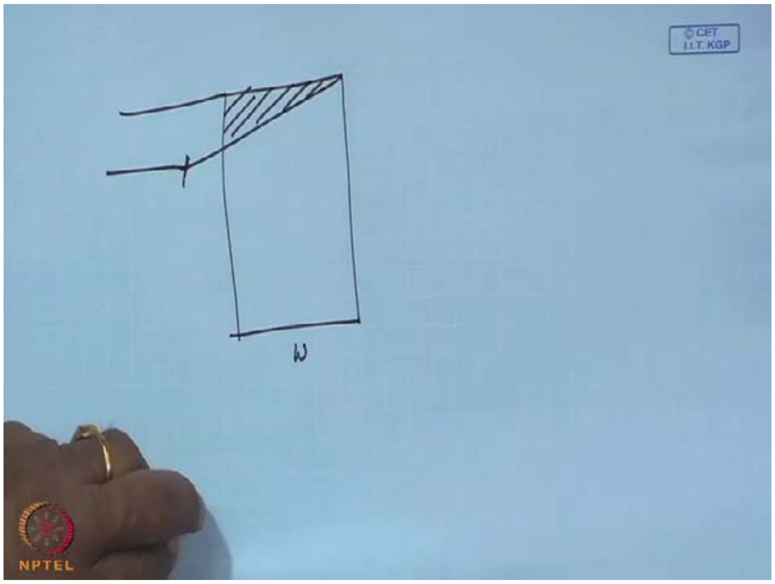

And the third last could be it may go like this. So, looks triangular but the again it becomes horizontal beyond the window width w. So, it is a complex thing it depends upon the time of the day of course then the location the day of the year.

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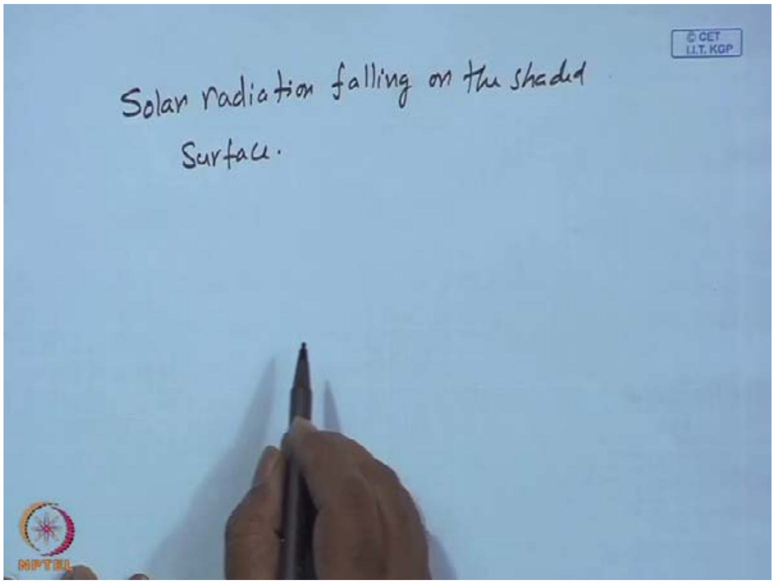

So what is it we want to do is solar radiation falling on the shaded surface. Whatever I have illustrated are also true for the wing wall.

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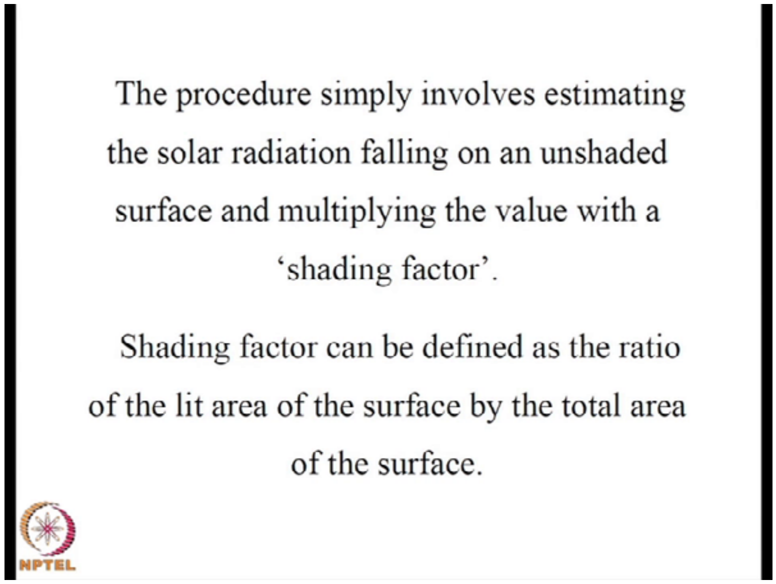

If this is the window I may have a wing wall like this and another one like this. So, if tentatively I assume this is south and this is east and hence this should be waste either this or this will cast shadow depending upon it is forenoon or the afternoon. So, the shading factor can be define as the ratio of the if you look at it like this I am interested in this part

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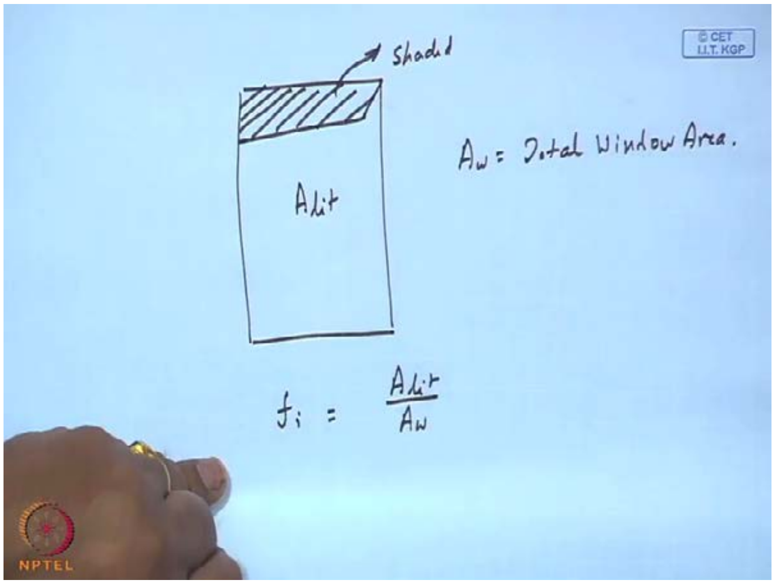

This is shaded and the remaining area is lit by the sun and A w is the total window area. So, we might define f i the instantaneous shading factor so this is what I tried to do it in terms of the figure that hatched portion represents the shadow and the now hatched one is the actual projection so this will be equal to a lit by A w so this written in such a manner that actually it may be the instead of the shading factor it could be the lit factor if a lit is equal to A w f i is equal to one if f i is equal to one that means the window is not shaded in f i is equal to 0 it is completely shaded. So, if you want a long term …

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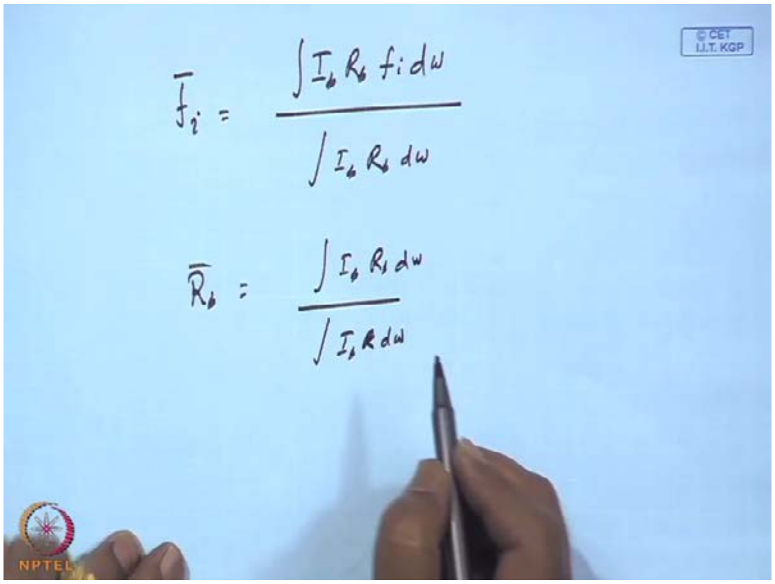

You can always have f i bar integral I b R b f i d omega upon I b R b d omega just like we have defined your R b bar as integral I b R b d mega by I b d omega this is the total amount of solar radiation falling on re-collector which is shaded by factor with changes with time by the total solar direct radiation that is like to fall on the window or the surface if there has been no shading.

So, the shapes we have already described it could be triangle rectangle or trapezoidal. So, this is the equation which I have already written if I bar now both the numerator and the denominator will be from apparent sun rise to apparent sun set angles relevant to the particular window under consideration.

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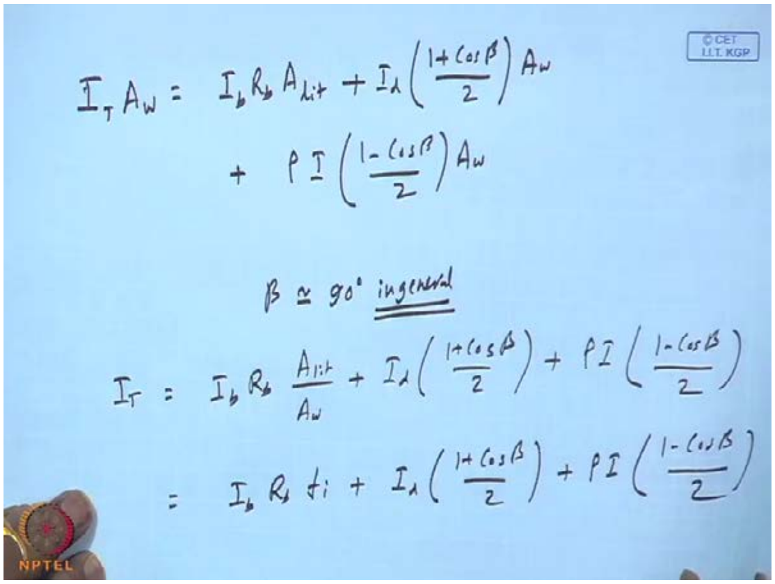

So if I try to write the solar radiation received by the window per unit area of the window so I T into A w is the total quantity of the solar radiation that the window is receiving should be equal to I b R b multiplied by only the a lit because the beam radiation does not fall on the shaded area times the diffused radiation 1 plus cos beta by 2 times A w plus rho ground reflectance multiplied by I into one minus cos beta by 2 into A w where beta in general equal to 90 degrees not approximately let me put it this way in general but it's not the essential that beta be 90 there are quite a few architectural buildings where the window or the class frames or not yet 90 degrees they are at a particular angle. So, if I try to calculate I T per unit area of the window that will be equal to I b R b a lit by A w plus the diffuse component plus the ground reflected component.

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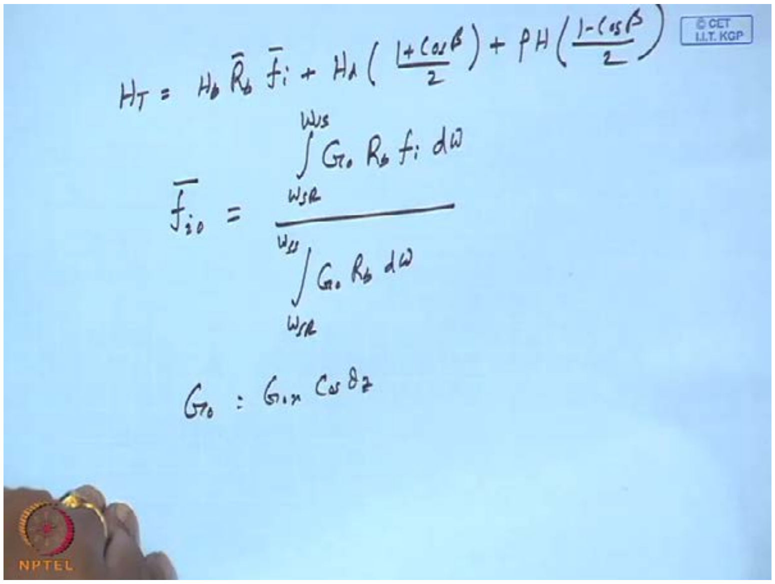

So, this we shall call it I b R b f i the shading factor plus these are very familiar terms for us should be by now. So, that is it here yeah I have dived throughout by A w so, this is if I extend this just like we have done it for the hmm just simple radiation un-shaded. H T should be equal to H b R b bar f i bar it is something like absorbed radiation except that this is a shade impact times the diffused radiation plus the ground reflected radiation. So, under extra terrestrial calculations just like we have done for R b bar. So, which I will indicate by suffix additional o will be omega s R to omega s s G 0 R b f i d omega upon omega s R omega s s G 0 R b d omega right. So, G 0 is something like G 0 we know equal to G o n cos theta z right that analytical expression is know and still we don’t know f i though R b is known for us.

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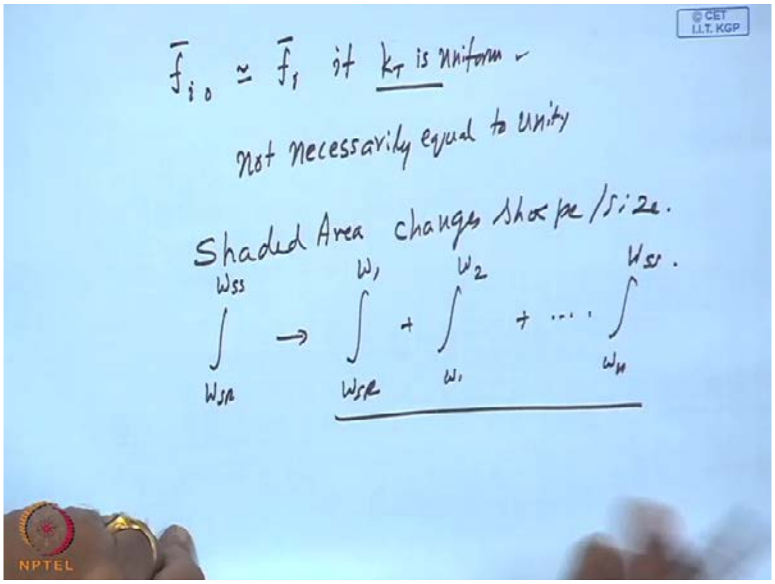

So, this f i bar 0 will be if very close to f i bar if k T is uniform not necessarily equal to unity. This we have proved in the case of R b bar looking at the success why the terrestrial calculation is yielding sufficiently accurate results as the extra terrestrial calculation the other way around extra terrestrial assumption is good enough for the terrestrial conditions also and we found that if k T not necessarily be equal to unity but if it is uniform I will be quite acceptable and it will be exactly equal to the calculations we made under extra terrestrial conditions. Right and k T is more or less uniform when the solar radiation is high in general let us say 10 to 2 p m consequently this will be acceptable as a good approximation. Now you have the problem of that shaded area changes shape and of course size.

So, that in other word this so called omega s R to omega s s may have to be split up into omega s R omega one plus omega one to omega two plus omega n to omega s s. So, it keeps changing from rectangle to trapezium to triangle just truncating at the edge of the window and going beyond. So, this is a little complicated issue and we need a thorough perfect algorithm to find out the area. On that and if your windows are not vertical if they are at an angle the problem is even more compounded.

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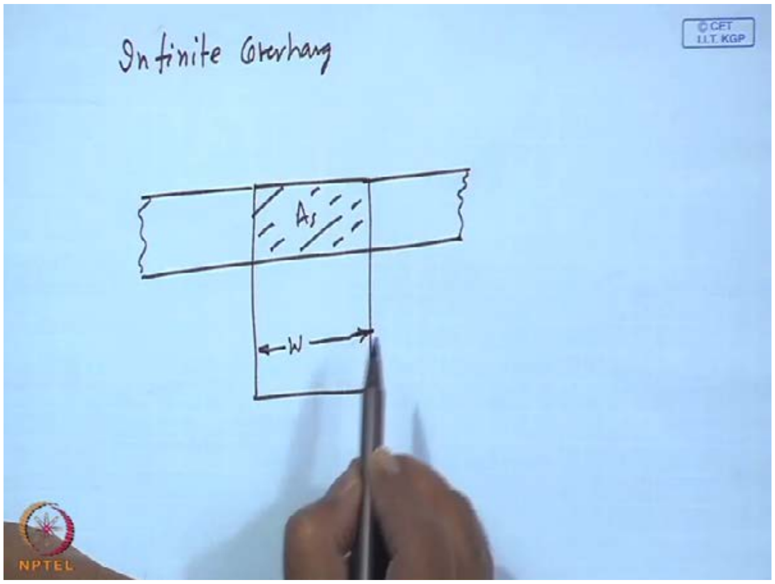

But, if you have an infinite overhang as I have shown over here. So, this may be 2 to 5 times the window the shaded area a s is all ways a rectangle. So, this gives us some respite. So, this I think something wrong with the screen

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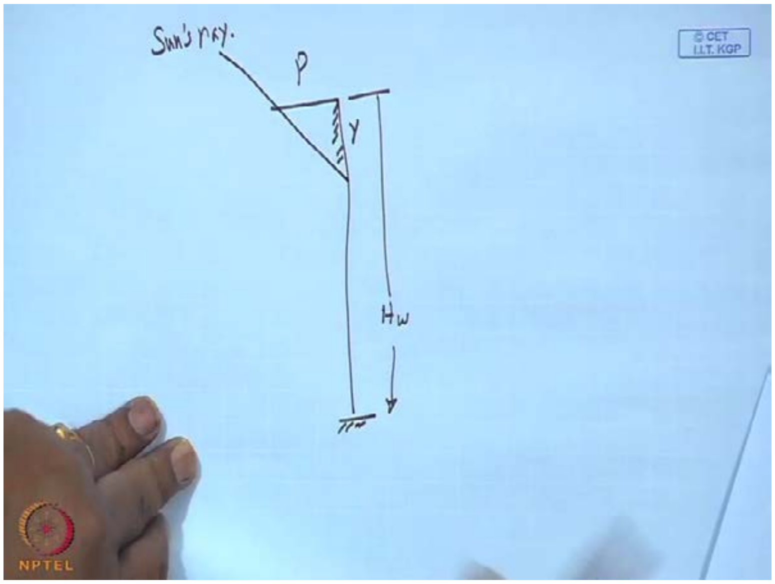

See if I show this in the side view this is the projection p and you have got H of the window height over a certain level and then this is the sun‘s ray. So, you have got a y it is not that it is uniform throughout. But, nevertheless because this sun’s ray could be towards me away but in the projection looks like a line it could be a pencil or in other words moving like this to like this. So, consequently how much is the lit area will depend upon the time of the day and the position of the sun.

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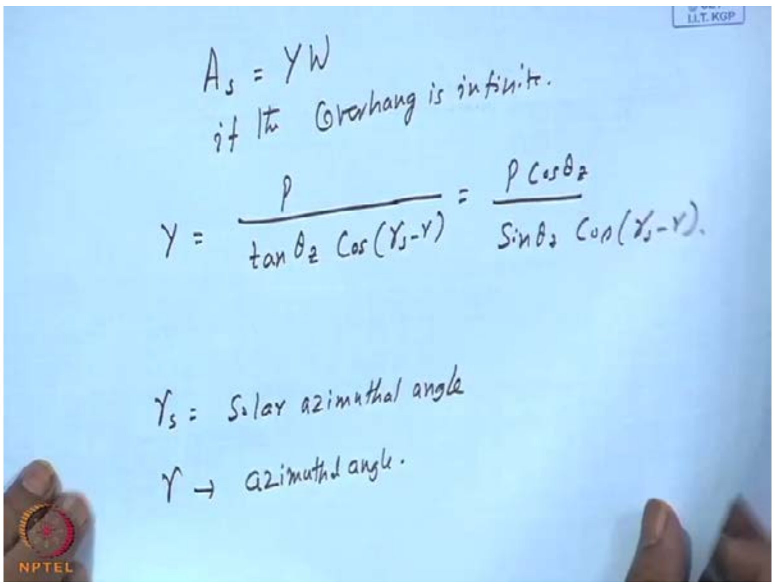

A s will be y into w if the overhang is infinite. So, it is a rectangle no matter how much more than the width of the window it is going to have and that you can write y will be equal to the projection p upon tan theta z cos gamma s minus gamma I shall explain which you can easily find out figure out from the trigonometry p cos theta z because this is sign theta z by cos theta z goes up. So, this is your sine theta z into cos gamma s minus gamma. Where gamma s is the solar azimuthal angle. We have recall introduced the azimuthal angle for the surface as a angle between the north south axis and the projection of the outer normal to the surface on the horizontal plane whatever is the angle that.

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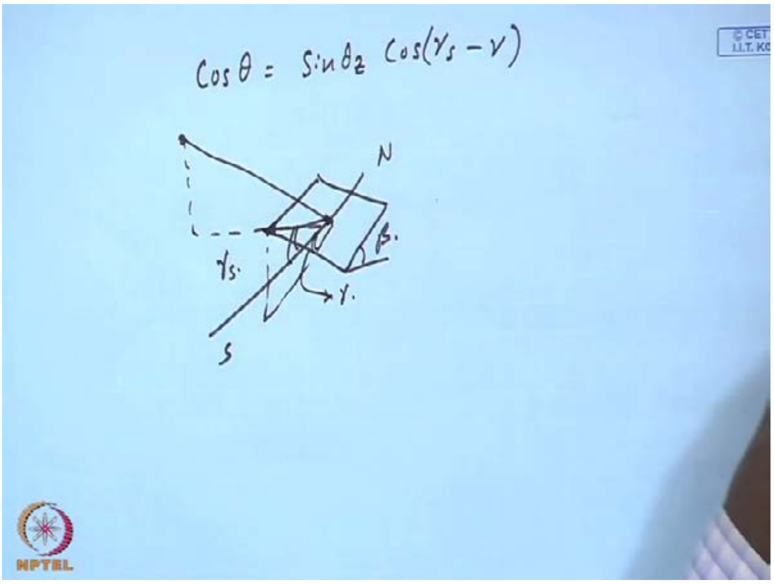

So, similarly I can take the sun's ray and its projection on the horizontal plane and that shall be your solar azimuthal angle. Which I think can be easily shown your angle of incidence cos theta is related to sine theta z times cos gamma s minus gamma. I thing the next picture should be you have got the tilted surface with an angle beta and the sun's rays coming something like this if I take the projection of the sun's ray and if this is your south north then this should be your gamma s. Where as we have taken the out projection of the surface and this we defined as gamma. So, you can the same picture is show over here where it looks like a alpha a but that should be gamma it's a gamma s R s is gamma s that is the sun's azimuthal angle. So, my shaded area for the rectangular shape because the overhang is infinitely long.

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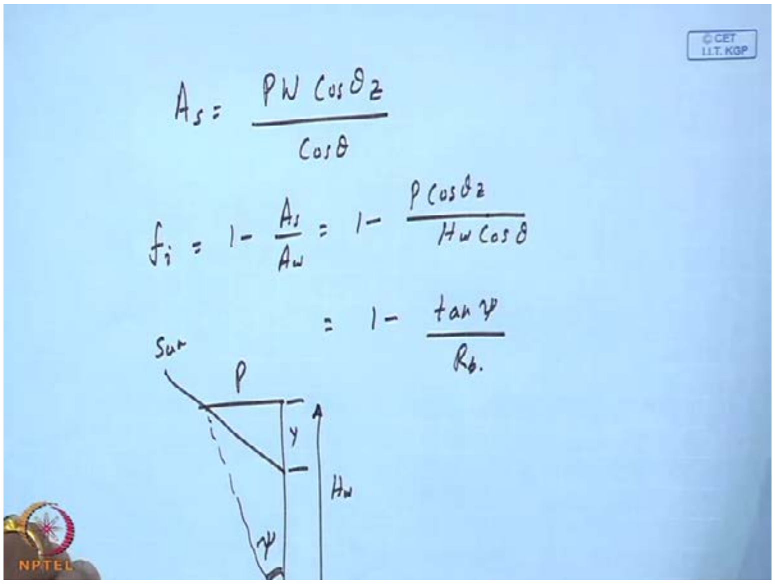

P w simple trigonometry upon cos theta. So, my f i is 1 minus a s upon A w equal to 1 minus p cos theta z by H w cos theta. Because, A w is H w into p so that is what you will get a s is equal p into whatever is y equal to one minus tan si by R b. Because, cos theta by cos theta z is nothing but R b and p by H w of the window is nothing but a tan psi where that angle size shown this is the sun's ray sun this is the projection this is y and this is H w and if I draw a line like this will be psi.

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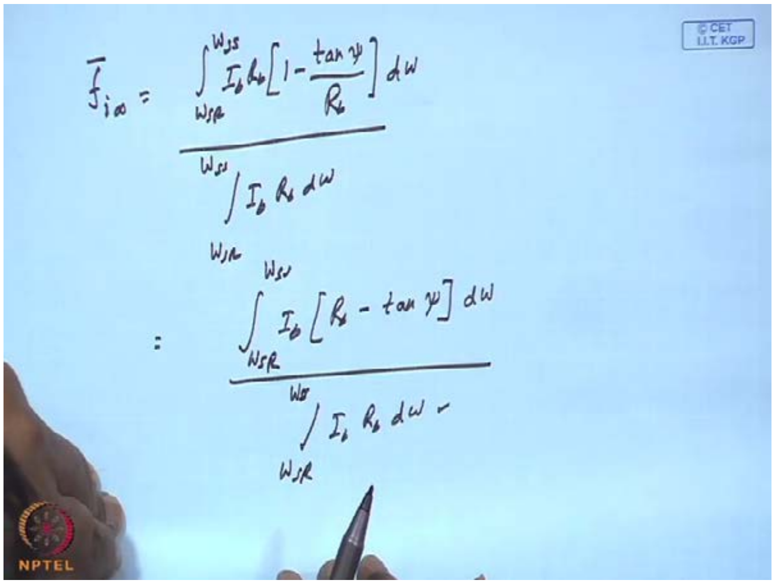

So, to indicate that it is for a infinitely long overhang… So, we f i bar infinity equal to integral omega s R omega s s I b R b times f i one minus tan psi by R b d omega upon the total radiation I b R b d omega s R to omega s s. Which shall be omega s R omega s s I b times R b minus tan psi d omega by integral I b R b d omega in the limits omega s R to this we have done number of times and R b size fixed for a given geometry. So, consequently it is not difficult to analytically evaluate this expression. Which has been done only thing is the assumption is that the overhang is infinite long.

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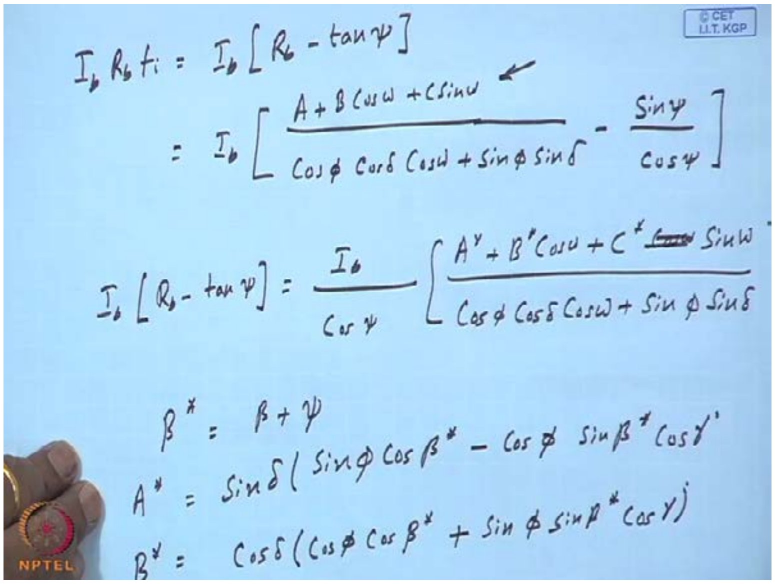

So, you have got I b R b f i is I b R b minus tan psi which shall be I b times in general a plus b cos omega plus c sine omega it need not be south facing by cos theta z cos phi cos delta cos omega plus sine phi sine beta minus sine psi by cos psi.

So, what I can do is I b times R b minus tan psi that is what you have here should be equal to I b by cos psi times a star plus b star u can work out this value. But, it is not difficult I am re-writing sine omega upon your cos phi cos delta cos omega plus sine phi sine delta. So, beta star is beta plus sine and a star is same as you are A B C except that beta is equal to beta star you recall. The fundamental definition sine delta times when we expressed cos theta is a cos a plus b cos omega plus c sine omega and that is what we have done here sine phi cos beta star minus cos phi sine beta star cos gamma. And here I am somewhat doing little faster than what I have done so far because by now you should be similar with the angles and this is nothing but just mathematical manipulation. So, we start with the equation put a cos theta cos phi cos delta psi etcetera.

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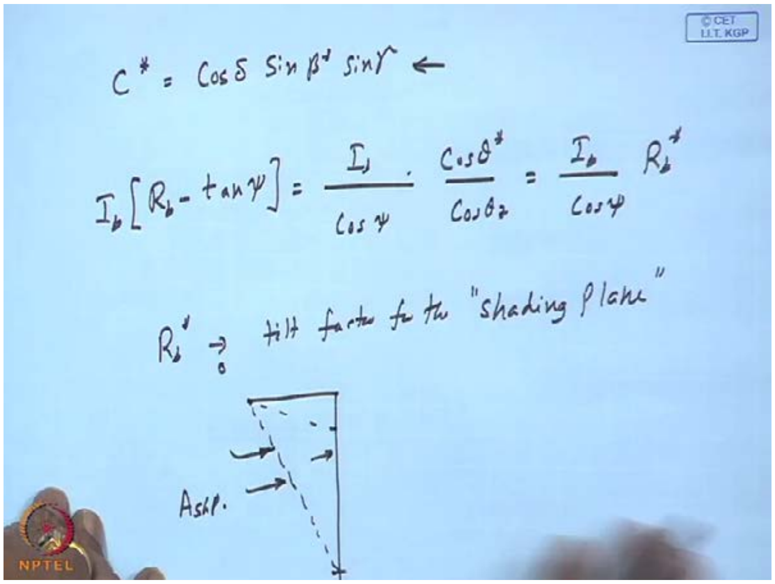

You will get this result and the final answer will be the so simple you really don not have to calculate all these things. But, this shows the basis I have put it in terms of a a star b star c star where your slop is not beta but beta plush psi that is the whole idea and you have got I b times R b minus tan psi from the previous equation I b by cos psi cos psi is that angle you remember that cos theta star by cos theta z which will be equal to I b by cos psi times R b star. So, this R b star is the tilt factor for the what we call the shading plane. If this is a overhang this is the window this will be the a s H p the. So, called shading plane. Right it is nothing to not the sun's ray casting a shadow just draw the tip of the projection to the base of the window you will get the shading plane.

The whole idea physically is whatever is the radiation entering through this will reach the window. So, you estimate the solar radiation based upon a s H p or the area of the shading plane that if it is converted back into the per unit area of the window you have your answer.

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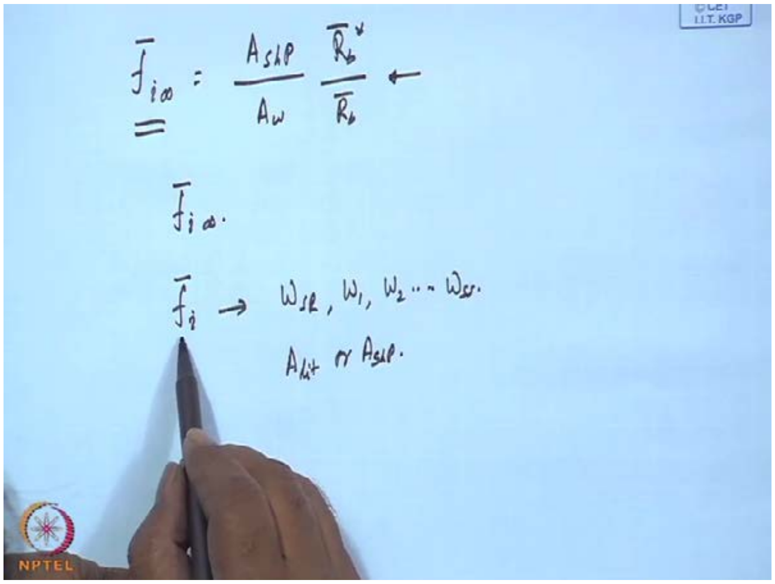

So, this f i bar infinity is one by cos psi integral I b R b star d omega by integral I b R b d omega. And where your cos psi is nothing but the height of the window by the diagonal p squared plus H w squared. Which is nothing but the area of the window by area of the shading plane. A s H p right. So, that is what I have shown in this picture the sun's rays will hit the window at some y distance away total height of the window is w H w and the angle subtended between the projected projection and the base of the window is the shading plane of the area is a s H p which can be given in terms of the geometry p and H w. So, this you can write it as a shading plane by A w R b bar star upon R b bar. So, in another words the concept of the shading plane or the shaded area has been brought into the average daily or monthly average daily shading factor f i bar infinity which should be the ratio of the shading plane to the window area which is purely geometry. And R b star will represent the how long the projection is and what is the height of the this thing it will window and R b bar is for the simple window.

So, with this you can calculate your f i bar infinity. And if you want to calculate f i bar I have already mention the problem of integrating between omega s R omega one omega two we don not know how many up to omega s s these psi's. And then the corresponding a lit or a s H p. It will depend upon the shape of the shadow on the window. So, this is a little tricky business so what people have done particularly the work at I i T kharagpur.

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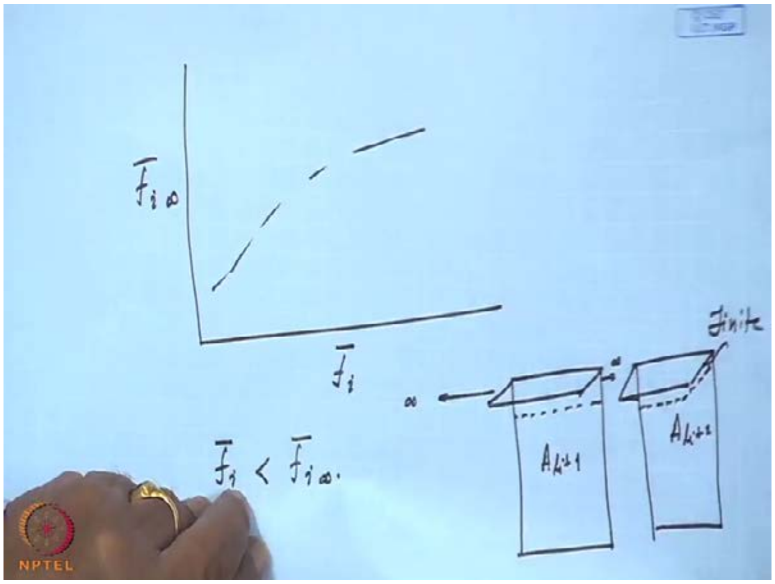

Calculate numerically. This f i bar versus f i bar infinity some curve will be there I don not know whether it is increasing or decreasing. But, we know that f i bar should be less then f i bar infinity. When the projection is infinitely long it is a complete rectangle or the height or the rather the line. So, it may be rectangular or it may not be rectangular as shown over here. So, but nevertheless this area a lit and a lit one and two. So, this I will say infinity infinity and this is finite

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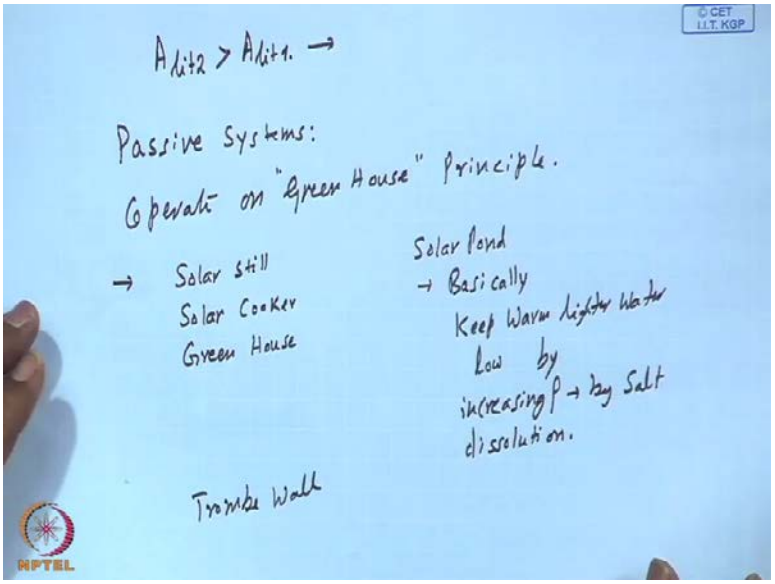

So, a lit two is always greater than a lit one. So, in one sense my shading factor here will be under estimated or rater than over estimated it assumes that more area is covered or rather than the less area. So, that is about it. So, in a nut shell when we are talking about the passive systems most of the operate on green house principal. You let in the solar radiation but let the not emitted radiation at a wave length larger longer it will not escape. Right it could be a solar steel or a solar cooker or the traditional green house itself of course the solar pond comes under different category it is not the green house principal. So, this is basically keeps warm lighter water low by increasing the density by salt dissolution. Then you have got something like a trombe wall. Which is basically a hollow wall where they return air from the room will be circulated and heated by the exposed sun's rays.

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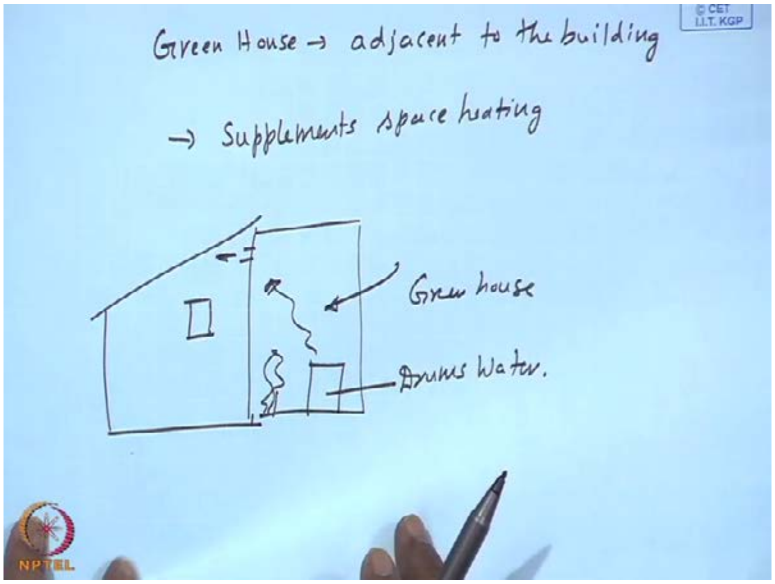

And then your green house can be adjacent to the building, which supports supplements rather space heating. So, you may have a small thing out let over here to the plants or whatever drums of water, which will gain heat during the day will release during the night keeping the room or the house attached house warmer. So, this is a standard practice or you can have a little garden in the winter months it does not die out and you will also have some space heating by this mechanism.

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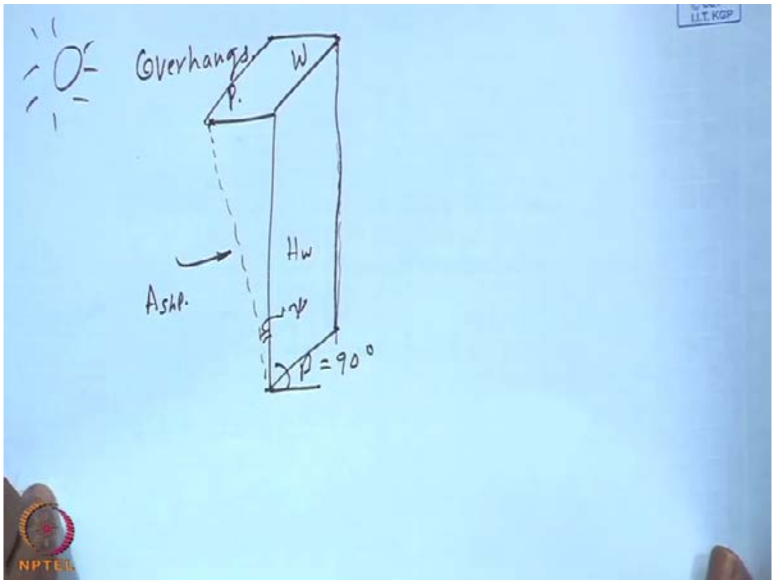

Then we consider the importance's of overhangs in a nut shell you can calculate the radiation received by a window of height H w and width w through a overhang of projection p by calculating radiation entering through the shading plane defined as the plane between the tip of the projection to the base of the window. This can be a solid line. So, this is what these and sun is somewhere here.

So, your R b concept and R b bar concept can be extended of course generally this is beta is equal to 90 degrees and this is your psi the additional angle. So, essentially it is a surface tilted with 90 plus psi or beta plus psi in general and you calculate whatever is the radiation falling through this it will reach the window.

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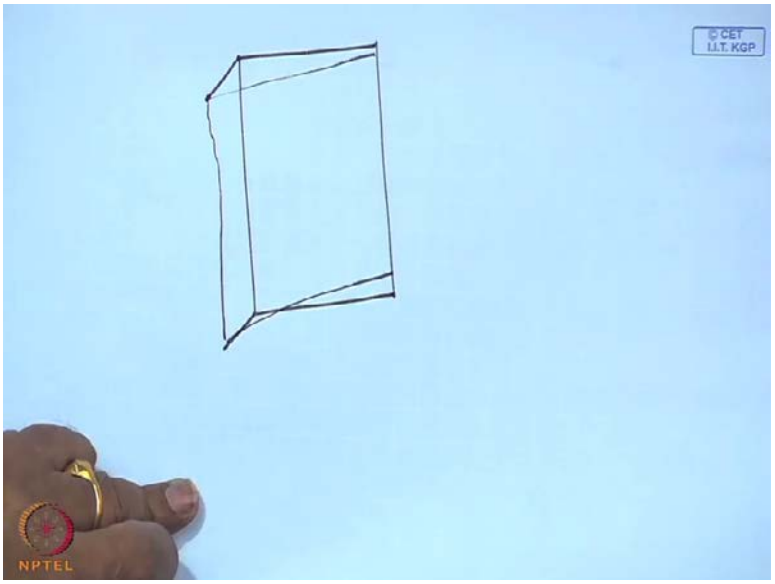

We did not do much about the wing walls that is what I was but you can expect and it has been established if this is the wing wall you make the shading plane from here to the other side of the window. In other words you have a I do not know whether the sketch is giving the impression it should be the other way round perhaps.

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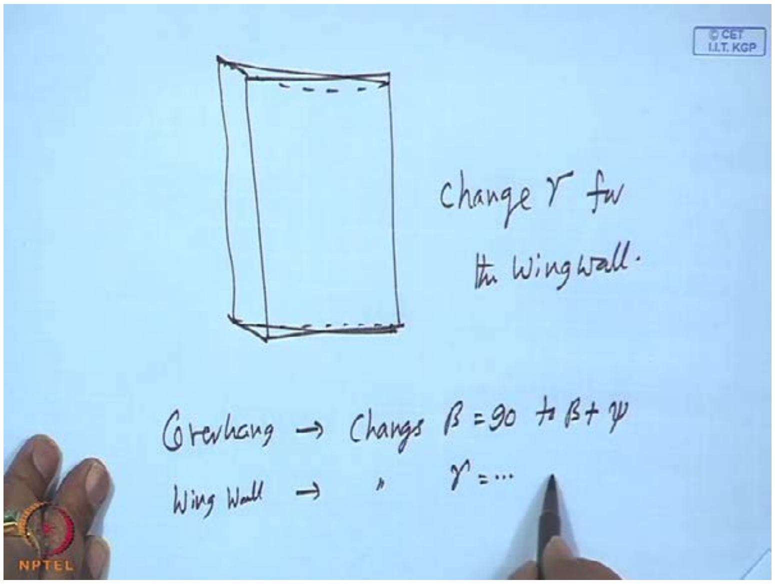

Let me try so, from here you join so this will from the shading plane in the case of a wing wall. So, you can say the same thing in other words you change gamma for the wing wall. Essentially you can summarize overhang changes beta and the wing wall changes gamma equal to whatever it is to some gamma dashed which you can easily calculate because you know the projection of the wing wall and width of the window. So, this is what we have achieved in terms of the what shall we say the passive systems.

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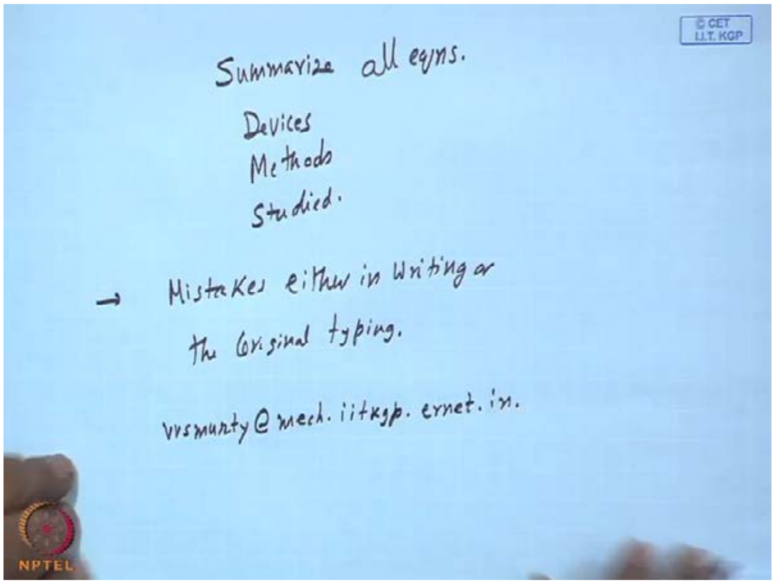

So, what we shall do in the next lecture is I will try to summarize all our equations and the devices and the methods we have studied. And one thing you should remember is this could be the topic wise the last lecture the next one will be the summary only. There could be some mistakes either in writing or original typing. So, what I would suggest is in case you find a mistake contact me immediately at your earliest at my email address v v s murty at mech dot I I T dot I I T K G P dot ernet dot in I shall rewrite it in bigger letters.

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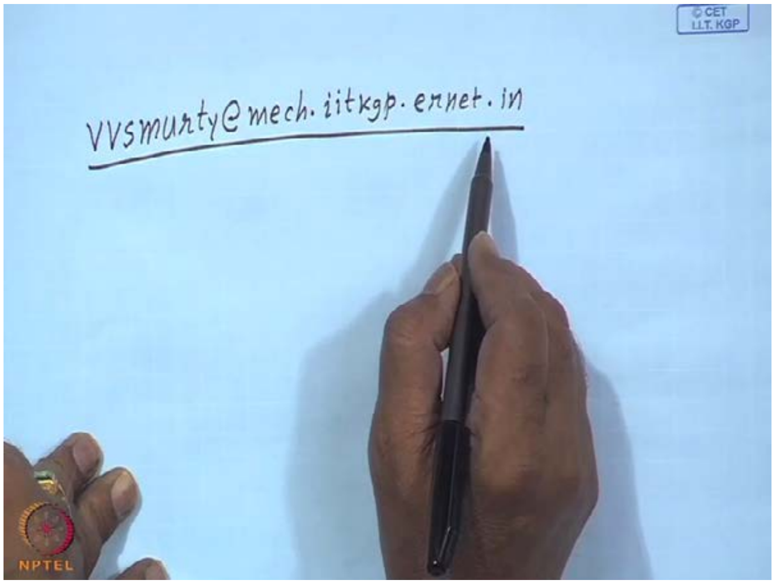

So, you can send a email to this address which your specific query and in case there is you find that some formula or some sign is wrong or something like that. Or this not a coaching attempt in other words I will not solve your problems for you I may indicate how you can solve a problem. If when if you write to me with the correct data etcetera and having done your home work but nevertheless the I have to take the responsibility. If there are some mistake either in quickly writing on the paper or in my original cut and paste of from my class notes. So, for that I am answerable and I shall answer you may be if not twenty four hours within forty eight hour.

So, please make use of this and that is the best way I thing we can improve the material and make the corrections where ever they are there and of course one of my professors use to say that he will give a dollar for every mistake but I do not make any such promise because I am likely to go bankrupt if all of you claim a dollar reach for each mistake. So, the feel free to write to me and thus one way I can help you and you help me in correcting if these are any mistakes or also try to present in a alternate manner in case you have got a confusion that will help in the long term for teaching of this course to the future students thank you very much. And next we shall go to the summary of all what we have done. Thank you.