Principles and Applications of Building Science

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Lecture – 19
Lighting – Basics

In this module we will be looking at Lighting. So far we have been talking about thermal as well as acrostics. Further, modules there is in the next module we will be looking at lighting.

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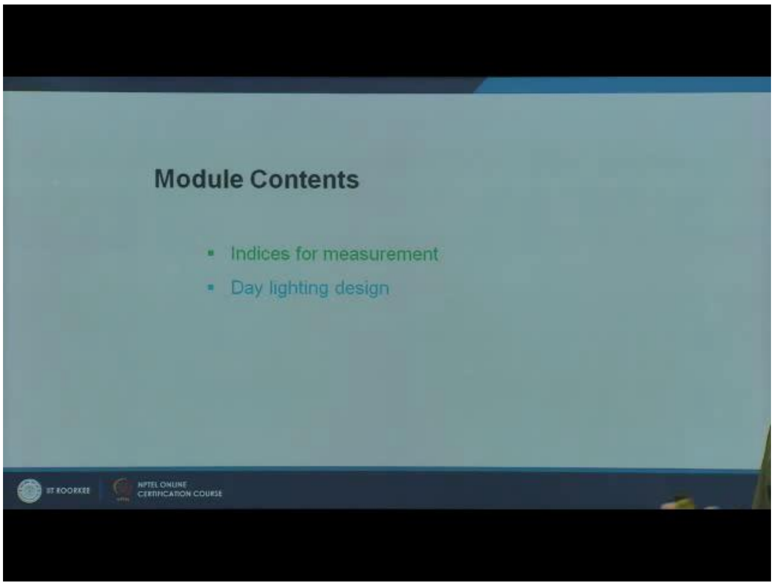

This specific module will cover indices of measurement, what does lighting, what does light energy, what are the indices primarily, what units they have on, what is essential. We will talk little bit about day lighting, how to calculate it primarily about estimating day lighting. In the following module we will look at day lighting harvesting system and how they can be incorporated in the design. Light is a part of electromagnetic spectrum, it is a visible portion this is the only thing human eye can see.

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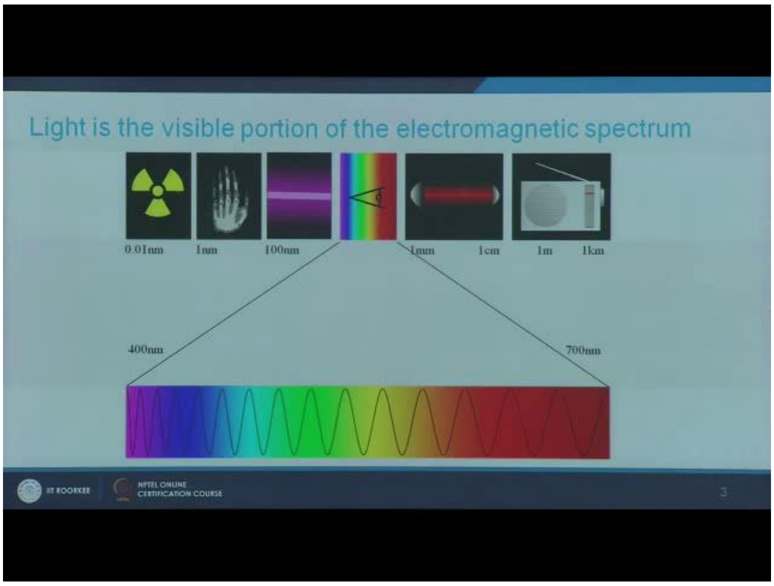

So, it ranges from around 400 nanometers to 700 nanometers below that you have infrared and the other side you have ultra violets. We are interested in the lighting that is a visible part of the lights mean visible part of the electromagnetic spectrum as for this module is concerned.

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Let us look at few important indices that you have to really understand. Lot of them is used and sometimes place of one is used in place of the other they are often confused indices. Let us take a look at few commonly used indices. First is light power, any particular energy we have to talk about the source the light power talks about the source it is the amount of energy or light emitted from a source, which is kind of if you compare it with the water flowing in a pipe. The diameter of the pipe decides how much amount of water can flow through it.

Now this is more or less equivalent to that we call it light power it is measured in lumens. The unit for measurement of light power is lumens. It is something like luminous flux typically when we say energy flow we talk about flux. So, this is luminous flux it is measured in lumens.

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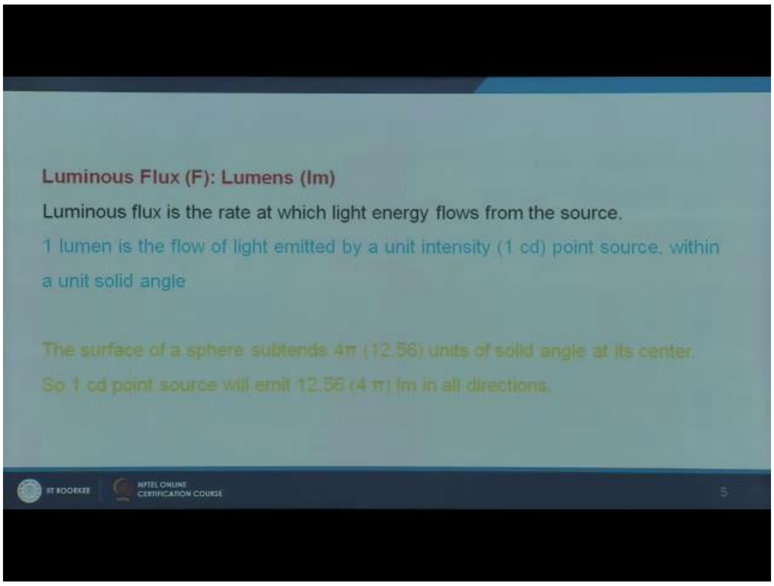

Typically luminous flux is a rate at which as we said the light energy flows from the source. One lumen is a light flow emitted by unit intensity; we will look at what is light intensity in the following slide. Let us just say it is a unit intensity of point source. Now we are talking about the point source with a unit solid angle. As we all know surface of the sphere a spheres obtains 4 phi units, solid angle at its center, so there is a 4 phi. If you say 1 candela or unit intensity point source we will define intensity shortly; unit intensity point source will be emitting 12.56 or 12.64 phi lumens in all direction. This is the conversion which goes here.

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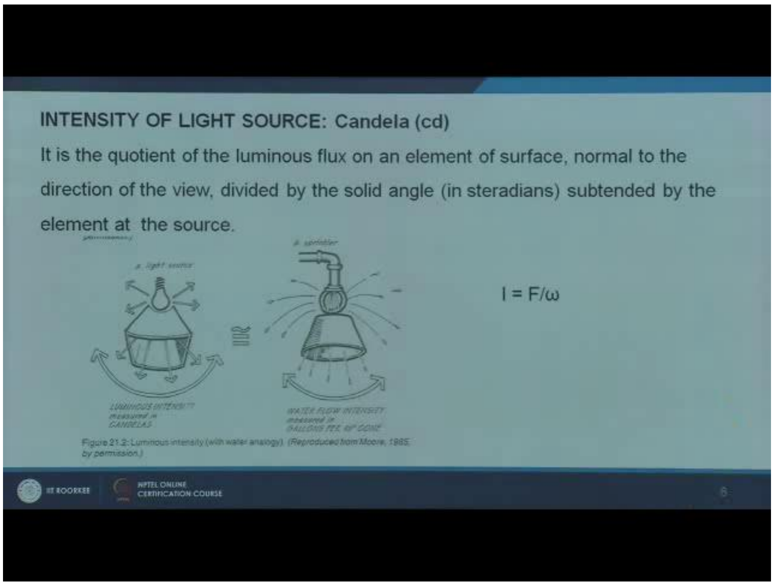

Let us take a look at what is light intensity. This is measured in candela, if you divide the luminous flux that we defined as f which is a luminous flux, if you divide it with the solid angle that is omega which we are defining as omega if you divide this, the quotient what you get is the intensity of light source. This is measured in candela as I said luminous intensity. You can compare it with the flow intensity through particular channel. So, if you are relating an analogue with light as well as this pipe we will be comparing this for a few more instances for a better understanding. First we talked about luminous flux. Once you derived luminous flux by the solid angle then you get the luminous intensity. This is measured in candela.

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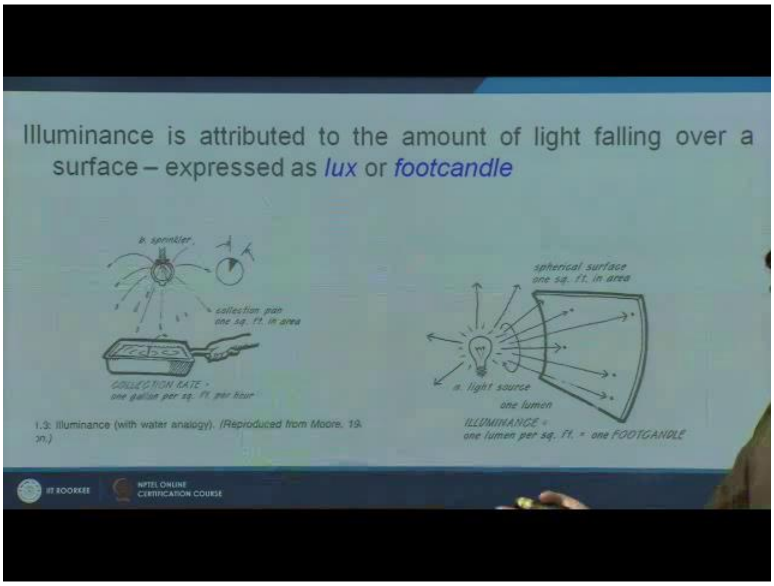

Now let us look at two indices which are more commonly used are any of the standards you refer to they will at some point refer or specify the amount of light required or the kind of lighting required in terms of these indices. The first thing we should knows illuminance level. You will know something like lux levels, people will talk about lux levels this is required amount of lux level. Lux is units are in older system it uses to be foot candle. It is something like you are collecting water in tray from the same water flow channel.

So, this is like the amount of light falling over a surface or amount water and this analogy which is collected over a surface. Older as I said it is lumens per square meter that is flux per square meter or square feet. In older units it uses to be called as foot candle. In the similar way if you are having a plane in which the light energy is falling on. So, how much energy will fall, how much lux you know flux luminous flux will fall on a particular area. So, lumens per square meter area for example, would be indicated as lux level. Lux is indicator of lumens per square meter or lumens per square foot. As I said in older units it is foot candle it uses to be called.

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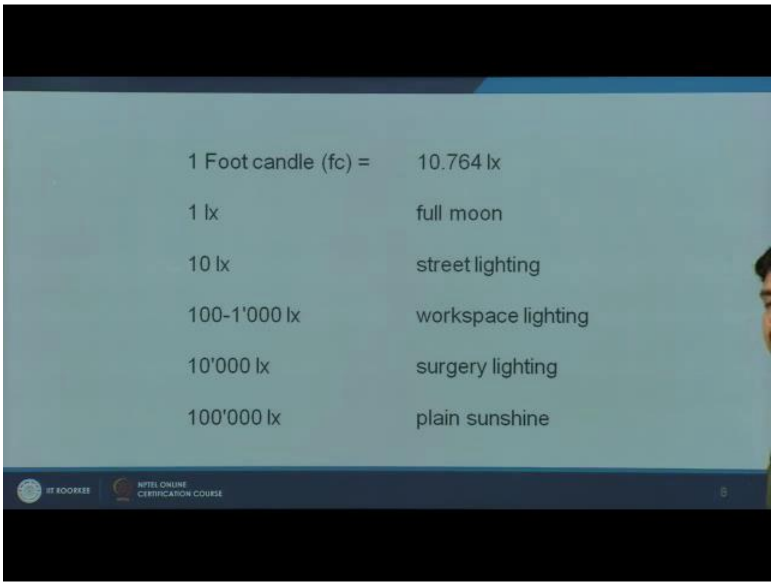

If you get the comparison one foot candle you can convert it to around 10.8 lux. If you say typical light sources full moon you will have close to one lux or pretty low light level. Simply you know Indian standards for example, recommends around 300 lux for typical reading writing activities say classroom lighting on your desk, on your table students table you should have a around 250 to 300 lux. You can still see visualize things or objects if you have 80 luxs to 100 luxs you will able to clearly see objects, but for task specifically here we are talking about task. There are two types of lights lighting which has to be provided typically - one is task lighting and other is a background or ambient lighting. In most places we do not go for these two layers at least minimum two layers are essential, typically we do not go for two layers we are simply going with one background layer. So, when you say 300 lux you try to increase the lighting level. So, that you get three hundred light lux on your desktop.

So, if you have to really talk about an energy conscious design then you will go actually go for two layers for ambient lighting you do not need 300 lux you still see as I said see objects at 80 to 100 lux. So, you can probably stop somewhere round 100 to 150 lux threshold for your background lighting. This is a background layer then on your desktop you will need somewhere close to 280 to 300 lux are slightly more in some cases where for a clear you know or a strain free visibility and doing of the task that you are doing reading and writing task. If you are doing some work in the computer type writing it may not require 300 lux may be it is lightly low.

Talk about a surgical you know area where an operation theater some surgeries being performed you need a very high lux level, you need close to 10,000 lux that is very huge amount of lighting is required. Typically in recording you know video recording studios they have something like flood lighting close to, when people are playing in the night time when you know day and night matches are happening, night time tournaments are happening you have something called flood lighting where very high light levels which is making the daylight more than 8000 lux close to 10,000 lux is provided. Plane sunshine, if go out on measure it will be close to 1 lakh lux you may get, directly on the you know if you put a horizontal sensor in a horizontal plane you will able to get as high as this.

Similarly example if you are going to work space where something like (Refer Time: 07:41) say hardware small you know fabrication is happening instrument hardware fabrication is happening or even simpler example is watch repair shop where very minor part circuits are being repaired in that you will naturally need higher lux level. So, in these cases typically we go for task lighting separately whereas the ambient are background lighting separately.

When you study lighting design in detail, light you know lighting design is dealt with in terms of layering we call layering principle. You take the example of a hotel you enter the hotel say imagine it is a five star hotel you are entering it you will have a reception area lobby then you will have the reception desk, you will have some mural artistic work, some you know statues few artistic things will be there, some landscape will be in outside, they will have certain areas you know longest to discuss, then canteen will be you know cafeteria might be visible, lifts will be visible. So, for each of these particular tasks which are performed reception desk general visibility of the reception area itself plus lighting the murals or painting sign boards each of these things will need a specific amount of lux level or lighting level.

You know more technically lumens per meter square that is amount of light required on a particular surface. For a task or a particular object to be seen more clearly, you want a person to see a sign board more clearly you may need slightly higher lux levels on the particular surface. This we call as layering principle. When we do artificial lighting design we will be actually dealing with light levels in different layers.

The next indicator which is very crucial is called luminance, often it is confused with the previous one that is illuminance that is the intensity of lights or the flux or the amount of light energy falling on a particular area. Here we are taking about lumiance which is also referred as brightness. So, movement we say brightness it is amount of light perceived or measured to reflect of a surface.

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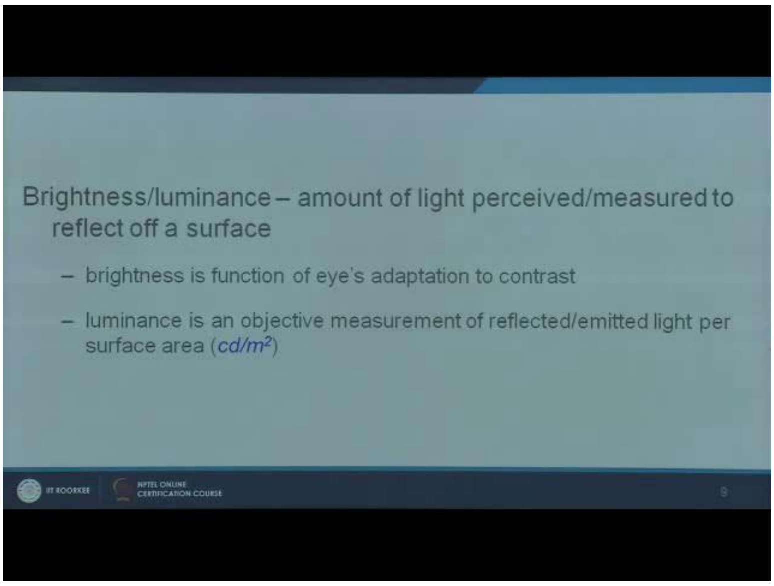

So, there are two things one is perception how does your eye perceive the same light and how much amount of light the surface is reflecting back. Imagine there is 500 lux which is following on a white table surface versus the same 500 lux light which is incident or falling on a black painted or mat black painted table surface. The brightness level these two cases will be drastically different because two reasons - one is your eye adaptation of course, there is a slight difference, but even neglecting that you know you are the same person is made to watch this same is judging the light levels then comes the reflectivity of the surfaces - the first one was a bright white reflecting surface the second is a mat black surface, so the surface reflectivity and observity characteristics.

Drastically effects the amount of right light reflected of a particular surface, this particular things is referred as brightness or luminance level which is measured as candela per meter square. The unit for measurement of luminance is candela per meter square. Lux levels or illuminance level you have very simple devices, illuminance meters are lux meters they have sensor you put them out they will be able to lock their you know more in expensive rather for you know you have a very easy way measuring illuminance level. Whereas when want to measure luminance there are specific devices where you have to focus on a particular surface, you have to set the surface properties then you focus it like a camera they are slightly pricey devices measuring which you will get what is a brightness level are luminance on a surface.

Both these things are crucial. Many of the standards are many of the specifications will stop short of saying what is a brightness level required. Typically they say this is lux level or illumenance level required on a particular surface. Many standards do not talk directly about brightness, but they talk about something called glare. Glare is resulting out of two three typical phenomena one is you have a focus, you have a background. You are looking at a task and you have a background. So, when there is a difference between the brightness level of the task as well as the background then you will have you know result in phenomena called glare. The other thing is you have direct light incident on your eye, then you will incur the same phenomena called glare. There are different types it is typically ions are the loss of clarity which happens you cannot see or read perform a particular activity with the same clarity or comfort which you will be you should be able to do. With that phenomenon we are referring as glare.

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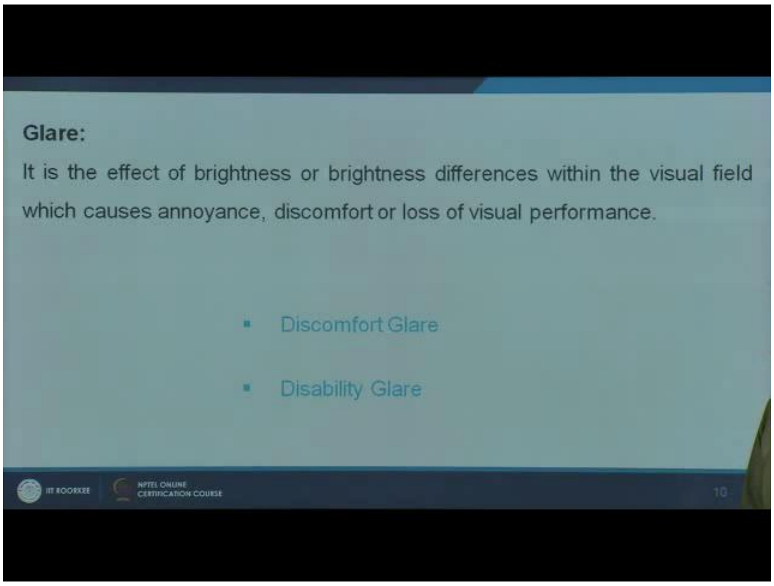

There are two types of glare - one is discomfort glare there is a disability glare. I can give you specific examples two to three examples where you can really understand what will be a discomfort and disability glare. You are seating in your classroom you are looking at your writing board say black board, if you have this sides both sides of the black board if you have two windows where you have direct solar incidence, where you have light from the sun falling on - say if it is a east facing surface you are looking at the board in the morning hour say 8 a clock you have a class. You have direct sun, there is this particular glazing surfaces which is not shaded in this case no curtains this two surfaces will be too bright. When you want to focus on your black board, you will be having certain visual discomfort this is one example.

Second is when you are driving you have a sudden head light which is interrupting you somebody is putting on their head lights they are you know putting on in a high beam, then you have phenomena which effects your visibility in a very short instance. It may be a fraction of second for which you lose your clarity of vision. The first thing is called discomfort glare where you are uncomfortable, but still you are able to see the task on work on it where as a sudden flash of light which very temporarily for a very short duration affects your visibility we refer it as disability glare.

Typically when you talk about glare some of the specifications say project specification will say you should follow national building code or this particular code where the lux level are the illuminace level is specified. Say for example, there asking you to guarantee you have 300 lux on your table top, they will also say you should avoid glare especially in workshops. For example, when you have a long working yard which has typically high stress roofs then you provide the north lights are few day lighting systems one is your trying to ensure with flood lights and daylight. You are trying to ensure you get the task lighting to the required amount say for example; you need around 800 to 900 lux for a particular task. So, you are ensuring that.

What happens some of the locations the light levels will be too high so that the light versus the task versus the background, the contrast will be too high we are talking about the contrast here. When the contrast is increasing beyond that is a maximum lux level available versus the minimum lux level available. Reflections of the task surface versus reflections of the backgrounds surface, if these things are drastically different when the threshold this crust there will be a discomfort associated this also you know kind of classified as glare in this case it is primarily visual discomfort we are talking about. Some of the standards will require you to work around and ensure the glare are visual discomfort is avoided. In these cases you will need both illuminance level as well as luminance level for your assessment.

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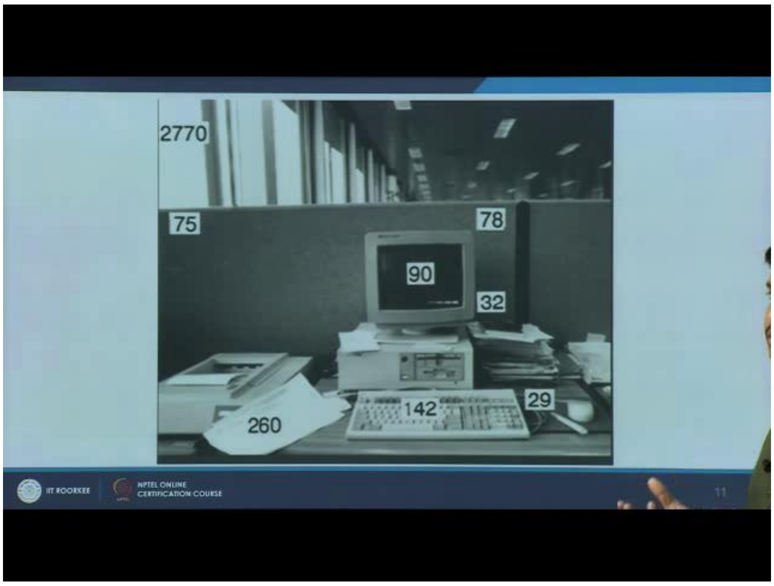

Take a look at this; this is a typical office work space you have around close to 150 lux on your keypad much lower somewhere around 30 lux in your reverse side of your computer there is a window glazing here. So, you get close to 25300 lux here on your notice board you will get somewhere around 80 lux when you just lift your eyes you look at the window you will be getting close to 3000 lux at instance. So, your eye is now expose to a variety of illuminance level as well as if you take a look each of these surfaces have different reflectances. Take the ceiling, take notice board, take the keyboard, take a sheet of paper plus you have your glass surfaces plus you have papers you know light dark surfaces where you are brightness levels also now are typically varying.

If these say for example, the task versus background the brightness is very high say if you are looking at your computer towards this side when you look at this screen the light levels are much low, the brightness is different, movement you turn out you see the large plane window then you have a different light level. If difference is too high then you will have a visual discomfort. Similarly if you are turning the computer to this side there is a direct light which is falling you have reflection of the window you have direct you know visible light getting reflected from your computer screen again this will result in glare.

So, these are typical do's and dont's are typical instances which I is exposed to. You can do a mapping face to face clear this is what we are talking about if we really want to save energy if your are really conscious about it say in a typical open office like this if you simply go with a ceiling lights which is a common things to do you have ceiling lights all around you will have if I am wanting to ensure something like 200 lux in this particular plane.

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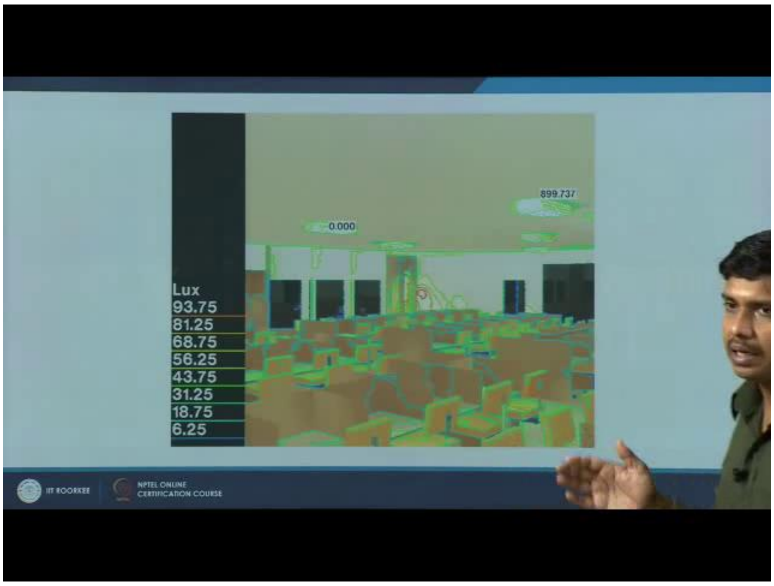

I will have to increase these luminaries the lux levels are the number of luminant lumens you know luminaries which are placed in the ceiling the numbers have to be increased. So, that I will get around 200 lux on my table top the other better idea are more you know logical idea here is to go for task lighting for each of these tables are at least four of these cubicles you have one task lighting one light separately. Whenever this people are out this lights can be turned off, where as the background lighting can just be around 100-150 luxs, as to ensure clear visibility of objects.

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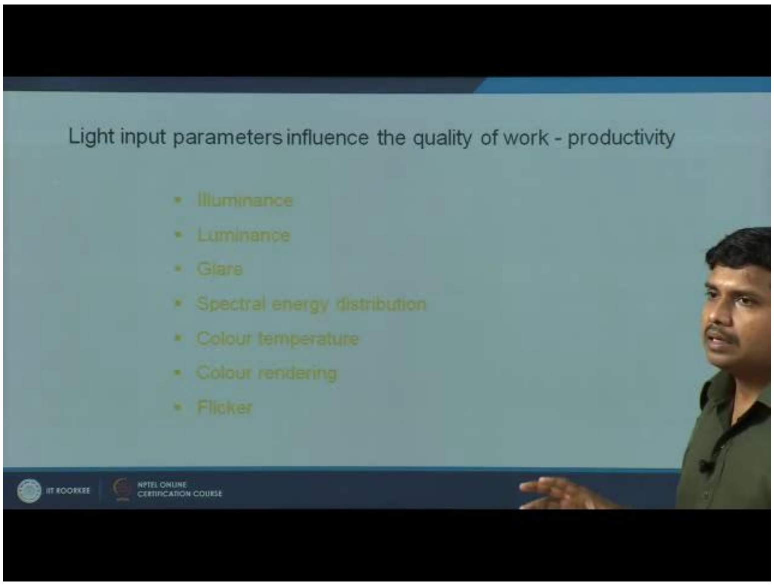

Other then this we have we talked about illuminance, luminance and glare other then this we have few other parameters spectral energy distribution at which part the light energy is distributed along the spectrum. Then you have something called color temperature and color rendering these are typically used in interior lightings for example, imagine you are going to a jewelry shop you have a gold section, gold jewelry you have a diamond jewelry, you have silver jewelry, each of this is a jewelry has a typical color gold has you know a typical yellowish tint where as diamond more crystal kind of thing you want different kind of light for the jewelry to be more appealing to the eye. Yes, if you put it in natural light if you bring it out show it in the natural light it will show the actual color where as what the seller is do they try to enhance the look on feel of it.

Similarly to a skill saree shop if you have to really enhance the particular project you know product which is being sold they will have a kind of color rendering which we call color rendering the color of the light is so adjusted that a particular product is more enhance its look and feel. Then with modern lighting like LEDs we have a phenomenon called flicker the rate of you know flickering there are devices to measure flicker rates flickering is another important phenomena which effects the health of the eye as well as the visibility and visual comfort. So, flicker is another important phenomena, but primarily as per this model is concerned we are limiting ourselves to illuminance

luminance and glare as we know daylight is very important one of the studies which I am referring to this is a study which was done some time back in Canada where they identify two different you know benefits of daylight.

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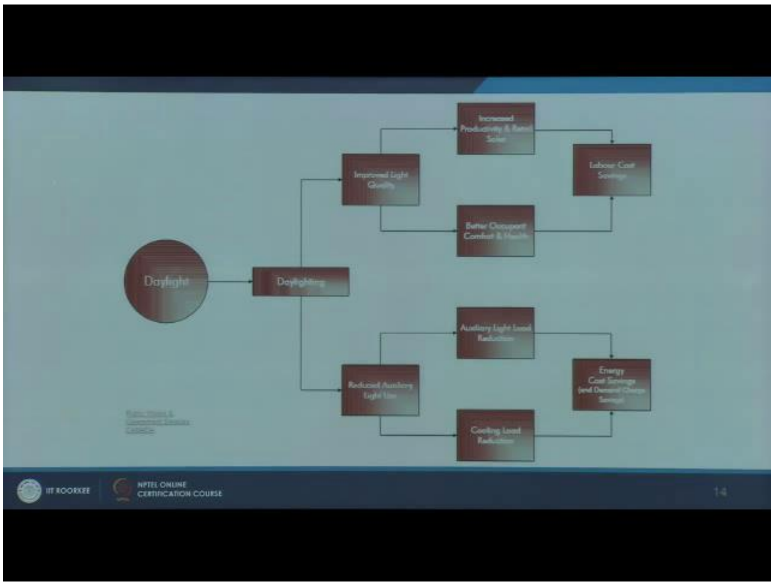

First thing of course, we know it reduces the artificial lighting load first is it directly reduces the plug loader, the light load associated with the electricity consumption for artificial lighting. Apart from this it also reduces the heat generated from these lightings, comparently reducing the cooling load of the system. So, both these cases you have considerable cost saving. Apart from this they also found that it improve the quality of the space, it improved the productivity of the workers then it also improved the salability it improved the health and comfort indoors finally, they resulted, they perceived a result of better labor and cast saving apart from an increased scale of particular product which are you know which was there.

Now, let us to take a step by step look at how day lighting is you know can be understood and how we can design for day lighting. The first thing we should know is, what is available to us how much amount of light at all visible light is available to us this depends on where exactly you are.

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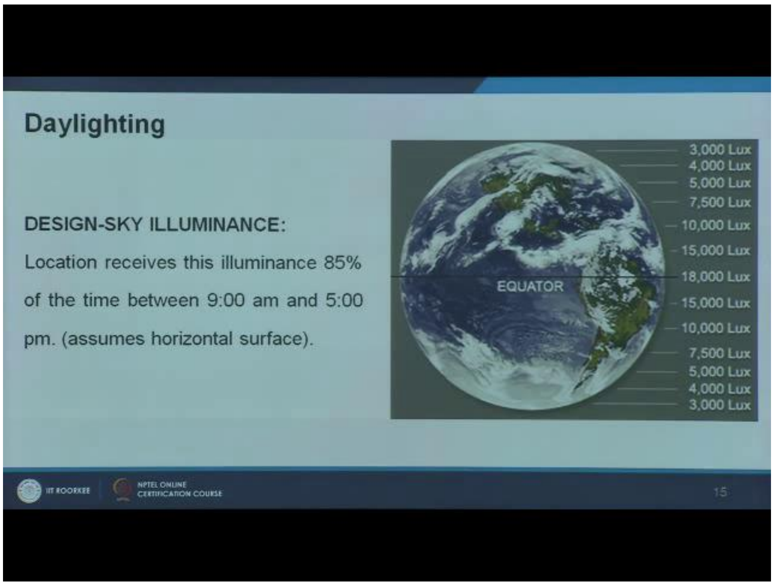

If you are in the equator you will have really high amount of light level we typically refer this as design sky illuminance, it is not you know just putting the sensor directly below sun and measuring it. Like I said you will have you know close one lack lux if you are putting a sensor and measuring, but this is something like what you will get from 9 am to 5 pm at least for 85 percent of the time. So, even if you are measuring an western facade in the mornings are eastern facade in the evening, you should be able to get this amount of light that is what we refer as design sky illuminance that is a minimum best available lighting visible light available on a particular location.

It varies from equator it is very high it can be around as high as 18000 lux as you go further you have around 3000 lux in your polar region. What we have understand if you are providing a window say for example, two meter by one meter window you will get more than enough daylight example for a small room - say 3 meter by 3 meter room with 2 meter by 1 meter window on one side you may get more than enough day lighting if the building is located in equator whereas, the same building if you are designing close to the poles the available light itself is much lesser. So, you may not be able to ensure the minimum amount of daylight which is required.

For example, when a standard says you should have at least 200 lux daylight available, you may not able to achieve it with the same design both in equator as well as in the polar regions because the available daylight are the design sky luminance varies. We are somewhere here as I said close to you know crisscrossing tropic of cancer. In India we take the design sky illuminance as 8000 lux some of the standard reference they also consider 8500. Typically we take national codes suggests around 8000 lux as design sky illuminance.

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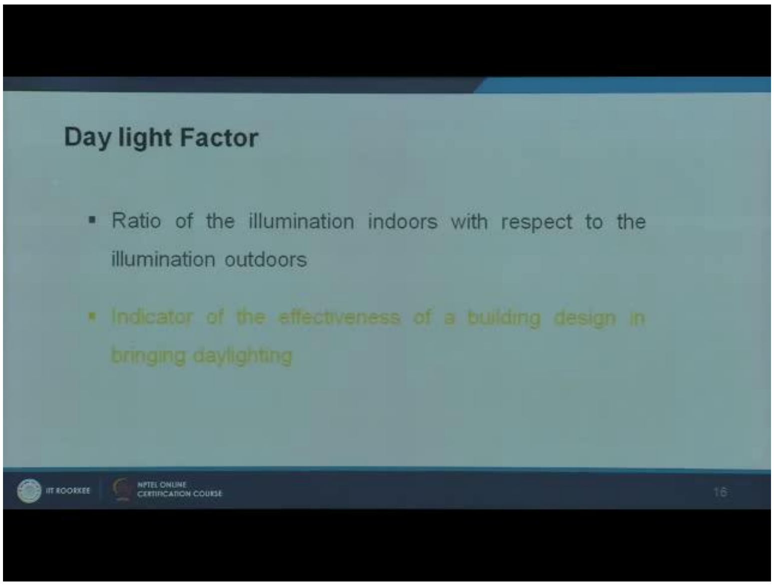

So, first step when we are starting to do day lighting design we will take 8000 lux as available to us outside the window. One of the main factors primarily which is talked about is daylight factor it is expressed in percentage it is a unit expressed in percentage it is nothing but the ratio of illumination which is available indoor to that of what is available outdoor. So, when I say at 8000 lux is a standard designs sky are what is available standard design sky illuminance which is available outside by window if I am located in India. If I am able to ensure say 80 lux which means I have 1 percent daylight factor this is as simple as that.

So, when a standard says you ensure at least 2 percent daylight factor, it is ideally meaning that average illumenance in your room, average illuminance I am talking about, it can be more close to the window it can be further less in the interiors, but overall the average daylight available inside the room should be 160 lux. So, without any artificial lighting you should ensure you should be able to ensure 160 lux from just day lighting.

So, you have to size your windows appropriately in order to get this. This is what is a simple definition of daylight factor. Of course, it indicates effectiveness of building design in harvesting or harnessing natural lighting. Apart from the direct component we have been talking about the design sky illuminants which are available.

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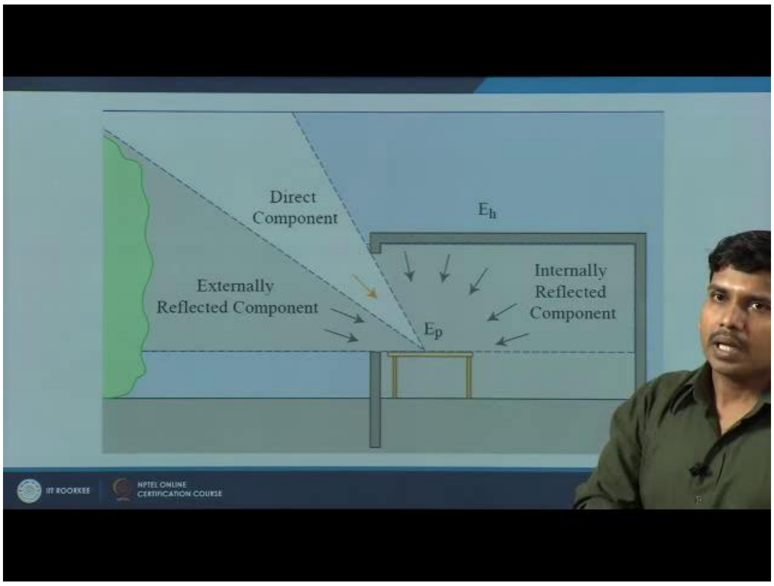

This direct component, this much is available this is getting indoor. Apart from that there are important parameters which affect the daylight into the building - first thing is an external reflected component and second is internal reflected component

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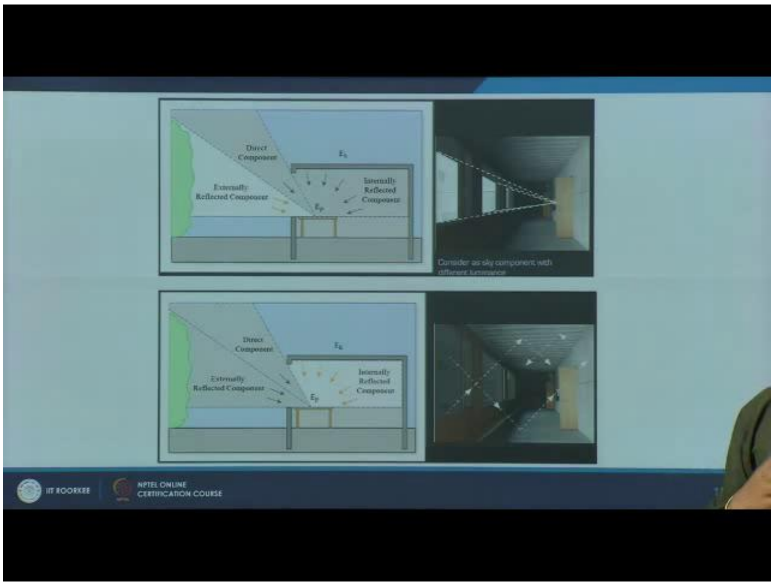

Imagine you have a snow cover or imagine you have a water body or imagine you have grass surface each of this surfaces I am talking about have specific absorption and reflection characteristic. So, when you grass surface or you have an empty terrain at dark black soil versus a snow clarity area snow would reflect more amount of light. So, the direct light apart from entering your window it also falls on these surfaces gets reflected. So, external reflected component in the case of snow you might get more, whereas in the case of dark wet black soil you might get much less external reflected component.

The second thing is the internal reflected component what if you paint your ceiling totally black. Once you have a direct light hitting a particular surface the second reflection, third reflection will be almost nullified because after the first reflection your black surfaces are going to absorb not much reflect these light, whereas if you have more reflecting surfaces it will help you or it will enhance the throw of daylight for into the interior.

So, here overall lighting level will be considerable high if you are internal reflected components are higher. So, there are three components here - direct component plus external reflected component plus internal reflected component three important parameters are associated.

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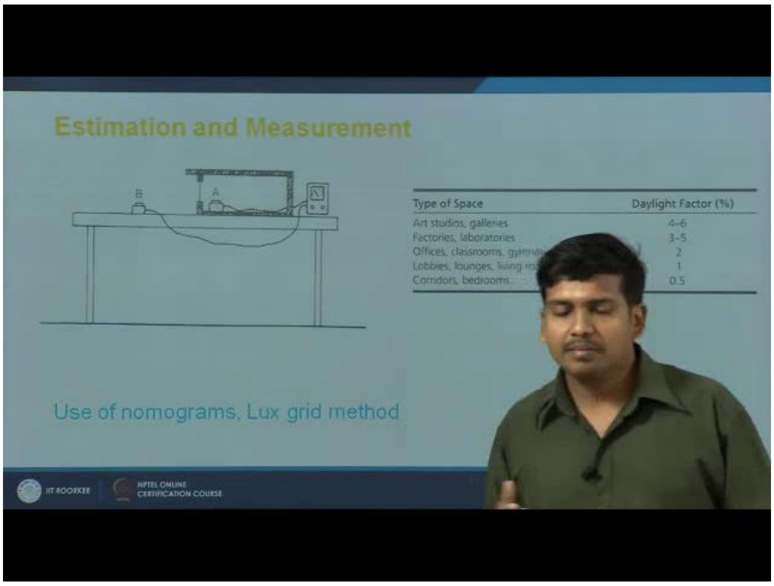

If you have to measure it take a sensor put one out and one in you measure this measure this you can simply get the ratio to find out what is daylight factor. If you take a look at naturally building code or SP 32 which is again associated standard with national building code. You will find the use nomograms extensively you have you know method called lux grid method which you can use to determine what is a daylight factor. There are nomograms nicely which seamlessly helps you to find out what would be the external reflected component, what is the effect of abstractions outside, what is the effect of internal reflected component. With these things how do I design or how do I size my window. This much easily presented in our national code.

You will have like lux level specification; you will also find some specifications relating to required daylight factors. Instead of saying this much lux or daylight levels are required people might say for example, corridors you need 0.5 percent daylight factor whereas lobbies lounges you will need 1 percent. So, if you are if this standard in case if this standard is applicable in India you will have to ensure at least 40 lux of day light available in this spaces because we have 8000 lux as your ambient here, you will have 80 lux, this will be 120 lux and further high, around 400 lux here for the laboratory. So, this is what the translation means.

Now we have been talking about lux levels, daylight factors, external and internal reflected component, these are for open window. Moment you have glass or glazing system third factor you know the forth factor comes into picture that is the effect of glass itself, we refer it to visible light transmittance in the heat.

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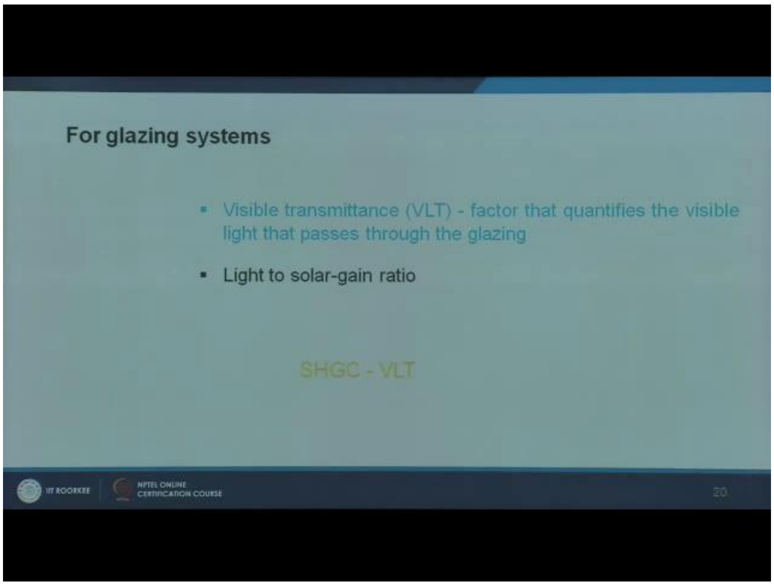

Thermal section we talked about something called solar heat gain coefficient or SHGC this is for heat we talked about SHGC, here for light we are talking about VLT that is visible light transmittance this is expressed in percentage how much amount of the incidence light is able to be pass through a particular glass.

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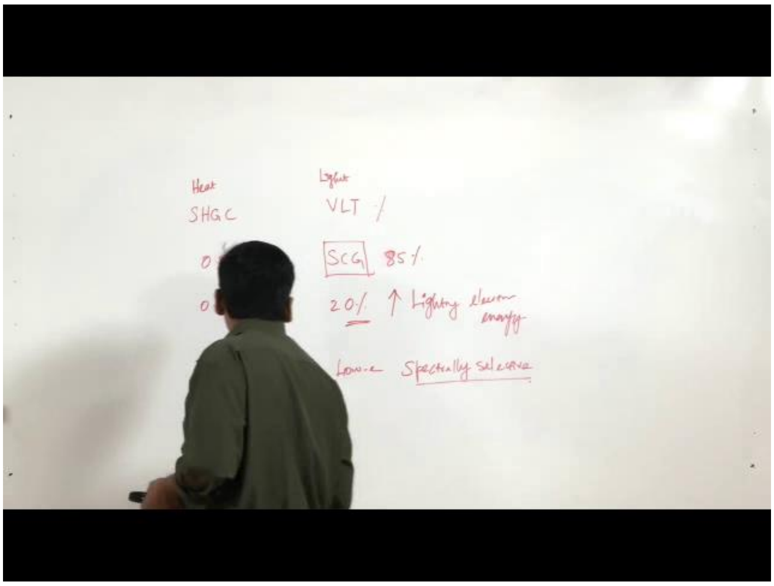

For example, if your are taking a single clear glass a single clear glass if you are taking as a example this will have a visible light transmittance of something close to say 90 percent or let us take 85 percent VLT is available. Same SHGC will be really high it will be around 0.8 to 0.9, it allows high amount of heat to pass through it also allows high amount of the daylight pass through. Say you know 20 years back when energy conservation and energy conscious design where started to be you know (Refer Time: 29:07) people started realizing the need for it, they started going for the double glass window of course, then they started going in for dark tinted windows, so that they can cut solar radiation.

So, in this context for example, if you take a dark tinted bronze tinted windows you will have an SHGC of something like 0.5 a double class with the bronze tint you, will be able to achieve a solar heat gain coefficient of 0.5 which means you are able to cut almost half of the radiative component as well as a conductive component SHGC s drastically come down. So, you are able to naturally save some energy there, but what is impact on VLT? VLT will be as low as 0.2 or 20 percentage.

The visible light available is drastically cut this going to increase your lighting energy, lighting electrical energy this was a negative impact with the new things called spectrally selective glazing are low e coated glass typically called low e coated glass. These are spectrally selective, if you recollect we saw different spectrums of the electromagnetic rays when we are talking about is visible spectrum here we are talking about the infrared spectrum. These spectrally selective glazing will permit the visible light to pass through while they will cut down the infrared especially the short wave solar radiation to be cut through.

So, if you take a low e double glass low e coated even a plane glass there are you know even (Refer Time: 30:51) plain kind of glass which are available which are good in thermal. In those glasses you will find SHGC s low as 0.15 versus VLT of the order of say 40 to 50 percent which means they are allowing 50 percent of daylight to come in while SHGC is drastically cut down. You are saving energy as thermal concerned you are also able to manage enough amount of daylight for your interior.

So, that the artificial lighting energy electrical energy consumption is cut down. So, this is the crucial thing you have to keep in mind when you are designing you are windows as well as glazing system. Take care of SHGC for energy conservation whereas also take care of the visible light transmission property of the glaze glass or glazing system. So, that you are lighting loads can be brought down. There is a simple indicator for this which is called light to solar gain ratio which is nothing but VLT by SHGC that is the ratio which indicates a higher light to solar gain ratio means the light transmittance is also better. So, this is SHGC versus VLT relationship.

So, as far this module is concerned we have talked about we have introduced a concept of light and various indices use for measuring it. We talked about illuminance luminance we talked about luminous flux lumens then we talked about luminous intensity we talked about glare. Apart from that we looked at what is daylight what are the parameters associated with daylight thing design what is daylight factor and we finally, looked at what is impact of glass and glazing system on the available daylight inside a building.

Thank you.