Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 53
Artificial Lighting

We will look into some issues of Artificial Lighting today and supplementary as well as artificial lighting right.

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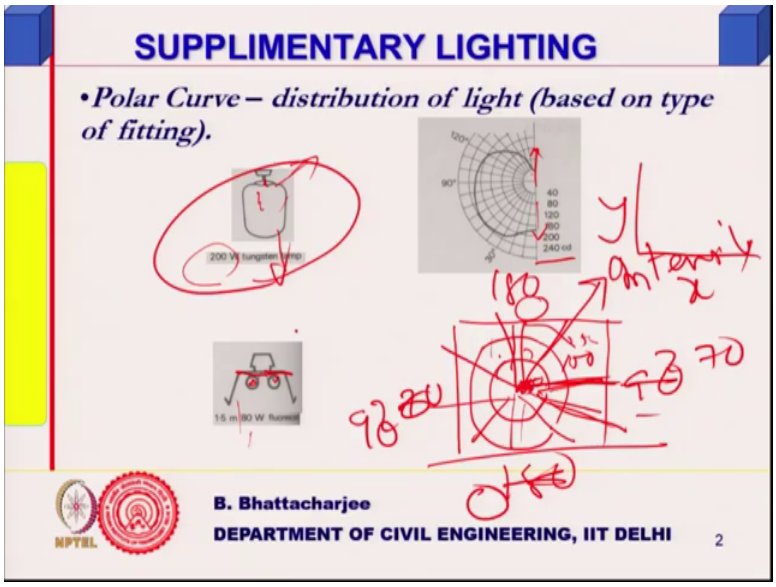

Now, first thing is whenever we look at artificial lighting I mean or supplementary writing it is the lamp, source is a lamp and we look at what you call distribution of the light from, but lamp does not come alone lamb comes with a fitting or luminaire as we call it so we look at their distribution and this distribution. If you recall we talked about directivity factor directivity directionality of sound source similarly here directionality of illumination source right. So, that we describe in terms of what is called polar curve right.

So, what is a polar curve supposing I have a lamp like this good old days 200 watt tungsten lamp it will have a see that polar curve is 1 which actually shows us the distribution of the light in different directions. So, it is a 2 dimensions this 1 is 2 dimensional we can have 3 dimension I mean another 2 dimensional also. So, what you

do is a plot it is a plot basically a polar plot which means that this I have radial lines right representing angles.

So, let us say my starting point this is 0, so 0 to 180 and you know 270 nin90 etcetera. Now Cartesian coordinate we use distances x and y right, a polar curve we use angle we use angle and this radial distances radial distances can be any other thing any other thing any other thing in the sense in our case of course, here it is intensity along that direction intensity along this direction right.

So, you talk in terms of candela intensity, so this might be let us say 50 candela this is 100 candela this should be 150 candela 200 candela etcetera. So, equal spacing like you remember when we talked of you know sun path diagram, we talked of projection of the sun path onto the ground that time also we are talking about various altitude angle and azimuthal angle, but altitudes angles were in radial distance direct radial directions each circle representing a particular altitude angle, here it is the linear intensity linear intensities.

So, intensities will be along these direction intensities and these are this. So, along this direction along 0 or 180 how much is the intensity or possibly 0 is something like this, it is other way around 0 is here 180 degree will be here may be 90 here and again either I can say positive 90 plus 90 minus 90 or may be 270 why 0 is there because, most of the lamps actually emit the light downward lamps in the fitting. So, this is a this is a lamp is somewhere there or for this the tube light say 2 tube lamps are there and if the fitting like this.

So, they are responsible for the distribution is a lamp and the fitting together they provide you the distribution, for example here I have a reflector back of the back of the twin you know tube lamps. So, these are reflector so most of the light will reflect back. So, something like we talked of direction you know directivity factor it is something similar. So, directionality or distribution of the light that is what is shown.

So, for example this 200 what old good old days tungsten lamp, maybe these days you might have this value change because you have got new kind of lamps. So, lumen output of the lamp is important and since this is a globe sort of thing distributes light. So, it actually distributes something backward as well as along this direction also.

So, this is a diffused sort of a light it is a translucent glass piece glass basically is a the fitting. So, this distributes the light except for this direction where it is very less very small other direction, it distributes the light along this direction more of course in this direction; I will just explain a little bit more about this a few minutes later, so that is what it is.

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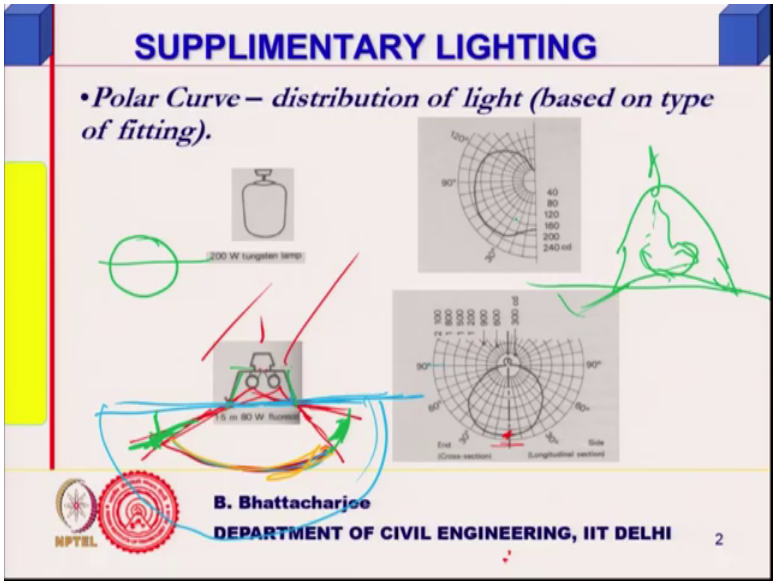

Now, if I go further with this tube lamp it would be something like this because, nothing will go upward nothing will go upward a little bit if there is a hole it might go small amount, but mostly the distribution of the light will be downward mostly distribution of the light will be downward right. So, you see you have got 0 degree maximum and this would be this line is 300 candela 600 candela 900. So, it is around 2100 lose to 2 to 2000 candle candela somewhere here 2000 candela somewhere there right I mean may be 1950 or something candela along this direction why because, both this lamp together lumen output is doubled now there are and this is only in one axis the other axis of course, we are not taking we can take the other axis also if you want to find a distribution along that direction as well.

So, it is a 2 dimensional graph and what is it what will happen light direct light will come through this portion you know direct light will come up to direct light. So, direct light from both the lamps will actually coincide here, so in this zone you will find maximum because direct light from this and this is coming also reflected light from this portion

from a reflected light from reflected light from this portion, because this point will reflect in all direction. So, whatever it reflects here they will go for total kind of internal reflection from the luminaire itself or fitting itself, but this will reflected light will come from here.

Similarly, so you get reflected light over the full 90 degree in a full bottom from full down below, while in this zone you get most of the sub total of the direct light from both the lamps, in this zone you get direct light from one of the lamps direct light from one of the lamps you know you are getting direct light from one of the lamps in this is this zone, this small zone direct light from one of the lamps direct light from one of the lamps in this zone.

So, so you see that is why it is maximum here somewhat less as you go up and in nothing goes up because, this is completely blocked this is completely blocked. So, therefore depending upon the nature of the work or task you have you can choose the type of fitting you can choose the type of fitting. For example, a table them which is very localized right, you want locally good amount of light for the purpose of reading or doing some work fine work or whatever it is.

So, in that case you actually have a direct fitting we have the lamp somewhere there somewhere there, you have the lamp you know somewhere there you have the lamp. So, actually most of the direct light will come within this zone some reflected light will come here, but nothing will go up unless there is a small hole there for you know hot gases moving or were coming in and things like that.

So, essentially this is direct light and if you have a globe this is a this is almost like a globe this is not a full globe, but supposing you have a translucent globe instead it will have then, you know like this will be almost spherical. I mean sorry spherical of course,, but in 2D it will be circular same light up same light down. So, it is actually diffusing in all direction, so this is a direct lamp. So, we have actually polar curve describes the distribution of the light and this important first you choose for your task.

For example, for your reading purpose you might choose direct lamps you know general office lighting you choose direct light that, but you want to do a kind of a overall lighting in the room you want to increase, it is not really not necessarily say something like a living room where people may not be reading necessarily, reading maybe you know just

generally talking and that kind of thing conversation places there you need a kind of general lighting may not need very diffuse, but not have direct lights as well.

So, you have to have you can choose the type of fitting and if it is just something like a garden; obviously, diffused light looks better you do not want very concentrated light, but people should be able to walk. So, depending upon the task that you have you choose the types of fitting and the lamp you know, so these are various kind of you know possible type of polar curves.

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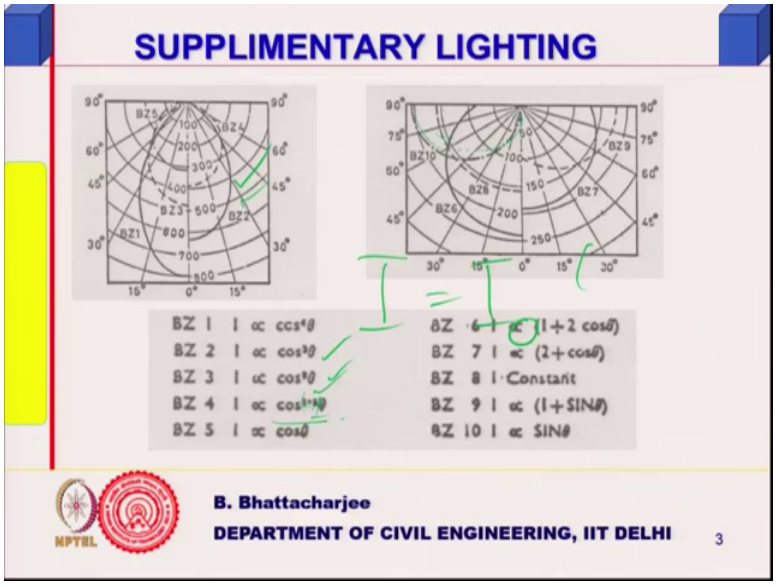

So, polar curve is the one which describes in 2 dimension, the intensity of light in different directions with respect to the source you know centre of the luminary in the, I mean centre of the lamp and the fitting together luminaire as we call it So, in fact there are number of British zonal classification Bz 1 Bz 2 Bz 3 etcetera is called B you know this you can describe by some trigonometric function because, the function of angle, so intensity I can be written as some I 0 into some value cos sin etcetera etcetera.

So, depending upon the functions there are fourteen types of actually Bz British zonal classification exist, but as I said this is of course some you know independent sort of research. But the organizations the industry which actually markets this items they have got their own kind of fitting and also they will tell you what is the polar curve what is the polar curve right. So, British zonal classifications are like this and this is there in our Indian code as well. So, B z 1, B z 5, B z 4 as you can see and then B z 6 9 7 etcetera

etcetera B z 8 10, so there are 10 of them here and possibly there are some more, so B z B z 10 of them that is the 10.

Now, 1 is B z 1 is intensity is proportional to cos to the power 4 theta cos square theta cos you know etcetera etcetera somewhere 1 plus 2 cos theta. So, some trigonometric function they define and accordingly this is there. So, lamp and fitting depending upon lamp and fitting this kind of this sort of curves could be there this sort of cars could be there, these are required if you are trying to estimate something called coefficient of utilization; I will tell you what is coefficient of utilization B z 2 is cos cube no 1 is cos to the power 4 B z 4 cos to the power 1 plus some 1 plus some 3 theta or some such thing you know of course, 1 plus some theta no 1 plus something theta; that means, it is also call square or some other terminology I mean this you get it in the code.

So, I have I mean just maybe you can look into the code 1 plus I am not sure what this is wants to look into that, but that is B z 4 but. So, that is how that is how actually that is how you know this polar curve can be classified polar curve can be classified. Now if you see that most of these are direct most of these are direct while this some of these are not. So, direct some can have something on the upper side also so that is that is it.

So, now how do I how do I how do I estimate how much is the light required, it is very simple if you are looking for a table lamp or something of that kind it is fairly simple because, it would be simply I is equals to I mean sorry E will be equals to I cos theta by simple as that, so I cos theta y r square.

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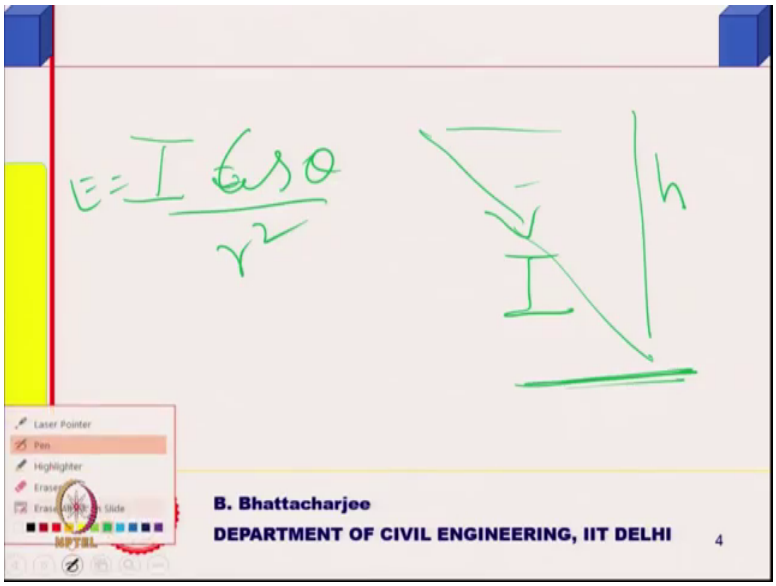

So, if you know you know as we talked earlier also basically in this direction if it is I, if I know along this direction if it is I and I have a I have a my working plane here. So, this distance is let us say h, so this distance will be whatever it is so you know we had this formula.

So, you can simply use inverse curve law if you use single lamp single lamp or multiple lamp you can sum them up, but more important is general lighting in case of offices space like this classroom or let us say many other places of course, place like place like a operation theatre right; where surgeries to perform we will have very high amount of illumination, you very high illumination amount of illumination on the actual working platform and there should be directly the direct lamp, obviously surrounding also is important. So, therefore you know surrounding comes from the reflected portion, but let us look at concepts related to general office lighting that 1 is called general this is called lumens method.

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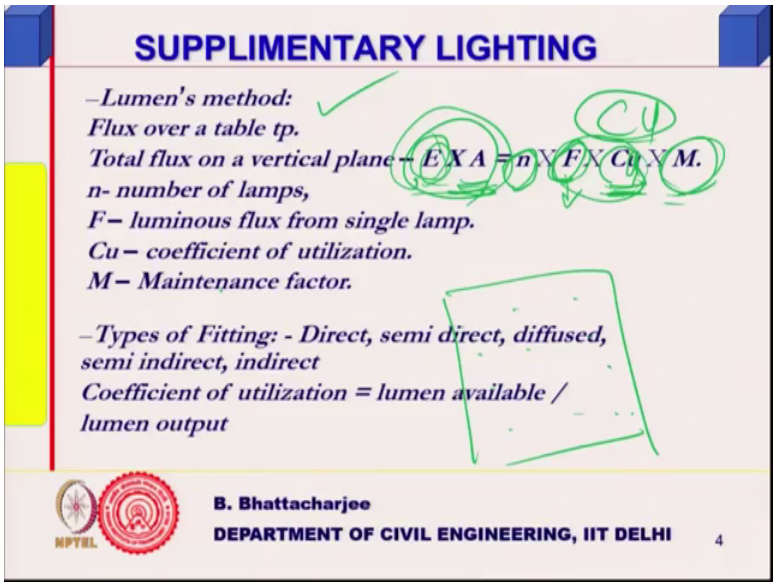

We use a method called lumens method you know we use a method called lumens method lumens method. So, it assumes that at the working plane level which is same as the area floor area of the room, illumination E illumination is E which is average illumination like classroom sort of thing you know if you go and measure the lux here by enlarge you will find similar lux level we will put off put on all the lights by enlarge similar lux level.

So, E average illumination multiplied by that is the flux total flux onto the working plane because, it is general illumination like in an office even office general illumination in an office. So, you have got number of lamps number of lamps and all of them contribute overall to an average illumination right and if the illumination level is E that multiplied by the area that is the total flux. Now I have n as a number of lamps and lumen output of each lamp is F then I multiply this by something called coefficient of utilization Cu, small u I have written some places you will find that it is written as C capital u it is called coefficient of utilization coefficient of utilization multiplied by M which is called maintenance factor which is maintenance factor.

Now from 1 lamp F lumen comes out coefficient of utilization is a fraction of the flux emitted from 1 lamp multiplied by I mean divided by the ratio of flux received onto the onto the working plane divided by the flux eliminated emitted by the one by one lamp 1 lamp lumen output of one lamp. So, ratio of the flux that will be available onto the

working plane now it will depend upon the type of luminary, how if it is direct most of it will come down below if it is not. So, direct only direct person will come directly, but a lot of indirect one will come through entire reflected components entire, if it will come from the entire reflected components right.

So, therefore this is coefficient of utilization will depend upon the type of fitting, it will depend upon the type of lamp and the fitting that type of fitting and also on the room dimensions related to room dimensions sorry excuse me M is maintenance factor M is maintenance factor.

What is maintenance factor? Supposing my reflectivity of the surfaces are high. So, the reflected component will be high if I if I mean you know lamp output varies little changes with time does change with time a little bit which time it changes, but that is not very major thing more important thing is that if the dust accumulates clean you know if you clean it regularly your lumen output will increase. So, that is called maintenance factor. So, this can be around 0.7 or point of that order. So, coefficient of utilization gives me flux coming from lumen output of 1 lamp is M multiplied by coefficient of utilization gives me the flux contribution.

From one of the 1 lamp multiplied by n total n number of lamps M is a maintenance factor because, whatever is the initial output of the lumen output because of the maintenance factor etcetera etceterax it might get reduced. So, I multiplied by a factor and that must equals to E by A, so this method is called lumens method lumens matter. So, that is what that is how we will find it out and coefficient of utilization is important. So, to look at this first I must know the type of fitting. So, fittings are direct we classify them as direct semi direct diffuse I mean direct and indirect now inductor will be something like this.

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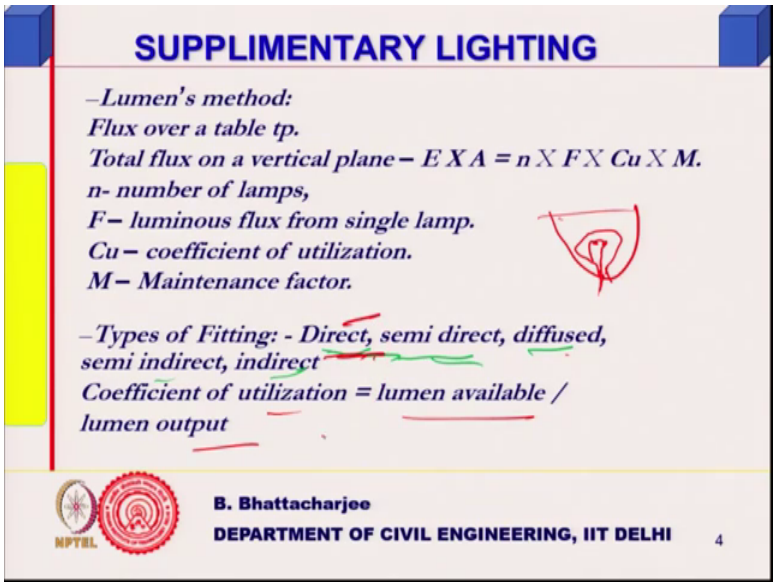

Supposing I have the lamp here you know this is the fitting and the lamp is somewhere some where the lamp is somewhere here you know this is the lamp. So, this is actually indirect directly you are not getting anything you go down below. So, this is direct semi direct diffused coefficient of utilization is lumen available by lumen output of a lamp, so this is how we define. Now, what is direct will have 90 percent downward direct you know direct have 90 percent. So, direct I do not know whether I have a table here or not if I do not have well do it ok.

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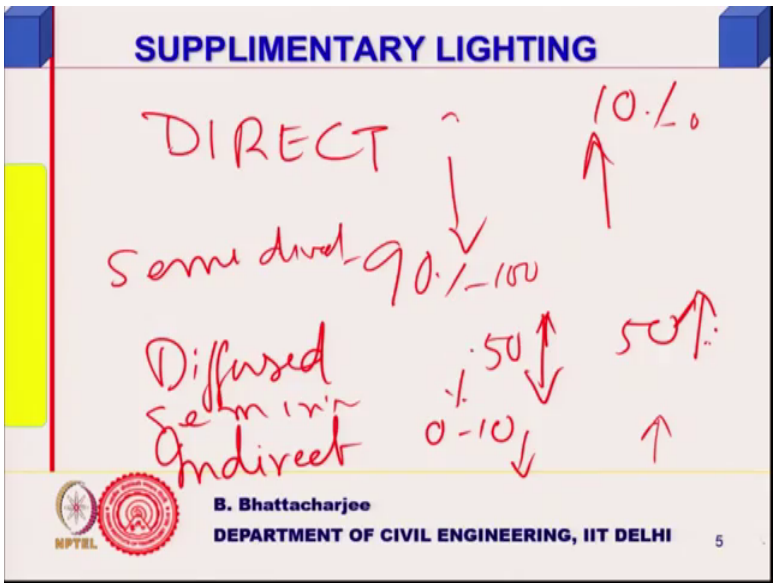

So, direct means 90 percent downward 10 percent upward, diffused means I will come to the in between then once, diffused means you know it is around 0 to 10 percent right and 100 to so 90 200 and 0 to 10 that would be direct downward nearly 100 percent. Diffused means 50 percent upward downward and 50 percent upward diffused right, it could be something like 40 to 50 there is a range or 40 to 60 40 to 60 that is the kind of range then indirect would mean 0 to 10 percent downward.

So, indirect would mean indirect would mean 0 to 10 percent downward and you know 90 to 100 percent upward and then I have got semi direct they are in between M semi indirect. So, this was 90 and 60, so if it is between 60 and 90 downward I will call it semi direct, you know 50 50 it was 50 so 40 to 60 that would be diffused 40 to 60. So, 60 to 90 I will call it semi direct downward I will call it semi direct accordingly of course, the upward would change accordingly.

So, this is how they are classified this is out they are classified right, this is how they are classified this is how they are classified. So, this is how 1 classifies this once, but that is gross classification you do not need what you need is coefficient of utilization value.

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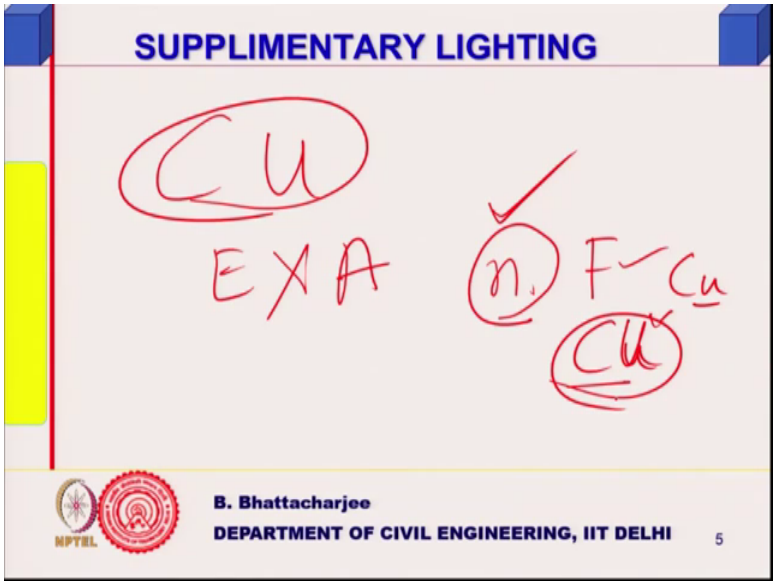

Because, if we want to find out required E is known area is known required E is known required area is known and you know F lumen output from one of the lamps. So, F is that the lumen output of one of the lamps and n is what is unknown to me, how many lamps I should be putting also unknown to me is I mean, I must have this value available

coefficient of utilization you know C small Cu or whatever you call it coefficient of utilization, that must be known to me for a given type of fitting and given type of you know given dimension of the room ok, why it is dimension of the room is important I will tell you.

Maintenance factor I will assume the conservative value let us say 4.7 right, even in the worst situation I should get the proper light. So, this is what I for my estimation requires that I should be able to find out how many lamps do I need in a given space, like you know is generally they are placed in matrix form row and you know rows and transverse direction also in a longitudinal direction equal spacing equal spacing, because it do not look nice, but you can always do if you want to do you know some aesthetic or something purpose you want to do.

But task illumination general office lighting or you know lighting in functional spaces or normally 1 would space them equally. Now how what is the principle behind how do I find out Cu Cu is actually given in tabular forms normally, but if you want to derive them then you can find out say I have let me just let me just give you the principle first.

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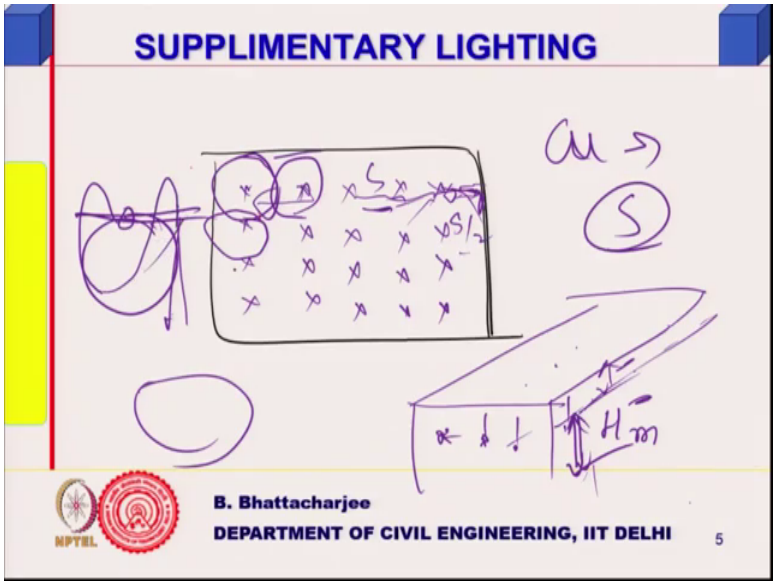

Let say I have this is my space floor area this is my floor area so or ceiling plan if I may say because, floor and the ceiling they will have same area and I have lamps like this somewhere some at some height I might be having at some height the lamps might be there at some heights some heights I will be spacing them like this right. Now why it is

not the area of the table or something like that because the light from this one will go over all the spaces, light from this also go over all the places light from this will also go over all the places including the vertical wall including the vertical one.

So, that is why I am taking n number of lamps and lumen output of each 1 of them. So, therefore I do not take only the sitting area or working area I take the full floor because, a general average lighting that is what I get by spacing these lamps in this manner and it is what I have to know is what is the spacing between this lamp. If I reduce down the spacing them obviously, lighting level will increase or coefficient of utilization will increase coefficient of utilization rule. So, this will depend upon the spacing, also spacing you know we assume this spacing half of the half of the spacing you know.

So, you might put half distance from the or some distance I mean basically half distance from that wall half spacing, if this is this is s this will be s by 2 or similar sort of thing right. So, the tables will give you the maximum value or codes will tell you how much the maximum value you should take, if you take less than that good lot of light will go to the wall they will not contribute directly to that. But it will go to the wall so, but does not matter let us say this is s in a simple case s by 2, so this is a s spacing. So, my C coefficient of utilization is a function of this spacing s spacing s spacing of the lamps spacing of the lamp.

Now, let us look at in vertical I mean in other plane, so this is my lamp I might mount my lamp somewhere here mount my lamp somewhere here you know every all these lamps I may mount. So, some height right now if I mount it here the mounting height from the working plane will matter, because that is the h distance you know it is inversely proportional to r square. So, it will be inversely proportional to in a way h square because you know cos whatever function comes in, so this height mounting height will play a major role mounting height. So, h h M sometime we write mounting height will play major role mounting height will play a major role right, higher the mounting height you will have less illumination coming on to the coming on to the working plane coming onto the water plane working plane.

So, the working plane height this is the height of the lamp above the working plane, anything goes into a floor cavity I have not bothered they are called cavities actually this is a ceiling cavity ceiling cavity the above. So, anything going below the floor I mean a

working plane it does not directly contribute, but it you know it will still contribute to the internally reflected component right.

So, internal so whatever is going into the wall does not go waste, actually after first reflection it contributes to the general level of lighting to the space like internally reflected component of daylight that we looked into, so fuse principle of integrating sphere. So, that that you know so whatever goes here into the wall or to the floor really do not they really do not you know they do contribute indirectly what comes directly is fine, but after first reflection that also contributes to the general diffused lighting general diffused lighting overall the room.

So, therefore the factors which governs the coefficient of utilization 1 is the spacing, mounting height, spacing mounting height, you know these are the room and also room that you know it will also depend up on room dimension because, spacing is fine because how many number of lamps will come in the whole area. So, it has it has it has to do it all this actually it has to do with all this. So, that is how so we will look at it look at look into it look into it actually write down x.

So, that is how coefficient of utilization can be derived from all this equations are simple, they are no complicate, but there is a large number of calculation involved and you got to know the polar curve of the lamp which is same for all of them, because depending upon the polar curve supposing it is it is something like this you know the lamp is something of this kind sorry circle, you know this polar curve is all downward right.

So, my wall is somewhere there and supposing another case I have got a polar curve of this kind; you know depending upon the nature of the polar curve and value of intensity along that direction how much light comes on to directly onto the directly on to the work plane or task plane, that will be known and how much goes to the wall that will depend upon what is the nature of the polar curve, how much goes to a ceiling will also depend upon use of an indirect fitting majority will go to the ceiling nothing comes down.

So, therefore they all contribute to internally reflected component you know. So, diffuse general diffuse lighting they hardly contribute to the direct lighting, so what you get is a totally diffused lighting. So, nature of the polar curve I must know and if I want to calculate out then it is better to form them in form of an equation, that is why all those B z 10 curves z 1 z 2 etcetera etcetera which is given in the code. But then as I said

manufacturers like philips or G C or similar other bodies who actually produce this kind of very special luminaries philips. For example, you get in the market you get special kind of fitting right.

So, they would for general office lighting they will even give you the coefficient of utilization value, but you can estimate them yourself if you have if you are you know trying to use a new fitting, you can actually estimate them based on this kind of principle mathematics is not very complex because, it is simple whatever we have done earlier only you have to find out how much is the area, how much of the part of the polar curve reaching to the wall, how much to your task plane integrate it because you know the lumen values will you know lumen I mean into I c candela value along different directions are different.

So, if you take a small solid angle a you know area, area divided by r square that will give you the solid angle I d omega that is the flux integrated throughout, you know then you will get that flux coming in and that flux divided by the lumen out. So, that is direct flux what is the indirect flux contribution from one lamp you can find out one lamp which is a wave, you know that distance from the wall will vary. So, each of the cases you can find out what those who are far off from the wall for them, you take the full thing sum it up each individual one, you find out sum it up for all the lamps and also find out the indirect lighting you can you actually arrive at the coefficient of utilization.

I am not doing this because; it may not be worthwhile to do this exercise unless you write a small program or something like that. But then mostly you would not be 1 would not be manufacturing that luminaire fitting you are not going to manufacture you are going to use some of them. So, therefore you ask you find out what is their coefficient of visualization and nature of the distribution. So, once you know the coefficient of relation how we calculate? I will just come to that in the next round next round ok.

So, any question? I like to answer then again we will you know come back here.