

Interior Design
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Lecture - 23
Interior Design: Green Interiors: Physics of Light -Day Light, Artificial Light,
Chemistry of Colours

Namaste, hello everyone. Welcome again to my NPTEL course on Interior Design. We are at lecture number 23 today, and we are still focusing on green interiors. Specifically, we will talk about the physics of light and the chemistry of colors. It is a very comprehensive, important, and technical lecture. I request your time and attention because it is very industry-oriented, and you will find it very useful.

So the broad contents for today are: We will talk about lighting design concepts and functions. We will talk about the physics of light. We will talk about vision and color perception within that. Then we will talk about the chemistry of colors, and we will try to understand the color wheel and the effects of color on space.

We will also try to understand photometric quantities, the transmission of light, the LED CI, the credits for daylighting, artificial lighting, and what LPD is. And, of course, we will see a comprehensive list of references. So let's start with lighting design and broadly try to understand the concepts related to lighting design when we talk about interior design projects and the associated lighting design. So it's important to understand the functions of lighting design. It is practical as one of the most important functions, and it ensures visual comfort while performing a task.

So if we look at a task or activity over here, there is a certain illumination that is the lux levels required for us to be able to perform that task. So that is of course related to the functionality. So for the casual seeing, walking, talking, we require 100 lux. And if there is an exceptionally severe task such as watchmaking, it could be 2000 to 3000 lux. And this is a reference from full moon to overcast sky to sunlight.

But for simplification and for understanding in terms of lux levels, what are the requirements for doing these functions, we can understand through this kind of a table. The other function of lighting design could be artistic, to create an ambience, mood or psychological effect. Now you know there is always this kind of a temperature

association when we talk about lighting design and we have touched upon it. There is also an association between light and color. So here if we talk about these lux levels on this axis and you know temperature on this axis we could classify you know

too warm to too cold to comfortable as these three different zones so this could be like a cold color that we see over here and this could be a warm color which has association with warmth and some temperature so there are a lot of interrelationships between you know color and light temperature and light temperature and color interrelationships between these And they do have implications on our mood as well as the functional aspects. So, physics of light. When I say physics of light, we have some background from science, most of us, and we may have studied physics. So, we have some understanding of

And why am I talking about the physics of light? Because I always say interior design is a technical subject, and it is important to have some fundamentals clear. So just trying to understand what light is and, when we talk about lighting design, why do we really need to begin from this point? So basically, it is a narrow wavelength band of electromagnetic radiation from 380 to 780 nanometers, from violet to red. So these are the colors, and this is the range for visible light.

So if we try to understand the electromagnetic spectrum, there is a very, very minuscule portion which is the visible light spectrum. So, you know, we have this visible light from this nanometer to this nanometer, and towards the left, it is UV, and on this side, it is infrared. So if we try to understand this broad spectrum, We have cosmic rays, x-rays, this is for radio, broadcast bands, and so on. And this over here, if we look at this portion, this is the visible light.

There is also the capacity of visual fields. We briefly saw this during lecture number eight. So we talk about the human eye and the capacity of visual fields. There is this focus vision, you know, which helps us in targeting, reading signs, and signals. It gives us visual lead.

Then there is central vision, which is for referencing the path of travel and sight lines. And there is also peripheral vision, which helps us understand motion and color changes. So it's very important to understand these fundamentals, and then we can also

establish what the sight lines are. How do we focus on a certain aspect? What kind of lighting design is required to aid that?

What is the functional aspect in terms of the levels of illuminance, the lux levels, and so on? So we can draw some correlations once we understand the fundamentals. So let's talk about the human eye, which has two kinds of receptors: cones and rods. So 6.5 million cones help perceive color. So we are talking about the importance of color and lighting all the time when we discuss interior design.

So this is how we perceive colors. And there are 100 million rods that perceive only black and white but respond to minute quantities of light. So if we talk about day and night vision, we see mesopic, which is dim light vision, and it's also called rod and cone vision. Then there is scotopic, which is night vision and primarily rod vision. And there is

Photopic, which is the day vision—the cones' vision—so the cones of the eye are of three different types, and these are the primary colors in light, which are red, green, and blue. That's how we are able to understand day and night vision, and we are able to perceive and see things. So there is also, you know, vision and color perception. There is a sensitivity of the eye to color. We were talking about this kind of range, you know, for the visible light. And if we talk about the sensitivity of the eye to color, the human eye's sensitivity is greatest around 550 nanometers, which is for the color yellow.

Then we talk about color perception. The wavelength of light determines its color. Light containing all visible wavelengths is perceived as white. Materials that have the same reflectance for all wavelengths of visible light and do not change the composition of light after reflection are known as neutral reflectors, and they will be seen as white, gray, or black. So when we talk about

You know, the absence of color in white, or we talk about neutral colors, or we talk about the maximum sensitivity of the human eye toward yellow, which is at a certain nanometer. Of course, there is profound science behind it. And that's why we call them the physics of light and the chemistry of colors. And we are trying to understand the human eye, our perception of color, you know, and vision and color perception—their interrelationships. Materials that are selective in their reflectance of wavelength by absorbing certain wavelengths of the incident light will show a color effect.

So these are the kinds of impacts and effects we will get to see. Continuing with color perception, we must have come across several times the RGB color scheme and the CMYK color scheme. So what are these, and how can we briefly understand them? Cameras, televisions, phones, and computer monitors use the additive color model. The additive color model describes how light produces color.

The additive colors are red, green, and blue, or RGB. The additive color starts with black and adds red, green, and blue light to produce the visible spectrum of colors. As more color is added, the result becomes lighter. When all three colors are combined equally, the result is white light. So if we look over here, the additive color includes red, green, and blue.

So there is the RGB scheme, and their combinations give us certain results. And these are additive colors. Similarly, there are also the subtractive colors. In the subtractive color model, pigment produces color using reflected light. This color model is used in printing, silk screening, painting, and other mediums that add pigment to a substrate.

The subtractive colors are cyan, yellow, magenta, and black, also known as CMYK. Subtractive color begins with white and ends with black. As color is added, the result becomes darker. Now we are seeing silk screening, painting, and printing. Here, the CMYK is encouraged.

And if we are talking about using silkscreen—some kind of silkscreening for interior design projects, some wallpaper, some printing—this would be important for us to understand the difference between the CMYK and the RGB color screen. So, we were talking about red, green, and blue, and here, cyan, magenta, and yellow. So, this is basically to understand the two major schemes that are utilized for different visual-related aspects, projects, and media—how they utilize it. Broadly talking about the chemistry of colors and trying to understand further from where we left off in terms of additive and subtractive. It would be interesting to get to know about the color wheel because it helps us understand the color system and interrelationships between colors very well.

So, it is a helpful tool to examine the relationship between colors. It represents the linear spectrum of visible light—the colors of the rainbow from red to violet—and joins the ends of the line to form a circle. The color wheel enables us to visualize and define

color combinations that work well together. So, we get to know about the color harmonies. So, if we look at the color wheel over here, we see the primary colors, which are yellow, red, and blue.

Then we see some secondary colors, orange, violet and green, the one in the dotted. And then there are tertiary colors which are formed by combination. So yellow-orange over here is tertiary, red-orange, red-violet and so on. So this is the color wheel and this helps us understand the primary, secondary and tertiary colors. And we will also see what are the effects of different colors on a space and how could we pick and choose the color scheme for us.

So to understand the color system in a very simplistic manner because it could be very elaborate and technical but putting things in a very very simplified form over here. The Munsell colour system, it describes each colour in terms of, first one is hue, which is the colour itself, red, blue, yellow, green, purple, so on. Second one is the value, the subjective measure of reflectance, giving light or dark appearance to the colour. And then there is chroma, which is the degree of colourfulness or the intensity of the colour. Now we are talking about the value.

Lighter values are called tints and darker values are called shades. And there are also tones. So tone is also denoted by intensity but it is created by adding both white and black which is grey. So it is slightly different from chroma. So, chroma refers to the intensity or saturation of a color, essentially how vibrant or pure it is, while tone refers to a color that has been dulled by adding gray, meaning it has a lower saturation and appears less vibrant.

For example, a bright sunny yellow would have high chroma, while a muted pastel yellow would be considered a toned version with lower chroma. So, depending on the choice and the typology or the function where that color has to be used, there are different options available, and the designers could make a decision. But it's important to understand what a hue, value, chroma, tint, tone, and shade are because color is a very important element when we talk about interior design. And if we are able to have a hold and command over creating and selecting colors, it would give us an edge. In fact, there are a lot of countries, especially Nordic countries and other parts of Europe, where color designers are seen as experts.

And there are demands and career trajectories that people have followed, focusing on colors. So, if I have to give an overview, the hue is pure pigment. Tone is a pure pigment with just gray added. Tint is a pure pigment with just white added, and shade is the pure pigment with just black added. So here, if we look at the hue, this is the pure color.

Tint is the mixture of color with white. For tone, we have added gray. And for the shade, we have added black. So we have this whole range and plethora. And depending on the functionality, the interest, and where we are using it, we could pick and choose and create our own customized color palettes for the projects that we do.

Again, tint, hue, tone and shade. So, there are a lot of colors and there is a huge variety within the color system and the color wheel helps us understand these interrelationships and helps us, you know, pick the colors, understand their potential use and also try to understand their proximity and association and interrelationships with the other colors. So going ahead with the color wheel, this is again another elaborate illustration. And here if we look at the pure color, we again see these variations. So tint, tone, shade.

And we see red over here, yellow over here and you know somewhere over here blue. And we have other color combinations which are present. So, of course, we can understand the different aspects like tint, tone and shade. But, you know, there are more important things to understand in terms of color. The color system when we look at the color wheel.

So there is dyad using two colors which are two colors apart on the wheel. There is triad using three colors equally spaced on the wheel. So like this scheme if you look at. The yellow orange over here and this blue green. They actually are a part of triad.

Then there is tetrad. which is a contrast of four or more colors on the wheel. So it helps us understand creating this system and which colors go well with the other colors on the color wheel. So there are complementary colors, there are split complementary colors and it is a very very detailed illustration which helps us understand this system. So complementary, then there is this split complementary, triads and then the tetrads.

So this is a very very good illustration to understand these broad aspects. Then trying to understand neutrals. True neutrals are black, white and grays termed achromatic meaning without color. But the interior design lexicon has expanded the meaning to include desaturated and less bright colors, particularly natural earthy colors as part of

neutrals and they are used quite extensively in interior design projects. Then color temperature and mood like I was talking about.

Each hue has its own visual temperature. Warm colors can make us actually feel physically warmer and cool colors can make us feel cooler. So there are physical as well as psychological implications on what kinds of colors we choose and then how they impact our mood. So if we look at the color wheel here, the warm colors and cool colors can be seen. So these are the warm colors, the yellows, the yellow oranges, oranges and here the blue green, blue green, violet, blue violet.

So there is an association of color temperature with our mood. And then, you know, if we try to understand the chemistry of colors and we have seen the dimensions of colors, we have tried to understand the color system. Now, moving on, if we try to see what are the effects of colors on different spaces, we can see some of the predominantly used colors and try to understand, you know, how do they impact the space and our moods. So, starting with red. It is associated with fire and blood and therefore connotes heat, force, intensity, of course also danger and therefore we use, you know, for a danger sign a lot of times red color.

When red is reduced to a tint, it becomes pink and loses some of its psychological intensity. Lighter pinks in particular are associated with femininity and delicacy. And when reduced to a shade, red becomes brown. So, we can see this entire range. Orange Red mixed with yellow produces orange.

Orange tends to produce a cheerful response, which is why it is widely used in commercial settings in interior design industry. Orange tints include beige and tan, which are popular background colours. And shades include browns. Looking at yellow, among the warm colors, yellow has the least intense impact. It is considered less aggressive than red.

It is the color of sunshine, happiness, activity, and mild stimulation. The yellow tints include creams, beiges, and light tints, which are considered pleasant background colors. Its shades include tints and browns. Then there is brown. Browns are warm, dignified, and comforting.

They can be rustic or refined. They carry positive connotations of wood, raw textiles, brick, and earth. They may also have associations with dirt and soil. Now, talking about green. Green is the warmest of the cool colors due to its yellow content.

Its association with grass and trees makes green calming and restful to the eyes. Green is the most natural color, with connotations of health and well-being. Tints of green share these characteristics in reduced intensity. Shades of green signify solidity. Now, talking about blue.

It is the coolest of the cool colors and appears restful and calm. Its associations with sky and water suggest spaciousness, simplicity and purity. So it adds to the volume. There is violet. Now violet and purple should be approached with caution as they incorporate the conflicting values of warmth and coolness, dynamism and calm.

Pale tints of violet are thought of as playful and feminine. Deeper shades of purple can be dignified mystical. So they are also in vogue and used in different ways in interior design projects. Of course, white. White is not strictly a color, but is the result of the combination of all colors.

Its absence of chromaticity makes it a symbol of purity, simplicity, clarity, cleanliness. White has also become a symbol of modernism, minimalism, and then also it helps in reflecting light because it's a light surface. It adds to the volume. And you know, a lot of people prefer white for interior design projects and interior spaces. Black, that is another non-color, the opposite of white.

Black is a strong color with implications of strength, or I would say black is a strong non-color, which has implications of strength, dignity and formality, with implications of emptiness or gloominess. The contrast of black with white can be striking. And, you know, we are going to see the case of tiny houses and compact spaces and how the contrast of black with white helps in achieving certain functionalities in compact spaces. There is grey. Grey results from the mixture of black and white or from mixtures of complementary colours.

Light greys do not have strong associations and are useful background tones for more chromatic colors. Darker greys share the characteristics of black, albeit to a lesser extent of course, and can be authoritative or ominous. So these are some of the colors and the kind of effect or association you know they have when we talk about their application

in interior spaces so when we talk about red it suggests excitement strength energy orange success, vibrance confidence, sociability yellow of course happiness, cheer, creativity Then there is green, healing, freshness, nature, talking about the cool color blue.

So it showcases peace, loyalty, more emotions that you know, the humans can relate to. Pink is seen as the color of compassion, sincerity, sophistication, sweetness. Purple is seen as the color of royalty, luxury, spirituality, ambition. Then there is brown, which is rugged and raw and rustic and, you know, dependable, simple. The non-color black, formality, you know, for dramatic effects, for sophistication.

And white is for cleanliness, simplicity, purity, and honesty. And the different colors. Permutations and combinations of what you see and more can also be achieved, and they could fulfill different functions and create different effects on the spaces they are applied to. Now, this is also a very interesting table, and it helps us understand certain materials and the color palettes associated with them, trying to classify them from very bright to very dark for this kind of gradation and understanding through this tabular format. So, anodized aluminum, white paint, plaster, or white coating.

These could be seen as very bright. Then there is brushed aluminum, and you know, there are white acoustical panels and white tiles. They can be seen as bright in terms of these categories. Then we have light birch, ash, and maple. I am talking about timber.

Pinewood, you know, new concrete, light wood fiber. These could be put here as medium. When we see this scale from very dark to very bright. Then there is mahogany, walnut, and hardwoods. We discussed these.

The light grey carpet, earthenware tiling, oak floor. These would be under the category of dark. And then red brick, worn concrete, dark grey carpet—they could be very dark. So, of course, there is a profound effect of the kind of colour we select on the space where we apply it. There is also colour perception.

And when we talk about colour perception, we talk about coloured light and apparent colours. So when we talk about coloured light, it can be created by an additive process of mixing coloured lights from different sources, with the resultant as a sum of the wavelength ranges of all the components. And then there is apparent colour. It is the resultant mix of the intrinsic colour of the object and the intrinsic colour of the light

source. So one scenario here, and then here—and then how we perceive colour and the actual colour versus the apparent colour.

Let's try to see briefly what the photometric quantities here are. And I'm just trying to showcase some of these important aspects here because when we work, you know, on the ground as part of the industry, And we have to connect to different vendors. We have to look at technical brochures. We have to look at manuals.

We should at least be aware of these important parameters and terminologies, which will come in handy when we work together. Especially focusing on green interiors, discussing lighting design, VLT, LPD, U-value, different kinds of glass, and so on. So, in an overview manner, I have just tried to present them here today. When we talk about photometric quantities, these four factors are very crucial. These are flux, intensity, illuminance, and luminance.

These are presented here very simply. When we talk about flux, it is energy per unit of time. It is usually measured in lumens. If we look here at this incandescent lamp and this discharge lamp with certain wattages associated with them, we see the amount of lumens produced. We see these kinds of numbers.

Then there is intensity, which is flux emitted in a certain direction within a solid angle, and the unit is candela. Then there is illuminance, which is very important when discussing lighting design and concepts related to daylight and artificial light. It is flux received per unit of surface. It is also called illumination, and the unit is lux; it is essentially a surface property. So, it is very important to understand illuminance, and it is presented here in a very overview manner.

Then there is luminance. Now when we talk about luminance, it's flux emitted by apparent surface in a given direction. It considers source. So it has source properties. So these are the four major photometric quantities.

And when we look at the light fixtures, we look at the technical specifications, we will come across, you know, these kinds of quantities, their mention and the kinds of units that we are talking about. So continuing with photometry, it is important to understand diffuse illuminance from the sky and, you know, some other concepts which we will see. Illuminance from the sky received on a horizontal working plane from the whole

hemisphere, excluding direct sunlight. So this is diffuse illuminance. Then there is direct lighting, which we achieve from luminaire or artificial lighting.

And then there is indirect lighting. Illumination achieved by reflection, usually from wall, ceiling surfaces. So here we see these three types. Now the quality of illumination depends on these. Color of light, color rendering, light distribution, luminance distribution, freedom from glare.

Let's see the transmission of light. And the reason we are talking about this is because there is a lot of use of glass and glazings, you know, in our interior design projects. And we have to understand important concepts like reflection, absorption, transmission, and which kind of glazing or glass is appropriate for our projects, and how the transmission of light occurs, you know, through different kinds of materials, particularly glass, which we use quite heavily in our projects. Amen. So the incident light on an object is reflected in three ways, and these are the ways which we must have heard by now, or some of us probably haven't come across them.

But yeah, these are some common concepts. So if I talk about glass, here, this direct solar radiation—some of it is reflected by the glass, some diffuse solar radiation is absorbed by the glass. Then, you know, there is a component which is re-radiated and converted into another form. And, of course, some is directly transmitted through the glass. So when we talk about glasses like translucent glass, it is a glass with the property of transmitting light diffusely.

So, ideally, reflectance, absorbance, and transmittance should be equal to 1, as per this equation. And we can pick and You know, select materials keeping these in mind. So if we want to have transparent glass, the reflection is zero. Translucent glass, like I was talking about on the previous slide, will have a component of diffusion.

If you are talking about an opaque glass or an opaque surface, the transmission will be zero. Therefore, these are the fundamental concepts. Therefore, we are talking about the physics of light so that we understand some technical aspects. So, we already see here transmission, absorption, reflection, the ideal equation, and the kinds of materials that could be selected and utilized for our projects. So, if we talk about a clear glass and a tinted glass, this is the kind of data that we are going to achieve: 100% to 40% only in tinted glass.

So, tinted or filter glass—a glass with the property to reduce transmission of light or with the property of selective color transmittance. So, we can accordingly select the kind of material that we want and what kind of lighting And what kind of lighting design we have to undergo for a project, for a kind of space, whether it's functional or artistic, or what is the purpose for which we are selecting certain material and designing light or trying to achieve a certain light. So, I was talking about some of the brochures. This one is from St.

Gawain. And there are a lot of technical brochures and specifications like this. This is something known as special architectural glass. And here, you know, this is glass—titanium blue, light blue-green. What's the code?

Coating face thickness. Here, this is like 6 mm thickness. Weight. Then there are light factors: solar radiation, shading, and these are some standards, ASHRAE. We will see the U-value, SHGC, VLT, all of these in the coming slides.

So light factors: transmission percentage, reflection, UV within solar radiation, transmission, reflectance, absorption, and so on. So these are technical standards. And these are already there for us to refer to. And it's important to do a market survey. It's important to be aware of such manuals and resources which are available for us to learn from and look at.

And we must be aware of these technical terms so that we can at least discuss them. And, of course, with practice, we can also excel at those. So you see those numbers continued here. Then there are prismatic panels. So these are very interesting unconventional choices that can be accommodated if the project demands them, and we could take advantage of this knowledge.

So prismatic panels are thin, planar sawtooth devices made of clear acrylic that are used in temperate climates to redirect or refract daylight. We see over here. So these kinds of panels are available. When used as a shading system, they reflect direct sunlight but transmit diffuse skylight. So also used as a shading system.

They can be applied in different ways in fixed or sun-tracking arrangements to facades and skylights. Then there are laser-cut panels. The laser-cut panel is a daylight-redirecting system produced by making laser cuts in a thin panel made of clear acrylic material. So these are the cuts. Then there are louvers.

Louvers are classic daylighting systems that can be applied for solar shading to protect against glare and to redirect daylight. These are the louvers, and this is no glare within this area. Then there is a light shelf. A light shelf is a classic daylighting system that is designed to shade and reflect light on its top surface and to shield direct glare from the sky. So this is the case of summer, and this is the case of winter.

The sun's angle is of course different in summer and in winters and accordingly these shelves are used. And you know, they are designed to shade and reflect light on the top surface and they shield direct glare from the sky. Then there are sun directing glasses. Concave acrylic elements stacked vertically within a double glazed unit. Redirect

Direct sunlight from all angles of incidence onto the ceiling. So this is the inside and this is the outside. So this is again an interesting choice. Then there is zenithal light guiding glass. The zenithal light guiding glass with holographic optical elements.

redirects diffuse skylight into the depth of a room. This is another very interesting choice for some interior design projects. Let's talk about LEED CI because we are talking about green interiors and let's focus on day lighting and artificial lighting because lighting is a very very significant component when we talk about interior design projects. So we are talking about IEQ, the Indoor Environment Quality Credit 8.1, which focuses on daylight. And either we could use software simulations or manual calculations or, you know, a light meter.

So daylight illuminance should be 250 lux to 5000 lux on September 21st at 9 a.m. and 3 p.m. And these are taken as base values and references for software simulations. Then there is this equation for manual calculations. I'm not telling this in too much detail.

But this can be done easily on site measurement using light meter. So there are apps actually for both Android, iOS and, you know, using a light meter. These calculations can be done on site. And I usually encourage this. And during my interior design course at IIT Roorkee, there is always an exercise which focuses on this.

So actual daylight levels on site measured by a light meter should be at least 250 lux. So this can be managed on site. There is also a prescriptive method and here We find out compliant window area and floor area for side lighting. So if this is the compliant window height, this is normally the compliant floor width.

So H to 2H. This is how it looks in plan, the floor area. H is to 2H and this is an elevation the compliant window area. So that's a sort of a prescriptive method that you know at least till 2H we could have light if we design the window in this manner. And again there are some references and tables which are already there for us to refer to.

So when we talk about windows they also have a lot of you know subsets of information so window head height sill height width bay width whether it's north south bay east west and so on whether it's on a corner so there are already some values which we could refer to when we do calculations especially for prescriptive method that we just saw now how much daylight is adequate Guideline standards give minimum light levels required for different spaces. It is recommended to provide this using daylight to minimize use of artificial lights. So we must minimize artificial lights.

That's very very important and it can be achieved through design. And through careful selection of fixtures, materials, proper orientation, proper circulation, alignment of furniture, utilizing the positioning and placement of windows. So there are also guidelines and standards which help us understand how much daylight is adequate. There is LEED-CI guideline, ASHRAE standards, NBC standards, the National Building Codes. And you know there are some recommended illuminance targets which are also there and we can refer to sources.

So for areas and activities listed over here, such as passageways which require lux levels of 40, or kitchen counters which could require up to 750. There are some standards already in place after a lot of research and validation that has been done. So good design will use daylight to provide the recommended illuminance levels during the day. That's very important if we can utilize this to the maximum possible. Now, factors affecting daylight.

So when we talk about daylight, I am essentially talking about glazing right now because it plays an important role in bringing daylight into the space. Therefore, it is very important to understand the properties of glass, particularly these three. So, U-value, which is concerned with heat gain or loss. The SHGC, the solar heat gain coefficient, which is again concerned with heat gain or loss. And then there is VLT, visual light transmittance, which is concerned with light.

So this is light, and here this is heat. So, U-value: less heat gain desired. So when I talk about U-value, we want less heat gain. Similarly, SHGC: we want less heat gain. We don't want more heat to enter.

And then there is VLT. Here, we want more daylight to come. So, we have to focus on these three and understand these technical specifications. We have to look at those specifications when we, you know, buy, procure, or decide on selecting certain materials for our projects. And we must try to focus on reducing the heat gain and maximizing the daylight.

So, if I talk about a scale from 0 to 1, We want the U-value as close to 0, SHGC as close to 0, and VLT as much as possible toward the higher side on a scale of 0 to 1. So, VLT, like I said—visual light transmittance—is a fraction of visible light transmitted through the glazing. It affects daylight and visibility. Higher VLT is better for good daylight, like we just saw.

A single-pane clear glass has a typical VLT of 85%, which is quite high. So, if I were to ask you, you know, on a scale of 5% to 50%, here, which one is the VLT that corresponds to 5% and the one that corresponds to 50%? You can take a few seconds. Here it is—very simple: 5% and 50%. So, more VLT, more daylight.

Then, of course, there are interior design guidelines for daylighting and to help us understand how can we really maximize the daylight, you know, the daylighting in the interior spaces. Light shelves can help through daylight to deeper areas of the space. We saw the light shelf. Interior layouts can affect overall access of daylight and views. Like, you know, we talked about the retail spaces and how the layout itself can be a part of the good design strategy, including visual merchandising.

Of course, whenever we talk about interior layouts, they can affect the overall access of daylight, circulation, views, overall quality of, you know, space, the experience for the users. Light colored flooring will also reflect light. Light colored finishes will reflect light better. Use interior blinds to control glare. So these are simple guidelines but very effective.

Now let's talk about artificial lighting because of course we need artificial lighting also when there is no daylight. So now there is a credit as part of LEED CI for optimizing energy performance through lighting. And when we talk about artificial lighting, we

have to think about lighting design and lighting controls in a manner that we are able to reduce the artificial lighting demand. So when we talk about lighting design, Reduce LPD, lighting power density.

I'll just show you after a few slides what exactly it is. And it has a lot of role for our interior design projects, especially when we are talking about lighting design and especially artificial lighting. So as per the LEED CI, the mandatory Norm is 10% reduction from ASHRAE 90.1 benchmark. So there is a benchmark which is set up and if we could have 10% reduction from that base value, that would be mandatory in terms of reducing the LPD.

And of course, if it is 20 to even greater than 40%, that is optional, but highly, highly commendable if we are able to do that. Lighting controls provide daylight controls for daylit areas. Provide daylight controls for 50% of lighting loads. Provide occupancy sensors for 75% of lighting loads. So we are trying to, you know, reduce artificial light.

So using occupancy sensors, many of us already must be aware by now. We use them in washrooms, you know, even at our cubicles when somebody is not occupying that space, the light would go dim or it would go completely off and, you know, things like that. So here if we look at like one inventory to help us understand suitability of lighting control application. So from good savings to no savings, this is the kind of mapping. So let's say small office, open office, which is daylit and open office interior.

Let's talk about occupancy sensors. They would provide good savings for all three cases. And if I talk about daylight dimming, it will provide good savings for these two cases, but not for this one. So we have to strategize, understand, and then implement these measures. So I was talking about LPD, lighting power density, and it's not very complicated.

It's a very simple formula to calculate LPD. So the total installed watts of lighting per unit area, watt per square foot, indicates the lighting energy consumption. So it's very crucial when we're talking about green interiors. And we're talking about lighting design. We're talking about different aspects related to lighting.

And we know it's a significant part of interior design projects. So that's the formula. So if I have to give you an example, let's say Building A has an area of 80,000 square feet

and a lighting load of 60 kilowatts. Building B has an area of 200,000 square feet with a lighting load of 120 kilowatts. Which building has the more efficient lighting design?

Of course, the answer is over here. So, we do this simple calculation, and here the value is less. So, less LPD means more efficient lighting design. So, we are trying to understand these fundamentals. Less hue value, less SHGC, more VLT, less LPD.

These are the ASHRAE 90.1 standards I mentioned a while ago. And these are the LPD values that have been put for our reference, and we can just see these already existing tables. So these are the building area types: office, gymnasium, hospital, workshop, office. School, university, and these are the LPD calculations in watt per square feet. So we can always refer to these and then do the LPD calculation in the projects we have designed or the spaces we are using, even for our houses or offices, and we can see how much the difference is from the base value and if it is significantly high.

What could be done? You know, what strategy could be implemented to reduce it so that the lighting energy consumption can be minimized? These are more tables, more sources, and we have a lot of data available to refer to, you know, against different kinds of spaces that we see over here. Hospital, performing art theater, atrium, hotel, all of that, laboratory facilities. More examples, different kinds of spaces: museum, workshops.

So when we talk about lighting power density, the factors that affect lighting power density are types of light fixtures, the total number of light fixtures, the wattage of the light fixtures, and something known as lamp efficacy. So there are different kinds of light fixtures available in the market, from compact fluorescent lamps to this kind of fluorescent tube. There is something known as T5 and T8. We have these metal halide lamps. There are halogen lamps that we come across.

Sodium vapor lamps over here, and within that, also high-pressure sodium and low-pressure sodium. Of course, there is LED, which is very, very popular and extensively used in all kinds of projects. So now we talk about lamp efficacy. All lamps consume energy to emit light. Different lamps have different lumen outputs.

So again, there is a very simple formula. Light output in lumens divided by energy input in watts. That is the efficacy. Efficacy indicates the energy efficiency of a light source. So this is a very important formula.

You know, this concept is something we will come across when we work, especially on projects that have a lot to do with lighting design. So now, again, a small example: if we were to find out which lamp is energy efficient, and there is Lamp A, it is a 20-watt lamp with 3000 lumens. Lamp B is a 40-watt lamp with 5000 lumens. So again, we just put this formula to use, and then we can see which one is more efficient. So the lamp efficacy of A is greater, and it is more energy efficient.

So I showed you some of the light fixtures in the previous slides. So these fixtures and luminaires have different efficacies. And we talk about the high-pressure sodium and lumens per watt. It is, you know, on the higher side amongst all of these, on a scale from 0 to 100. There is metal halide, there is CFL, and we see the incandescent lamps have very low efficacies.

So we are using them less and less, of course, because they are not so energy efficient. But here also, one has to see where we are utilizing these luminaires or fixtures. We cannot use high-pressure sodium lamps everywhere. So that functional aspect has to be taken care of. But LEDs and CFLs do provide, of course, a better solution compared to conventional incandescent lamps.

So here again we see some allowable luminous efficacy and this is as per Griha. And here we see the light source and the lumens per watt. So for CFL it is 50, for fluorescent 75, metal halide and high pressure sodium vapor lamp and then of course there are LEDs which are quite common and popular these days. So, we did talk about LPD and we did compare, you know, two calculations for two different buildings. But to understand LPD in a more comprehensive manner, we did talk about the factors that affect LPD and we did talk about light fixtures and wattage and efficacy.

So, then we have to consider all these aspects and then we have to apply the formula and then in watt per square feet we can calculate it in a detailed manner. So, this is one table explaining that. All light fixtures give out heat. We have been talking about this association between light and temperature, you know, also color temperature and interrelationships between all of these. So this is incandescent.

And here, if you look at heat versus light, this is the index. A lot of heat and very less light. And fluorescent, it is this number. For metal halide, it is this and this for the HPS. So, all the fixtures give out heat.

Now let's try to understand daylighting and views because they are also important when we talk about LEED CI and certain numbers while calculating the green interiors aspect for designating our projects to be green. We do consider daylighting and views. So when we talk about daylighting and views, views to the exterior matter a lot. Providing a connection to the outdoors affects overall indoor environmental quality. And indoor-outdoor relationships of a space depend on the context, the interior layout, and base building.

And there is this credit for daylight and views, like I was saying. So provide daylight in 75% or 90% of regularly occupied spaces. Achieve a direct line of sight through vision glazing for 90% of occupied spaces. We will see the visual glazing. So this is vision glazing, and here if we look at this dimension where we have the effective window or opening installed, this is the

Section which is vision glazing, and we are seeing this in elevation and this is in the section. So sitting from here, I am getting these kinds of views from the vision glazing. Determining exterior views. So there is this index that has been created to help us understand what spaces come within the LEED boundary and the ones which do not fall under it. Let me try to show a zoomed-in picture.

So this is the zoomed-in picture, and this hatched portion here is basically what is not included in the lead boundary. When we do calculations for determining the credits or the points associated with our project, we are trying to get designation for it as green interiors. So, this staircase, lifts, and other common areas. Then there are regularly occupied spaces. Cubicles and functional areas, non-regularly occupied spaces—some areas which are again not regularly occupied—and then regularly occupied spaces without views, the brown ones.

So we have to maximize the views, maximize daylighting, and provide exterior views. That's very much essential for indoor environmental quality, and it does reflect on the tally of points when the calculation is being done for the project to be considered green or not green. So this kind of demarcation and indexing helps understand the occupation of spaces and their interrelationship with exterior views, etc. So some of the factors we could see and understand under the broad umbrella of green interiors, especially focusing on lighting and color, help us understand how, as designers, we can learn from these norms and practices, technical specifications, and be informed about And we can

make responsible decisions and try to create interesting, vibrant, green interior spaces. I'm going to share this very interesting quote here, which is by the designer Victoria Hagen.

Good design is all about the light. You want to create a space that is inviting and warm, and light plays a huge part in that. Layering ambient, task, and accent lighting creates depth and dimension, enhancing the beauty of your interiors. In the next lecture, we will continue with green interiors, and we will especially focus on policies, incentives, materials, and finishes. Some of the references for today.

Like I said, it is a very comprehensive, industry-oriented, and crucial lecture. I have tried to include many books and websites for reference. Thank you so much. I'll see you next time.