Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 48
Daylighting (contd.)

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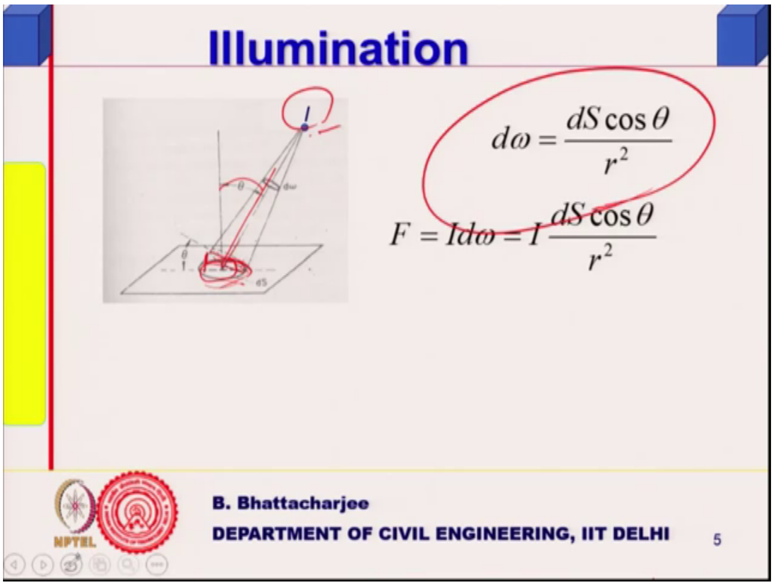

So, having looked at the, having looked at the you know definitions I can talk in terms of some formerly, simple formerly. Now, supposing I have a point source like this emitting I right and I want to find out what is the illumination here. Let us say the surface area is dS small surface area is dS and if I want to find out how much flux coming over here I must find out what is the solid angle subtended by dS on to this point source right. Because I into solid angle will give me the flux that is coming out, I want to find out the illumination here.

Now, when I want to find out the solid angle I must take that projected area normal to this direction right, projected data normal to this direction. So, if this angle of incidence is theta this angle also will be equals to theta. So, if this area is dS the projected area will be dS cos theta, projected area will be dS cos theta and divided by r square thus d omega, the d omega is the solid angle subject you know subtended by subtended at this point by this surface dS right. So, dS cos theta because projected surface area is divided by r square that is d omega. So, the flux will be I into d omega which will be equals to which is equals to you know I dS cos theta by r square.

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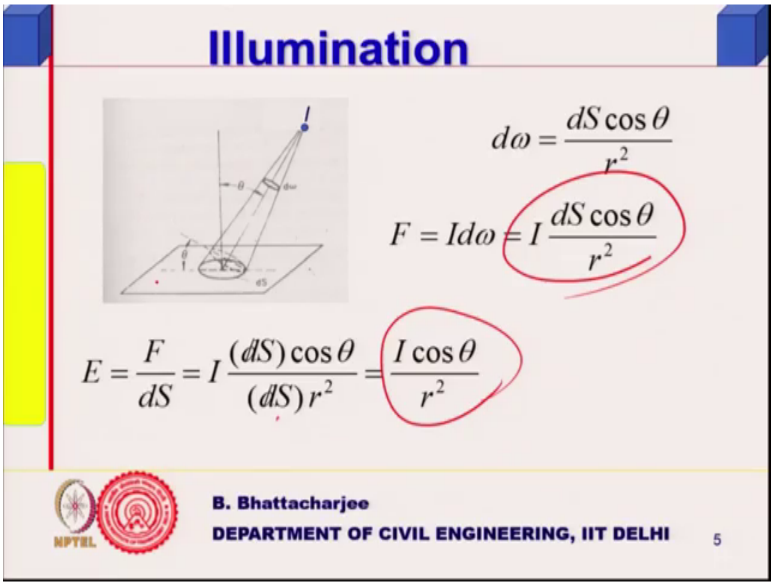

So, that is the flux received here onto this surface and what is illumination, this flux divided by area of the surface that is dS again. So, illumination is F by dS again. So, this dS and dS will cancel out so I cos theta by r square that is inverse square law that is inverse square law.

So, illumination received on this surface is I cos theta by r square. So, if I have a point source at a distance r, angle of incidence is theta then the illumination will be I cos theta by r square, I cos theta by r square right I cos theta alright. So, this is sort of this.

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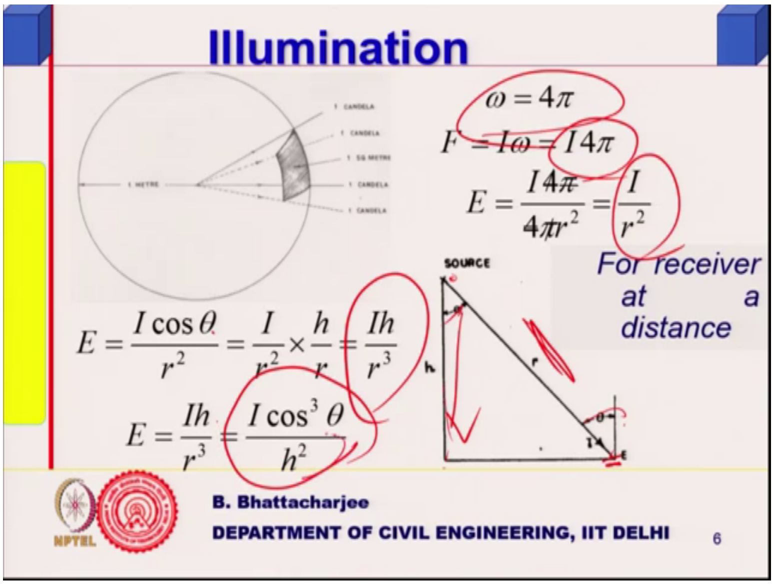

So, you know like this is shown again 1 candela is a source the distances are. So, total in all direction if it is a 1 candela source it will emit 4 pi, I 4 pi flux in all direction divided by 4 pi r square will lead to I by r square. So, it is all one normal direction, if it is a long normal direction, but if it is general equation will be because there will be general law would be if it is projected. So, if it is spherical front going in all direction that is simply I by r square because theta would be equals to 0, cos theta is equals to 0 right; So, normal incidence.

So, for a receiver at a distance, say this is my source this is this is a normal direction. So, I cos theta by r square, I cos theta because this is a theta; So, I cos theta by r square that is what it is this was theta. So, I cos theta by r square, now cos theta can be written as h by r and therefore, height if you know I h by r cube so; that means, you know it is a simple thing that hardly anything in this if I were source, I want to find out what is the illumination there height is known and its distance r is known, then simply I by I h by r cube was simple extra extrapolation of that earlier relationship. So, that is how one can relate illumination with intensity right.

So, I or you can write in terms of I cos q by h square etcetera, etcetera all kind of permutation combination you can do because this is cos theta is nothing, but h by r. So, therefore, you can write you know just change this I h by r cube, make it h cube or you know cos cube actually you all have to divide them by h square. So, that is how it is alright.

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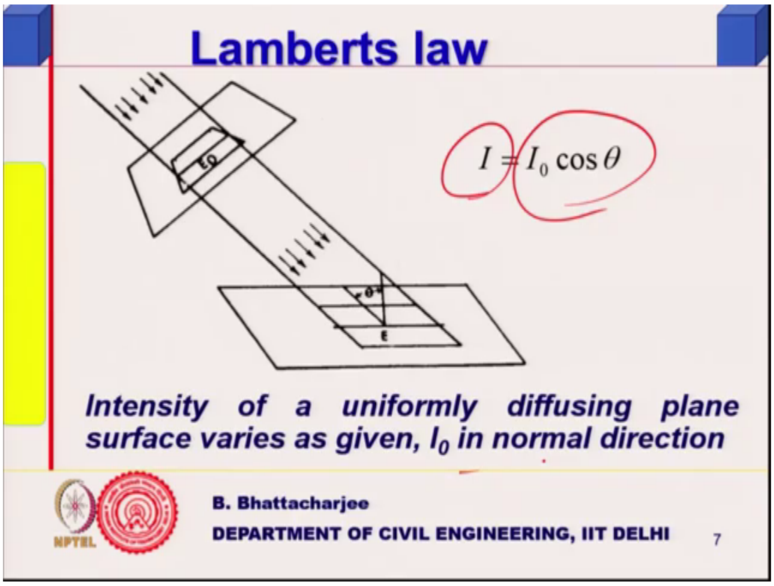

Now, Lambert's law states this is inverse square law and this is quite often we use them, Lambert's law states that if its intensity along given direction of a flat source it is normal direction is I 0 intensity along any other direction will be I 0 cos theta. The intensity for example, I have a source like this right all lamps are vertically downward that direction is I 0, but if I were put now my flat projected surface at an angle the intensity there would be I 0 cos theta.

So, intensity along other direction for sources could be I 0 cos, we do not use this much, but anyway since there is a there is a law I am just stating this intensity of uniformly diffusing plane surface varies as given I zeroes in the normal direction right. So, intensity varies along different direction ok.

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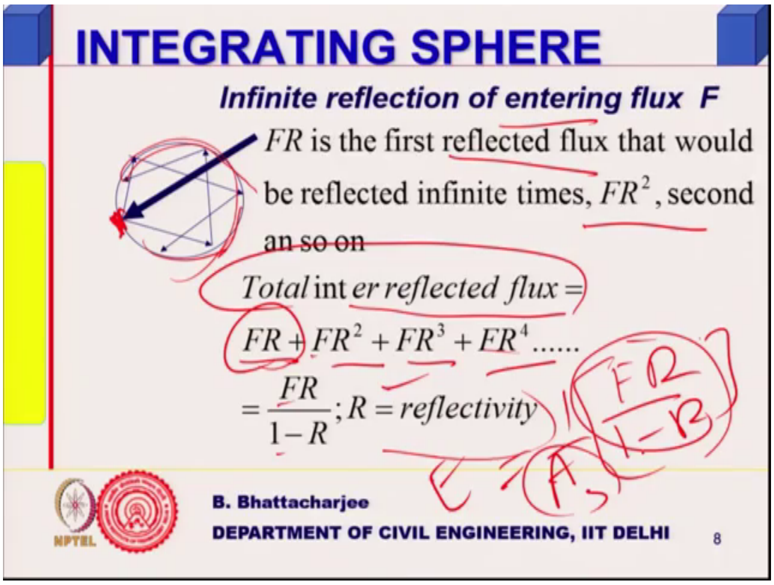

Now, this principle is important this called principle of integrating sphere, supposing I was feared and I were supposing I was fear and I have a light coming in from some point you know through 1 point light is entering there. Now, what will happen if this surface is diffusing then it will reflect in all direction.

So, I will have again infinite reflection, now at this point what will happen I will have very high brightness right, but I will have illumination on the whole surface as well, even though direct light is not being received on those places that is because of the infinite number of reflections coming from this place. You know after first reflection whatever enters into the diffused field that will have infinite number of reflections right.

So, infinite reflection of entering flux F after first reflection. So, FR is a first reflected flux if r is a reflectivity of the surface, 1 minus r is a fraction that is absorbed, R is the fraction that is reflected. So, after first reflection FR is the flux that will enter into the space and it will have infinite reflections. So, FR square will be what will be available after second reflection and then after you know their all inter reflected flux will be first reflection, second, third, fourth etcetera etcetera infinite number of them, it is in a g p series first one is FR. So, FR r is the reflectivity so 1 minus R. So, R is a average reflectivity or constant reflectivity of that sphere.

So, this is the total reflected inter reflected flux, I am leaving the first one F I am leaving, but ever is what enter and this goes on reflected several of them after second, third influence general brightness will be more or less uniform. Even if the brightness here is a point, but you will find in uniform brightness all across the internal surface because of that many number of internal, you know inter reflected component number of fluxes as reflection and this is the total flux and what will be the, what will be the illumination due to this. Illumination will be, illumination will be, illumination will be simply FR, FR 1 minus R divided by you know internal surface area which could be some pi r square or let me say internal surface area of the sphere you know spherical one internal surface.

So, illumination will be given by this. So, illumination will be due to the reflected component, only due to reflected component the illumination general illumination it will be there in all surfaces you know like the top surface the bottom surface side and everywhere. So, all internal you know sphere surfaces, its illumination will be given by this is the total reflected flux inter reflected flux divided by the internal surface area of this. So, this is called principle of integrating sphere.

Now, a room can be also treated like this, supposing I have got one small entry point I put up all right one small entry point through which light is coming or a window let us say. Now, window will have a direct light coming somewhere, but you will have a lot of reflected component. So, general bright you know illumination would be there in all the surfaces and that will be given by this kind of a formula, we will do use this sometime later we will you know it is used we will use this sometime later on when you try to calculate out the total illumination on a surface all right.

So, this is called principle of integrating sphere, the point that I am trying to make is that life does not come from you know the direct light is one thing, but that is something called a diffused light also which will come from reflected component right. So, illumination that you receive on your table, reading table not only comes from the direct light, but it also comes from the wall and those places as well and when I want to estimate that I can use this formula right.

Total light that is received on a working plane or a task plane or the object that you want to read letters at the blackboard there it comes directly if there is a lamp coming in if there is a lamp or window through which the sunlight comes, but there will be a total reflected component also which will eliminate that portion, but all other portions as well. So, that is that is there we will use this principle so let us proceed.

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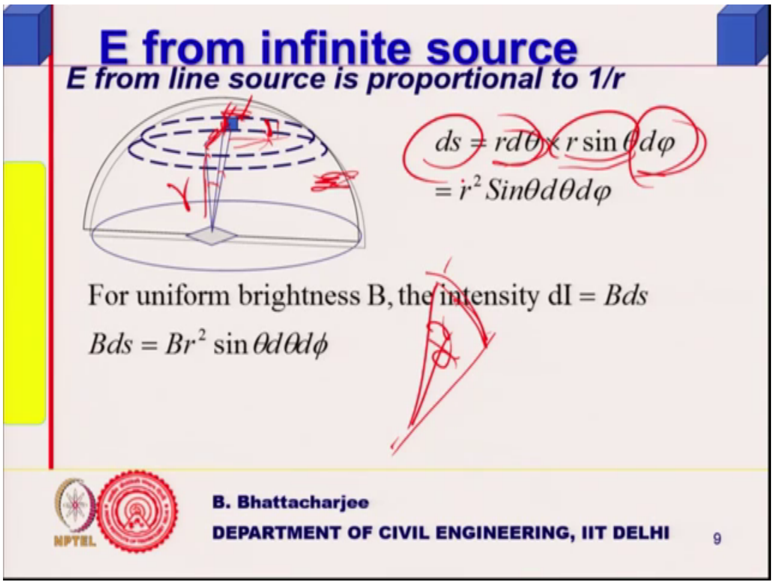

Now, supposing I have a point source then we have seen that I depends upon 1 by r square E is proportional to one by r square illumination.

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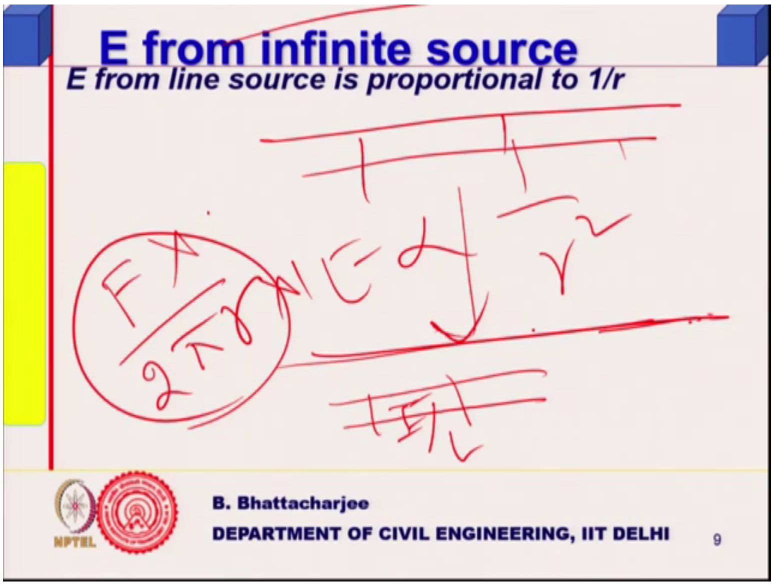

Now, supposing I have a tube lamp, like sound we talked about and I know the I per unit length or flux per unit length I will call it, it will pass through twice pi r into 1. If I have a lamp, long lamp and its flux per unit length is known to me. So, the at any distance r from there it will be F divided by twice pi r, I have a long source long source F per unit length. So, at a distance r it will be uniform illumination in this cylindrical internal surface and it will be F divided by twice pi r right because twice pi r is a surface area into one and this was per unit length; So, through 1 length so therefore, F.

So, from line source it is proportional to 1 by r, for point source it was proportional to 1 by r square. Now, if I have an infinite source let us see how it works and that is had got a relevance because my sky is something like this, sky volt is something like this it is a hemispherical sky volt. Therefore, if I am interested unobstructed illumination on anywhere on the ground surface, I might be interested from an infinitely large source, sky volt sky supposing I have a ground field open field and sun is all covered by cloud ideal condition, you know on a cloudy day you see uniformly bright sky diffuse sky you do not see the sunshine.

So, let us consider that sort of a situation, actual skies are not like that. So, I have a totally covered sky let us say and just you know this infinitely large source at infinite distance right at an infinite distance and I am interested in finding out the illumination here. So, this illumination I can find out by considering a small surface area here, like I have done earlier small surface area.

So, this is a small surface area in the sky and this is my the surface on which I want to find out the illumination, this is the surface on which I want to find out the illumination. So, this is the centre of this circular you know circular I will say it is a ring, it is not unlike there we took an volume element remember in sound we took a volume element for diffused scenario.

We said that everywhere the fill intensity will be same therefore, I pick up a volume inner and which will pass on like sound to a surface here, but here I am sky volt so which is a surface actually. So, it will appear like a surface in between I am not bothered the surface that surface is acting like a source, the sky volt acts like a source and that is this is the distance of this one this is a, you know this distance is r and its a surface this is this distance is you know this distance is, if this distance is r and this angle is theta.

So, this distance is how much r sin theta, I am interested in finding out the surface area of this one. So, it will be r sin theta d phi d sighs size the angle along azimuthal direction you know this one this angle, angle it makes here is this and vertical this height will be how much r d theta because this is the angle you know the theta angle is this angle theta angle is this angle, theta angle is this angle this is the surface I am looking at. So, this is r d theta, r d theta right elevation angle changes changing by theta because this circle could have been somewhere there. So, r d theta so this length this length of this one is r d theta because r is the distance the elevational change is theta angle d theta.

So, I have taken this as theta angle and there is a change in the elevation is r d theta. So, this r d theta is the height and r sin theta d phi is a width of a surface there, small elemental surface there which I call as dS and if its brightness let us say is uniform brightness is B sometime brightness is denoted by B, sometime it is denoted by L, like she said luminance.

So, luminance sometimes therefore, people denote by L and brightness sometimes we denote by B, I might use them interchangeably some book you will find it is written as B, somewhere L. So, might use most probably I will use most of the time B brightness as B.

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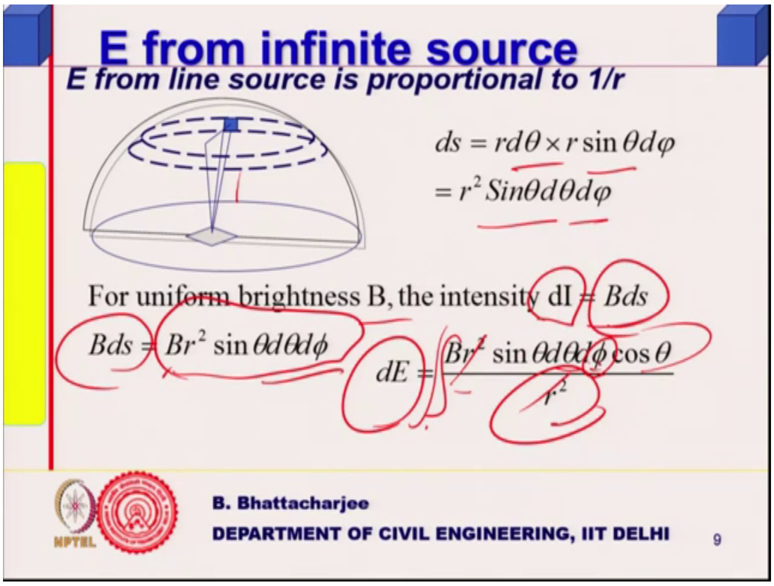

So, for uniform brightness be the intensity of this from this surface will be equals to dI is equals to B into dS lets a sky is uniformly bright, you know uniformly bright then B into dS will be the intensity because brightness is defined as candela upon meter square. So, B candela per meter square multiplied by dS that is the source and B dS therefore, will be equals to be r square sin theta d theta d phi right.

So, what will be the illumination here, I by r square cos theta I by r square cos theta. So, illumination d E will be given as Br square sin theta d theta d phi cos theta divided by r square if r is this distance. Now, you see what is happening this gets cancelled. So, therefore, it is independent of r, independent of distance for a point source it is in inversely proportional to r square for a line source if I define the flux, as flux per unit length it is inversely proportional to r for a large source at infinite distance it is independent of r.

So, 1 by r square, 1 by r or is independent of that. So, this is independent of that. So, d is independent of that anyway I want to find out illumination, then I will integrate this I will simply r square will cancel out I will in from whole of this sky volt if I want to find out the illumination on this surface it will be given as integration of this one and theta will go from where to where.

Theta will go from 0 to 2 pi and phi you will go from sit I will go from 0 to pi by 2 and phi will go from 0 to 2 pi and since this is nothing, nothing else is depending on 2 pi. So, I can take out I can write like this you know I can simply write.

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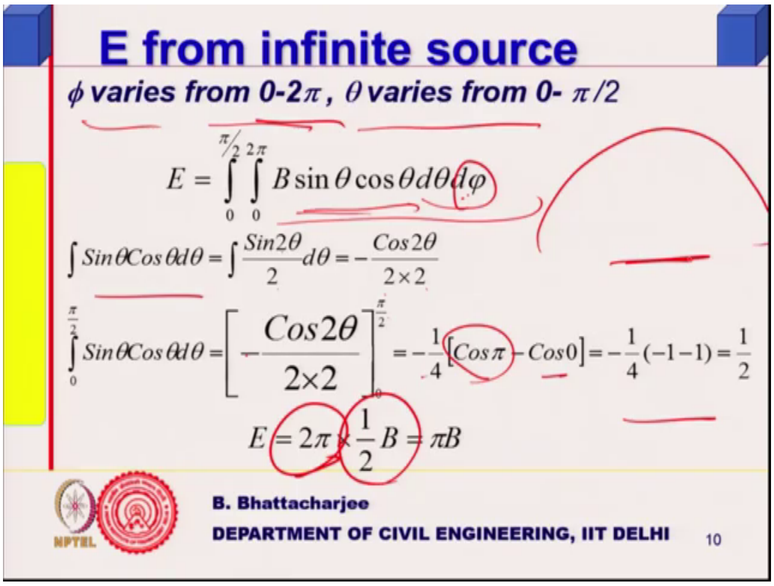

This is what I can write and this will come out very easily. So, theta phi varies from 0 to 2 pi theta varies from 0 to pi by 2 and you remember this sin theta, cos theta, d theta I wanted to do integration which we did earlier also. So, this is simply sin theta 2 theta 2 theta by 2 which if I integrate I get cos 2 theta by 2 into 2 minus sin and then put this 0 to 2 pi. So, this is simply first one is pi by 2 corresponds to pi, cos pi and there is a minus sign. So, minus sign outside minus cos 0; So, it is half this you remember this this was half we did it earlier also I believe something similar. So, this is half.

So, this integration is half. So, I am left with now what I am left with the is the 2 pi this from this I get 2 pi because this varies from 0 to 2 pi and this simply half b so pi b. So, for a uniformly bright hemisphere the illumination E on horizontal surface is given as simply pi into B pi into B for a uniform brightness for and its independent of the distance. So, something like a large hemisphere here I get illumination as simply pi into B, pi into B pi into B all right pi into B ok. So, this is this important deduction we will recover this will recover this.

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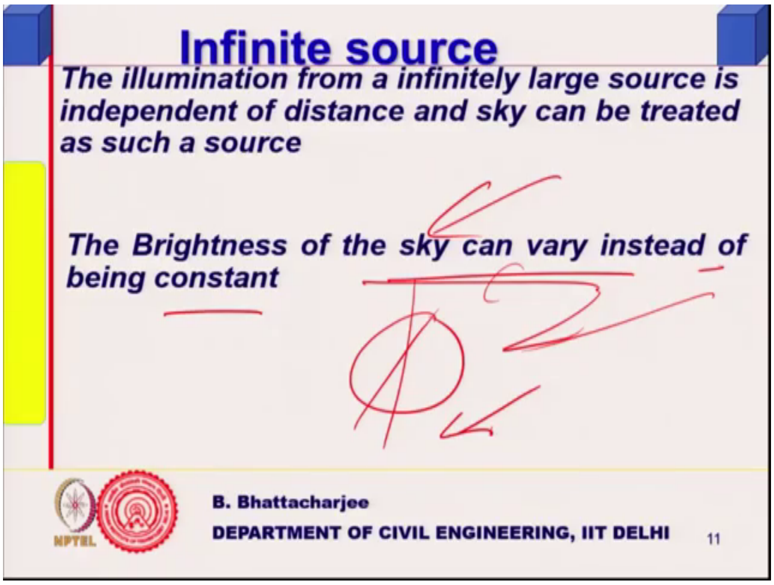

So, the illumination from infinitely large source is independent of distance and sky can be treated something like this as a source right, but then sky brightness is not uniform right. Sky white brightness is not uniform, uniform brightness only you can get if it is sun is fully covered because sun is too large. So, if this is if my, this is, this is this is my you know this is my arc the sun's radiation come from all direction.

So, it will come from the sky wall diffused, diffuse light will come from sky volt, if the sun is blocked we had diffused radiation you remember we had diffused radiation and direct radiation. So, if I sun is blocked then you can have uniform brightness, but otherwise the sun is there. So, uniform brightness is an ideal situation it really does not occur, initially it was thought that perhaps for the overcast sky fully overcast sky is uniform right, but such kind of sky really does not exist in reality. So, brightness of the sky can vary instead of being constant. So, it is actually varies and if you remember when we talked of climates we said that the brightness near the horizon in tropical countries is much higher, it is high very high right, it is very high.

So, we will look into this so it will vary and therefore, we got to take the specific sky for specific, may be specific location the type of sky that would be say suitable for let us say subtropical areas is not suitable for tropical areas. It also depends upon might depend upon the pollution level and things like that many other things because you know how much radiation is coming finally, all this will all depend upon. So, so brightness of the sky can vary and therefore, we new want to calculate out, you can calculate out.

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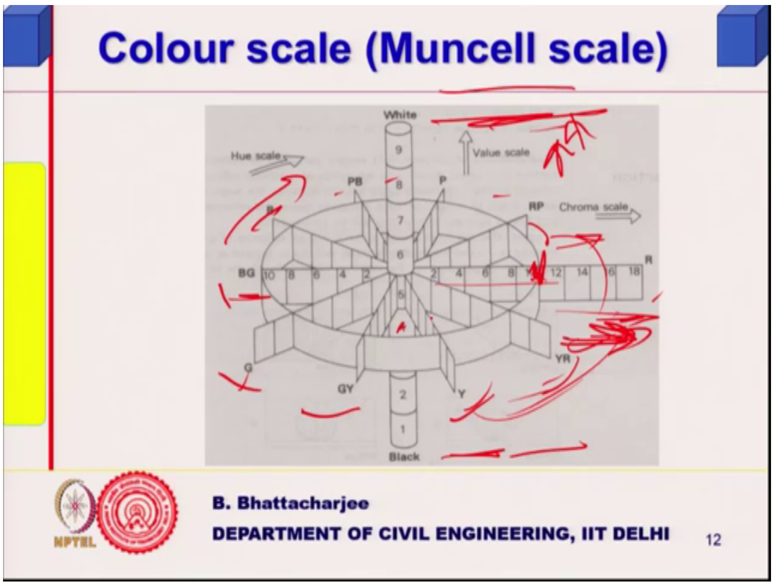

Right we will do that sometime later on, but let us look into some more fundamentals like you are talking about colour. So, a scale of colour is called Muncell scale, scalar colour is called Muncell scale right.

Now, this scale actually colour depends on 3 things, colour depends on three things it depends on reflectivity as well because if it is not reflecting it will appear as black and if it is highly reflecting, you know it will appear as absolutely white and reflecting all wavelength. But if it reflects selectively then also supposing it is only reflecting green colour let us say particular wavelength corresponding to the green colour if reflectivity is 0 then it will also appear black. So, the shades of the green will depend upon reflectivity.

So, it depends upon reflectivity, also brightness so therefore, this a scale has been, you know a scale has been actually devised called Muncell scale we may not use this much, but at least I want to leave introduce this to you because task elimination really does not require this much, but you can have always question.

So, that is why you know I thought I should talk about this. So, you see there is a scale along this line vertical line its black to white, black to white black to white, black is 1, white is you know like it is 1 to 10 scale 9 scale actually. So, these are called value, these are called values right values. So, value varies from 1 to 9, relative scale relative scale actually value corresponds to reflectivity, value corresponds to reflectivity then there is huge scale, huge scale along this direction right.

So, for example, you have red which corresponds to something you know some value of red, red yellow red, yellow green, yellow green, blue blue etcetera etcetera. So, there is a hue, hue is associated with the wavelength you know you talked about hue seen literature also sometimes people do talk about. So, hue is this hue is this right, hue value and there is a chroma scale, chroma scale in this direction, hue scale is in this direction chroma scale is in this direction, chroma scale is related to kind of a brightness these are all relative scale. So, let us see something more.

So, chroma can go from very bright you know to depend upon brightness for example, red colour can be bright red or less bright red and there can be reflectivity. So, you define this colours defines in 3 terms, like how it is written let us see if it is written like this. So, principle user red the yellow green blue purple an intermediate user that is what I said the circular scale you know red, yellow, green etcetera etcetera and intermediate on a yellow, red etcetera etcetera right. So, these are the hues.

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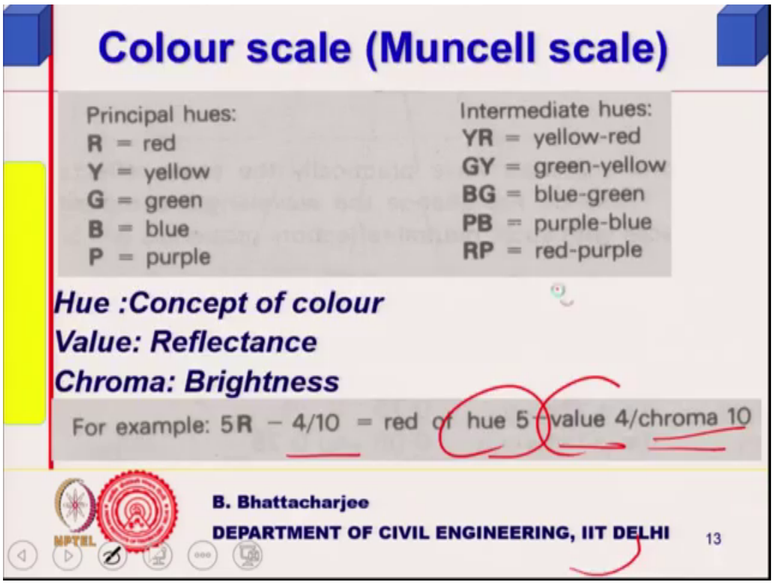

Yellow red, green yellow, blue green, purple blue, red purple etcetera etcetera hue concept of colour the wavelength as I mentioned that is it depends upon the wavelength, you know of the light itself concept of colour value is related to reflectance that is what I said value.

So, it is high value means it is white, no relevance it is black one, value value would be lowest to be black highest will be one it is in its in relative scale and then chroma is brightness brightness. You know like it is more of subjectively dealing in the situation also bright red, dull red you talk of this kind of thing. So, when the one is expressing colour one will write it like this v red, 5 r, 5 r, 4 by 10 what it means is hue is 5 right, hue is 5 reflectivity is relative reflectivity is 4 and chroma brightness is 10.

So, let us go back to 5 r 4 by 10 you know 5 r this will be written the colour if it detailed colour you were interested in right; So, colour if you are interested in; So, 5 r right, 5 r right. So, r is in this direction r 5 r. So, hue scale is 5 r right 5 r, 5 was what? 5 was it value hue hue, here hue 5 r 5 r is somewhere there a chroma is 10. So, it is somewhere there the brightness is 10 brightness is 10.

So, it is somewhere here actually and value was how much 4 by 10, 4 4 is somewhere there. So, it is not very bright I mean it is not reflectivity is not very high. So, it is expressed in this kind of scale actually red of hue 5 red of hue 5; that means, not going towards yellow red or its average red actually and then value 4 means reflectivity is not.

So, high 5 would have been average chroma means relatively bright 10, 18 can it can go up to 18.

So, these are these are used in what you call decorative lighting, task illumination we are not really interested in this, but largely, but this is the scale. So, that distinguishes all. So, colour is not as understood simply through wavelength, it is understood through wavelength reflectivity, as well as relative brightness we distinguish right, we may not use this anymore in our class anymore because we are not dealing with decorative lighting, we are dealing with illumination related to object lighting and task lighting for purpose of reading or similar kind of activities, human activities. So, that is what it is you can express the colour in this manner right alright.

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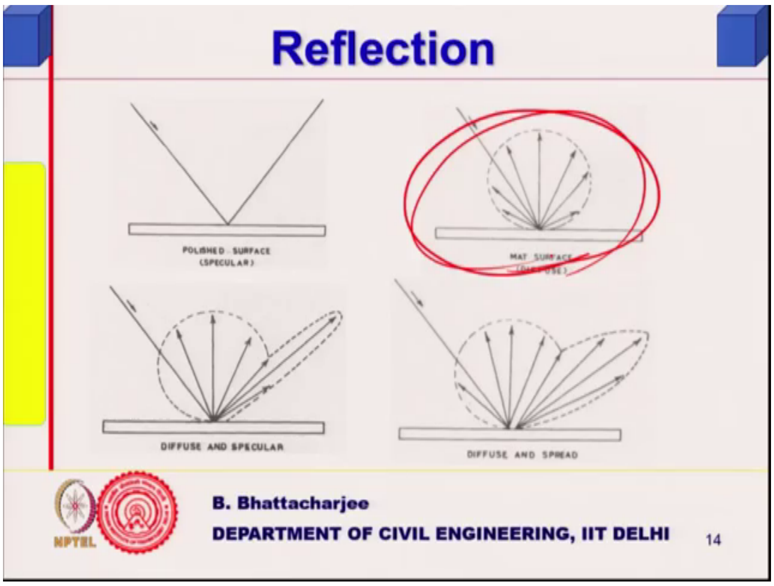

Now, reflection as I am saying its important, reflection is important this is polished surface their specular reflection this is matte surface fully diffuse, but I can have partially diffuse also and this is diffuse and spread, this is diffuse and specular.

So, this is also spreaded somewhere. So, generally task elimination this one would be that what we will consider like while defining apostilb we actually consider this sort of situation or integrating sphere who is considered this sort of situation.