Illumination Engineering and Electric Utility Services
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Lecture -14
Colour

Welcome to this course on illumination engineering and electrical utility services. This is lesson 14 which is titled as colour. So, after having brought in the need for illumination and the need for artificial sources of light and having examined various types of artificial lights and looked at what constitutes an illumination system.

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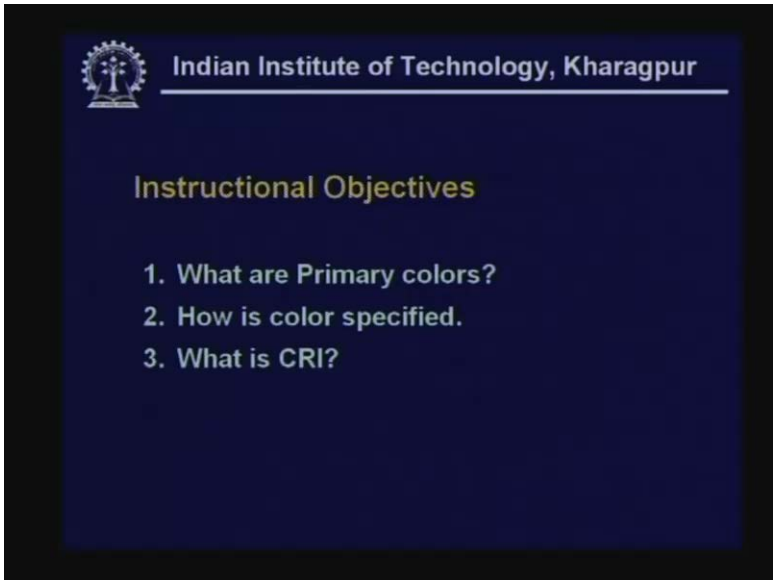

It may be appropriate to know what colour is. With that in view the objectives for this lesson may be stated as what are primary colors, how is colour specified, what is CRI. These are the three main instructional objectives which should be answered at the end of this lecture.

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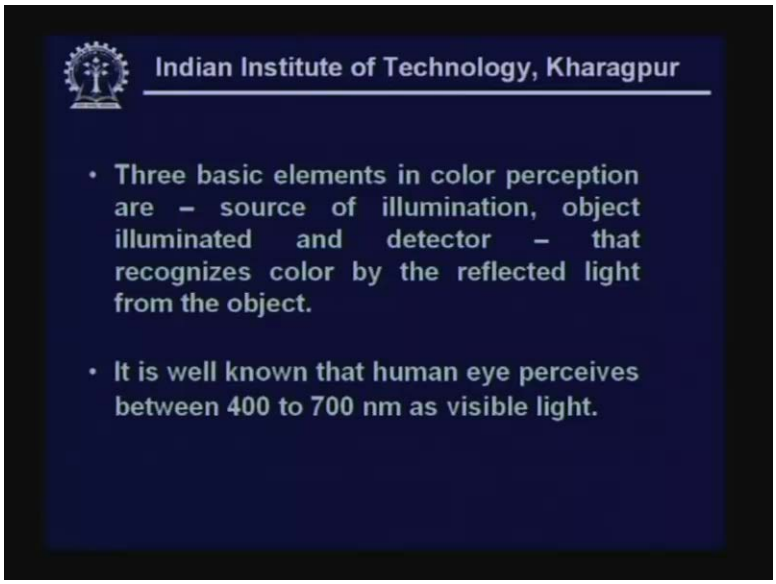

Now, recall that most of our things are made pleasant or enjoyable by virtue of the colors present and any illumination system is trying to create sense of perception to the human beings same as what exists. Therefore artificial lights should be able to create the same appearance as the natural day light does to a particular object. With this the basic elements for colour perception, colour becomes a very important thing, we talk in terms of a radiation having a colour, object having a colour and therefore it's necessary how we look into this colour. So, colour perception has three basic components, the source of illumination that is the light source, other radiance source object illuminated object obviously using the artificial light we are carrying out certain activity, there are certain objects involved.

So the need is to look at those objects. And detector, all perception of light is through our eyes therefore detector our human eyes that is we say that recognizes colour. How do we recognize the colour? We recognize the colour by the reflected light from the object. So we today try to look at what constitutes colour radiation and in trying to use a lamp, how are we going to specify colour perception ability of, colour rendering ability which we call, these are the issues which we take up. Now recall the detector which I said is a human eye has the sensitivity between 400 to 700 nanometers during our frequency wave length range where the light is visible zone. In fact recall in the first lecture where we talked about the radiation spectrum and the subsequent lectures where we discussed about the human eye ability the visible range to which eye responds is between 400 to 700 nanometers.

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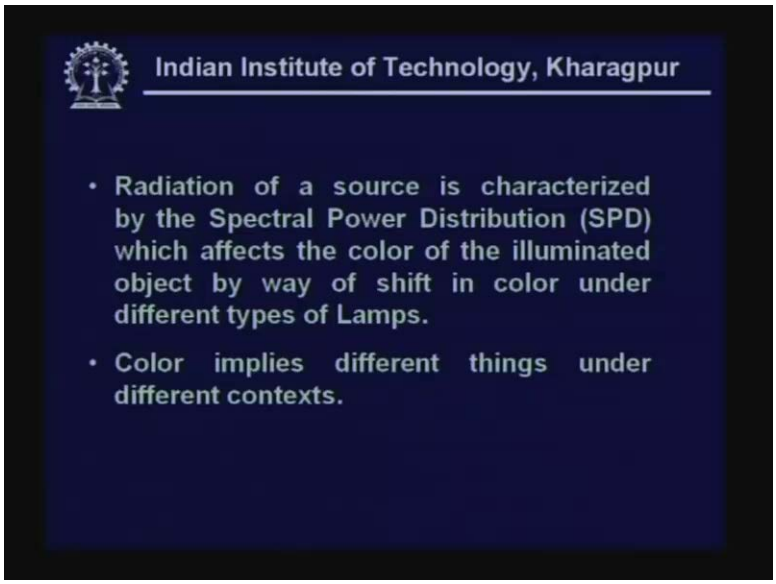

Keeping this in mind the radiation perceived is always characterized by what we call spectral power distribution. Spectral power distribution essentially means amount of light or the amount of energy available at various wave lengths. In fact when we take a natural light due to sun, we can split into various elements spread over violet to red, vibgyor spanning over 400 to 700 nanometers. Now the spectral distribution affects the object and depending on the characteristics of the object, characteristics in the sense there could be some absorption and some reflection and object colour perceived would be based on the colour that is reflected. And therefore there is a shift in colour and depending on the type of lamp. In fact when using a lamp, we try to have, see that the object appears same as it would appear under natural light conditions that is the emphasis. That being the case how do we look into these aspects let us see.

The colour could in fact mean different things under different contexts, so that as the back drop we need to look at what colour could be and how colour needs to be specified, this is the important thing. So the basic elements as already brought out are the radiation from the source which is often specified in terms of the power distribution then the object colour and thirdly the detector of the human eye, remembering that human eye responds in the visible zone between 400 to 700 nanometers.

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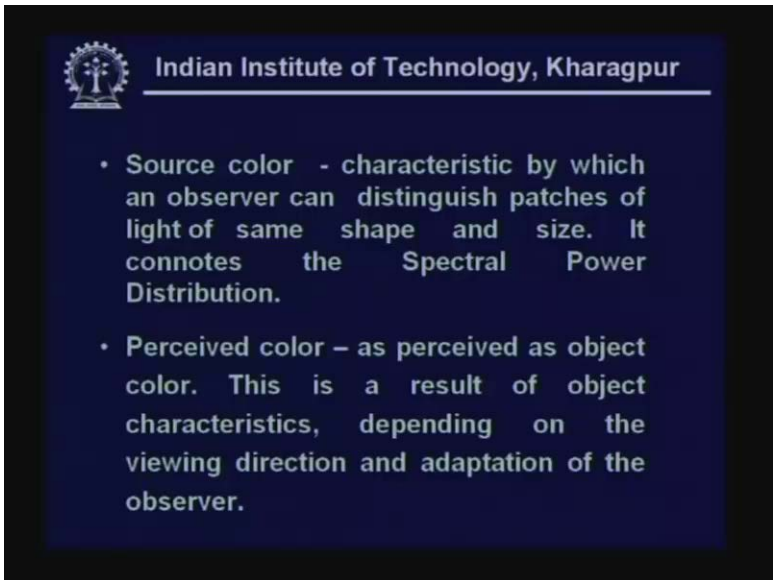

So, the source colour characteristics by which an observer can distinguish the patches of light, same shape and size is what we called the spectral power distribution. The characteristic, we said the source colour is the light radiated from the source which is often talked in terms of the spectral power distribution. This is nothing but ability of an observer to distinguish the light of same shape and size okay, that being the case then what is perceived colour. So we observed that since there are three elements, colour can mean different things under different context as already brought out. You have a source colour, object colour, a perceived colour, perceived colour is what the detector detects.

What is the detector in this case, is the human eye. The perceived colour as perceived as object colour, how does it arise? It arises as already told based on the characteristics of the object, what characteristics? The characteristics of absorption of radiation, characteristic of reflection of radiation plus the viewing direction and adaptation of the observer. So we have source colour predominantly characterized by the spectral power distribution which essentially tells us that how the light of same shape and size is different from one to the other. In fact based on the radiation distribution, we have associated certain colours to say sodium vapor discharge lamp and neon vapor lamp whereas we associate a white light with the incandescent lamp. The perceived colour therefore is the result of object characteristics together with the source light which very much depends on the viewing direction and adaptation of the observer.

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Then comes the object colour, object colour essentially is the light that is reflected and the characteristics of the object we have already mentioned which come in to play are the reflection, absorption and transmission. So whenever an object is exposed to radiation from a standard light source, the radiation that comes out, the colour is what we call as the object colour. There is some selective absorption, therefore the colour under different lights depends on the absorption ability and therefore the colour appearance depends on the light reflected. So thus these three things form the three basic issues. Then in order to examine whether illumination systems are adequate, it is necessary to the look at an index and this index is what we call as colour rendering index. It is an index which looks at how an object appears due to a radiation, okay.

Now, we looked at depending on the nature of the source it has a certain spectral power distribution which characterizes the source colour. For instance we say sodium vapor lamp has orangish colour, neon lamp has reddish colour. Then the perceived colour is of course depends on the observer because it's the detector which detects certain perceived colour depending on the object that is lit and from the angle at which the object is viewed. And the object colour is based on the properties of the object namely absorption, reflection and transmission and in order to assess ability of a lamp to function properly for absorbing objects of varying colours and to be able to distinguish the index used is called colour rendering index.

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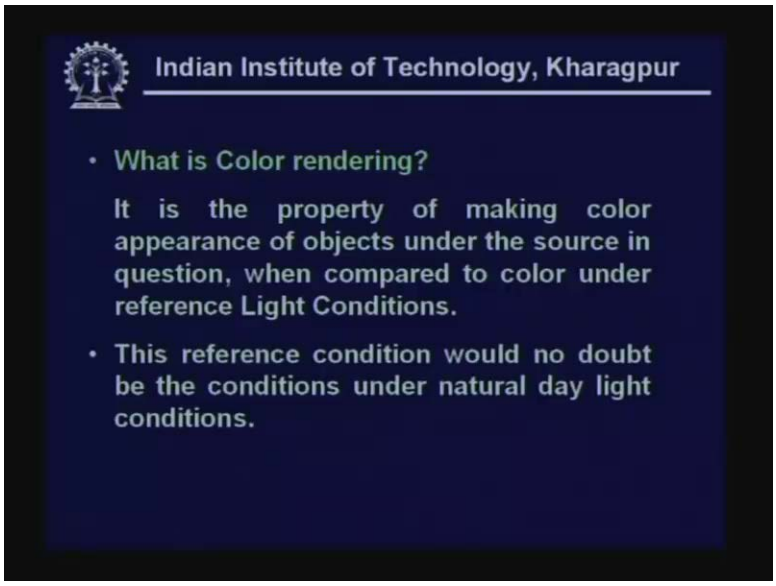

So what is colour rendering? The colour rendering is the property of making colour appearances of objects under source, under a test source namely when compared to colour, same colour under reference light conditions. So this is a property of the colour appearance obtained from the object under the test source I mean whichever source we are trying to examine or we are trying to investigate with respect to the source under reference light conditions. No doubt, the reference condition, best reference condition would be natural day light conditions. Recall the spectral power distribution due to a natural sun light and the sensitivity of the human eye are very close having their peek around yellow green.

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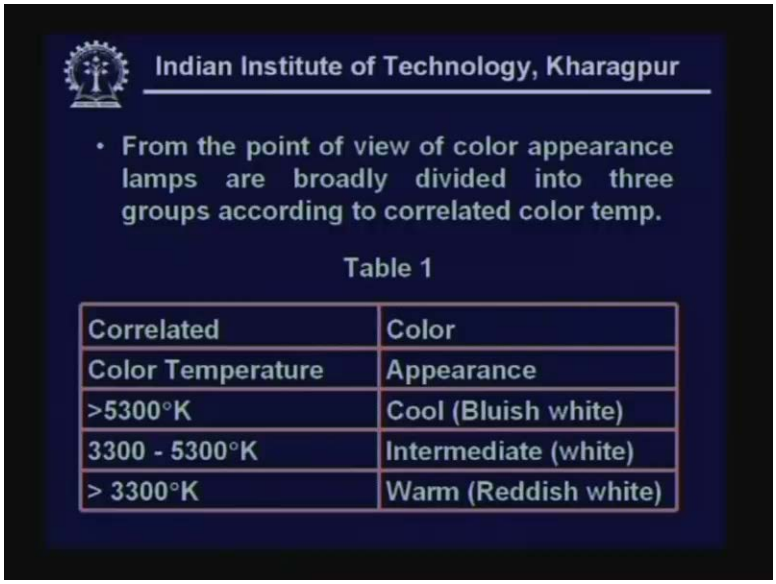

And therefore in applying any such index and trying to compare the effect of these radiations in making colour appearance, the reference conditions most suited would be natural day light conditions. From the point of view of colour appearance, the lamps are therefore divided into different groups and they are correlated according to colour temperature. Now recall the colour temperature term was introduced to talk of radiation from a lamp to be similar, if a perfect black body was heated to that temperature. That is to say if at certain temperature T is assigned as colour temperature to a source then a perfect black body raise to temperature T would naturally give out the same colour appearance as the source. So, what we are trying to say is in terms of the appearance, the source of the source colour, the varying lamps that are available are categorized correlated with colour temperature. You can see there are two columns in this table, one is the correlated colour temperature, the other is colour appearance.

So, you have the three ranges, one below 3300 degree Kelvin then greater than 5300 degree Kelvin and between 3300 to 5300 degree Kelvin and depending on the appearance they are called cool, intermediate, warm and they are termed bluish white, white, reddish white. The last one, last row it should be less than 3300 degree Kelvin. These are the correlation between the colour appearance and colour temperature. Recall colour temperature was what? Colour temperature is associated with a particular source radiation is that temperature if a perfect black body is heated would radiate similar colour radiation.

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Now, we have already emphasized that any good lighting would require good illuminance levels and we have also seen as the illuminance levels increases, the colour temperature also increases that is it is to say it should be whiter should the source be. This has already been brought in mind. Now if that is the case, what do we do to specify the colour? In fact we have seen what the basic components in specifying a colour are. The three basic components that are involved are the light itself the source colour, the object colour as it appears and the perceived colour by the observer and therefore it's appropriate to see how one is going to specify the colour.

Now one of the earliest techniques or methods was to use according to what we call Munsell system. According to Munsell system, the colour has three dimensions which are called hue, value and chroma. So we need now to look at how do we go about specifying the colour. In order to do that, we said the one of the early methods was to use Munsell system and according to this it has three dimensions that is hue, value and chroma. Now how do we go about doing?

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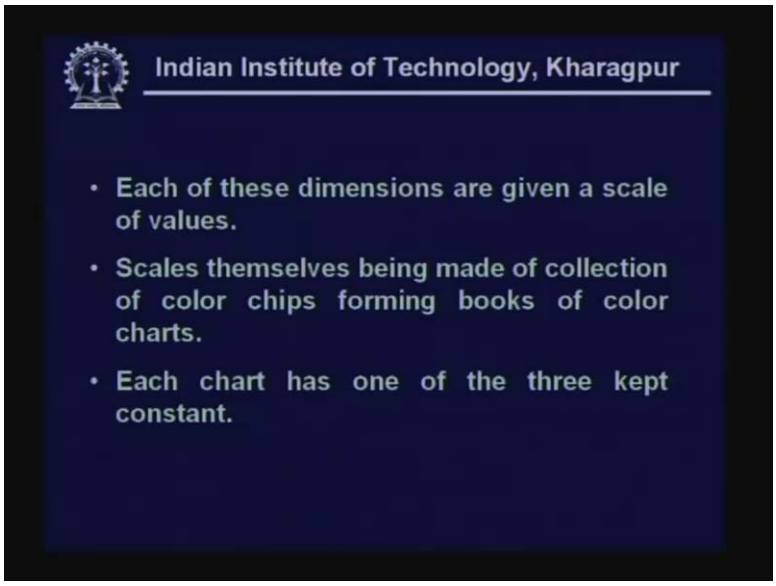

Now that is as though you have a three dimensional specification, each having what we call hue, value and chroma and each of these dimensions themselves have scale of values from a low level to a very high value. Scales could be in fact are made of collection of colour chips and form what are called as books of colour charts. So, Munsell system depends on having three dimensions that is hue, value and chroma and each of them having scales and how are these scales formed or scales taken? Scales are nothing but a collection of colour chips forming books of colour charts and when they set of charts in a particular chart, we find that one of this three is kept constant. That is to say either hue, value or chroma is kept constant. So, Munsell system which was used for specifying colours on the surfaces during day light conditions was the earliest specifying system and it had the three values that is hue, value and chroma.

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Now hue is again specified in terms of 5 principal hues, they can be broadly talked in terms of a or loosely the way we refer to colors. They have these hues, you can associate red which is specified as R, the yellow Y, green G, blue B and purple P. So you have 5 principal hues forming that is red, yellow, green, blue, purple spanning over the visible spectrum plus it also has what are called as the intermediate hues that is bordering between the two of those principal hues.

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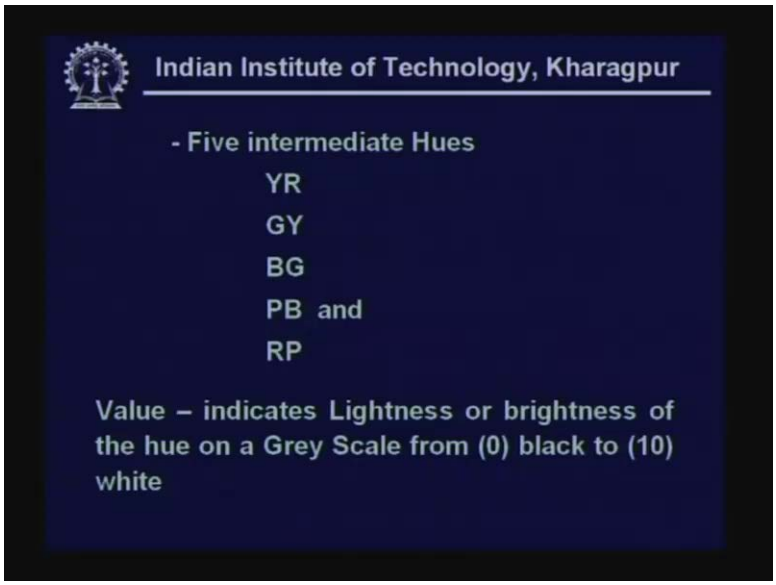

For instance YR would be in between yellow red, GY would be in between green and yellow, BG would mean between blue and green, PB would be in purple and blue and RP would be between red and P. So what do we have? We have 5 principal hues which are red, yellow, green,

blue and purple with 5 intermediate hues YR, GY, BG, PB and RB. The value, the second dimension of dimension specification indicates whether the hue considered is light or byte. It is specified on a grey scale with 0 corresponding to black, 10 corresponding to white. So a value indicates lightness or brightness of the hue on a grey scale. So, we have two of the three dimensions discussed that is hue and value. Hue had principal hues, intermediate hues and value connotes the lightness or brightness of the hue on a grey scale from 0 to 10, 0 corresponding to black, 10 to white.

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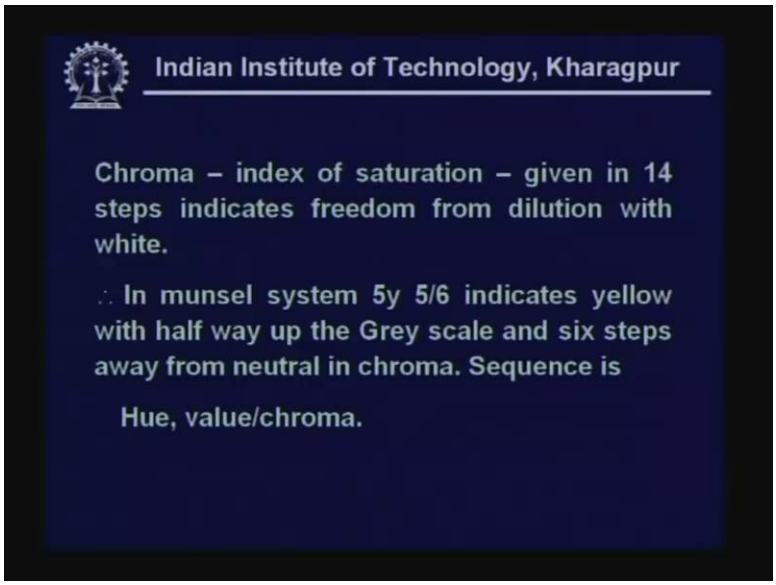

Chroma is the third dimension which is an index of saturation. So what it says, how free it is from dilution with white. One can say a mixture with white of any hue would dilute that hue, so this talks about the saturation which is normally given in 14 steps. With these, they if you have dimension chart in a book of colours specified as 5 y 5/6 indicates a yellow hue with half way of the grey scale 6 steps away from neutral in chroma. In specifying how do we do it? The first one is hue, the second term is value/chroma. So we have the hue which could be any of the principal hues or intermediate hues and then their lightness or brightness on a grey scale is indicated by the value followed by chroma which talks about the saturation. So this is what as already brought out is specified in terms of what you call the colour chips in a chart and that can be seen a typical colour chip for 5 y 5/6 can be seen here.

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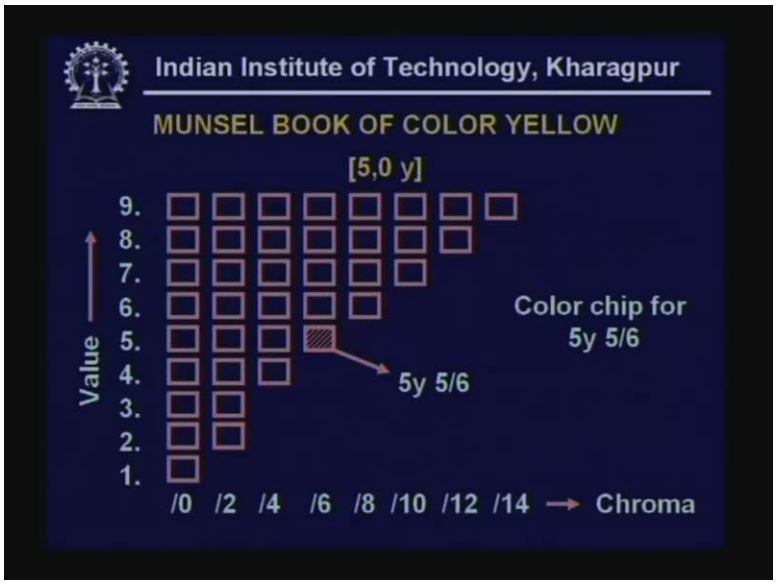

You have, this is the, what we call a book of colour, this is for yellow and you can see on the horizontal axis we have chroma marked in terms of /0 /2. We said that the saturation goes on from in steps from 0 to 14, you can say 0 2 4 6 8 10 12 14 and the value increases from the scale of 0 to 10 on the y axis. And what do we see? Consider the colour chip 5 y 5/6 is what we were talking about which is shaded, this denotes that this is a yellow hue half way up and it is 6 levels higher in chroma that is saturation. So this is one way of specifying.

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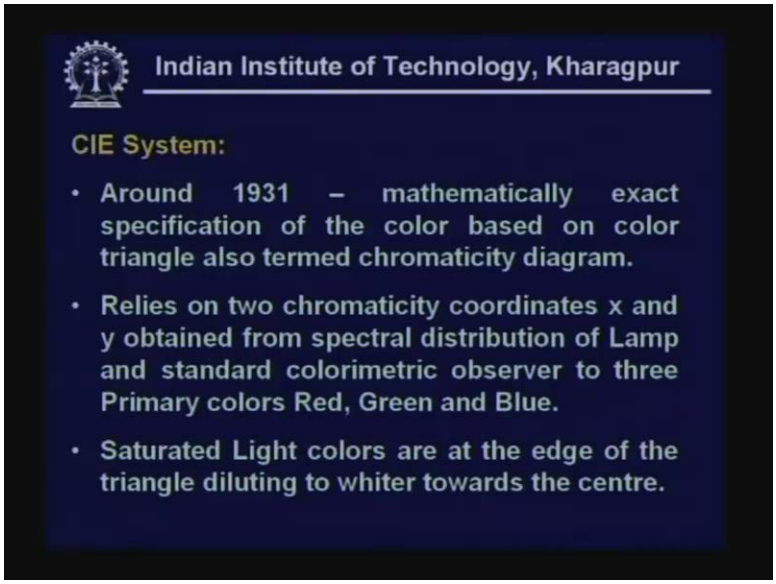

As opposed to this there is a system call CIE system, confederation of illumination engineers. They came up probably around 1930's a mathematical way of specifying colour by using what is

called as a colour triangle and this is also termed as chromaticity diagram. So, CIE system came up with a view to have mathematically exact specification of the colour based on colour triangle termed chromaticity diagram. This used what are called two chromaticity coordinates x and y. And these coordinates were obtained from the spectral distribution of the lamp then based on standard colorimetric observation to three primary colours, the primary colours spanning over the entire visible spectrum are red, green and blue. In fact we know that the most colour monitors do use this kind of a combination to arrive at the colours that are required.

The way this triangle works is that saturated colours are the edge of the triangle and they become dilute to whiter towards the center. In fact one could, the colour getting diluted means colour tending towards becoming white that's why we are talking about becoming whiter. So this is the CIE system.

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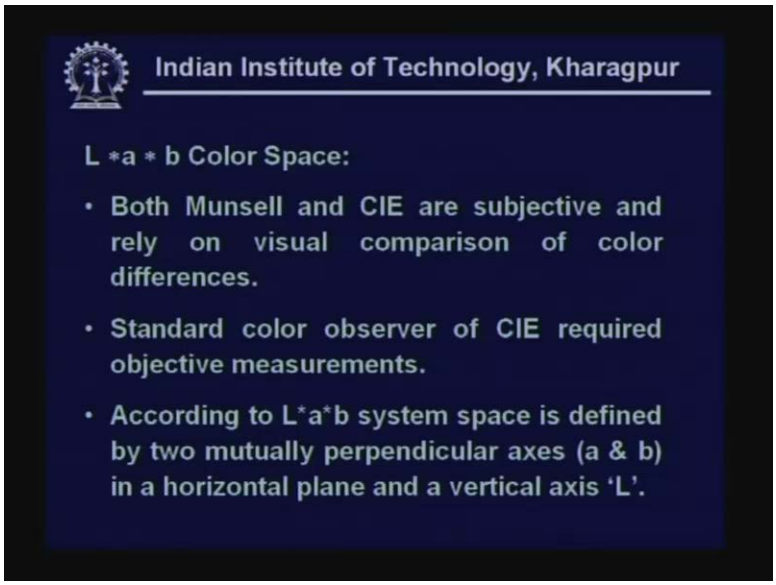

The more common system is what we call as L a b colour space. In fact L a b is what we call L a b colour system because the both Munsell and CIE are subjective and rely on visual comparison of colour differences. Why go in for another system? This is arisen essentially because both Munsell charts and CIE are subjective relying on visual comparison. So in fact a standard colour observer of CIE requires objective measurements. Now the L a b system is again takes the space where we are trying to specify the colour in terms of two mutually perpendicular axis a and b and a vertical axis L.

In some sense it is similar to Munsell system where you have three dimensions value, hue, value and chroma. Similarly you have the x n and are two perpendicular axis in the horizontal plane and a vertical axis L. So the L a b space system would have these three put together, so you have L a and b.

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In fact in this system, the way it assess the positive 'a' or the positive 'a' indicates the predominantly red content whereas a negative 'a' indicates predominantly green content. The positive 'b' indicates yellow content whereas the negative 'b' indicates blue content. So you have the hues specified in terms of the, what you call the three primary colours. Then the values along L just as in Munsell system, the value of lightness from 0 to 100 is specified. So you have 'a' and 'b' giving rise to hue and saturation whereas L gives the, what you call the value when compared to the Munsell system. So this is how a, L a b system would work.

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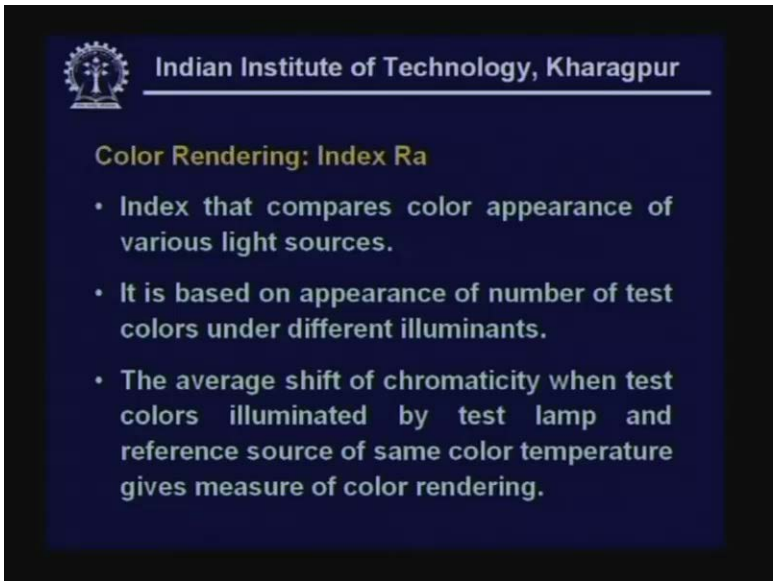

The colour rendering index we have been talking about in order to look at the lamps, it becomes necessary to talk in terms of colour rendering which we said is the appearance of the object due to that radiation when compared to the standard reference conditions which we said best would be to consider the natural day light conditions. This is the index that compares colour appearance of various light sources and it is based on appearance of number of test colours under different illuminants that is the lamps in question.

Now this is what we abbreviate as CRI in fact when the colour rendering is specified by considering the average shift when test colours illuminated by test lamp in different source, how much they shift. So if there is a shift then that says the colour rendering ability. So we expect, see in fact here we are talking about a reference source and we have already mentioned the best possible reference source would be natural day light condition.

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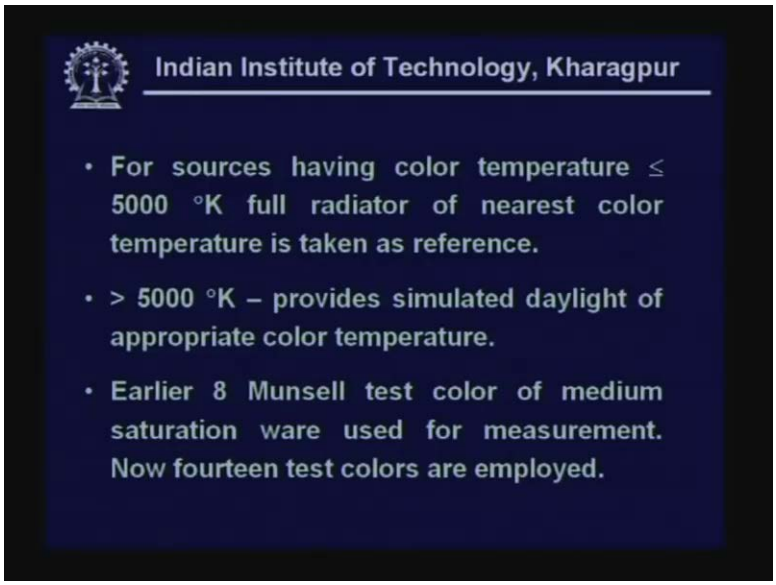

For sources having colour temperature less than 5000 degree, so for full radiator of nearest colour temperature is taken as references. In fact earlier the sources having temperatures greater than 5000 degrees, they need simulated day light of appropriate colour temperature. So here in order to use the reference, although we said best thing would be to use natural day light conditions, the sources have been classified based on the colour temperature in to two categories less than 5000 degree Kelvin and greater than 5000 degree Kelvin. So for sources having less than 5000 degree Kelvin, one can take a full radiator of nearest colour temperature as reference. For those having more than 5000 degree Kelvin, one can take a simulated day light of appropriate colour temperature.

In fact earlier 8 Munsell test colour of medium saturation were used for measurement and now 14 test colours are employed in fact recall that here test colours are placed in the test lamp as well as under the reference conditions, reference lamp and the shift in chromaticity is observed and that is specified as colour rendering. So in doing this in early days the 8 Munsell test colour of medium saturations were used but these days 14 colours test colours are employed.

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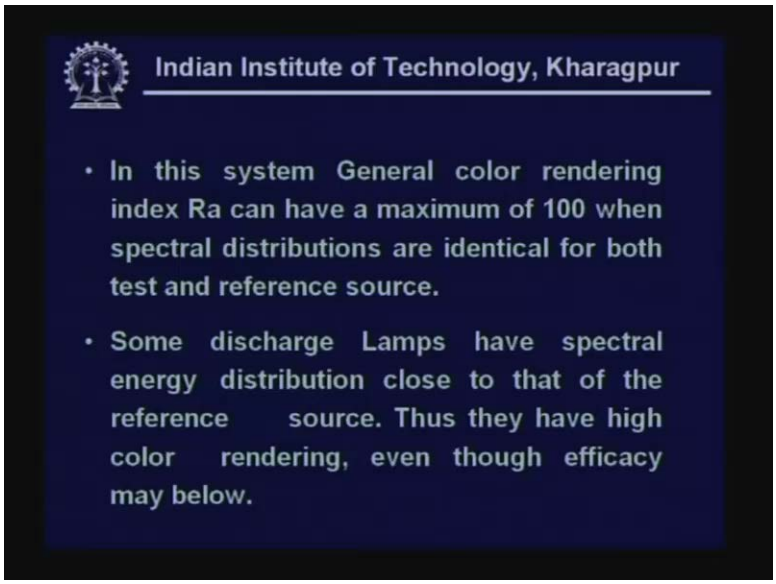

In this system in fact if you buy a lamp, you find the colour rendering specified in terms of a certain 70 80. It is believed that Ra the colour rendering index or CRI can have maximum 100. When does that have? When the spectral distributions are identical for both test and reference sources. Ra is allowed to have a maximum when the spectral distribution is identical that is for the various test colours appearance is same under reference condition as well as test lamp condition. Now in fact some discharge lamps have spectral energy distribution close to that of the reference source therefore they have high colour rendering even though efficacy may be low.

Now recall in terms of efficacy we talk in terms of a lumens per watt and we did find and the spectrum, we did find that from the point of view of efficacy and utilization the sodium vapor had higher efficacy than the mercury vapor but it's believed that mercury vapor has better colour rendering that's what we are trying to say. So this lecture in that sense has tried to see how one could look at a colour. Colour as you all of us are aware is a very important issue in terms of a, because that is how one is able to distinguish between one object and the other object and therefore what constitutes in the colour appearance of an object plays a vital role.

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The three basic components that are involved are, there are three components to the entire process and this is what we called are the source of illumination, object illuminated and detector. The source depending on the spectral power distribution is assigned a certain source colour. Recall based on this colour in fact we have the temperature classification for sources which we call colour temperature and that is obtained by considering what we call the ability of a perfect radiator to appear similar to the source. The object colour or object illuminated is a second issue leads to object colour which again depends on the characteristics of the object by way of absorption, reflection and transmission.

Then the detector obviously is the observer for whom we are trying to make the whole illumination system. It depends on the eye and recall that eye has a visible range specified spectrum over 400 to 700 nanometers and the detector leads to what we call perceived colour. So the colour although radiation may have a certain colour, the object by virtue of its own properties may radiate or reflect colour of different radiation and they could be shift. And this depends on the kind of absorption it may have which we can call as a selective absorption due to its own properties and that is what we call as a perceived colour. Now when I mean by object colour is under the natural light conditions but depending on the radiation colour it may differ.

Now this is the, this form, the form, this forms the basic colour components. Now the source colour essentially tells us what kind of a light output is available or in other words what we call spectral power distribution. Recall the diagrams we had with the wave length what is the energy that is light energy that is being radiated. The object colour depends, the appearance of the object. Now this is due to the selective absorption of certain radiation, certain wave lengths and due to the incident light and object appearance very much depends on, what? It depends on the reflected light. The perceived colour, we have already been talking about is the combination of the object characteristics together with the viewing conditions depending on the viewing conditions namely the direction and the ability of the observer.

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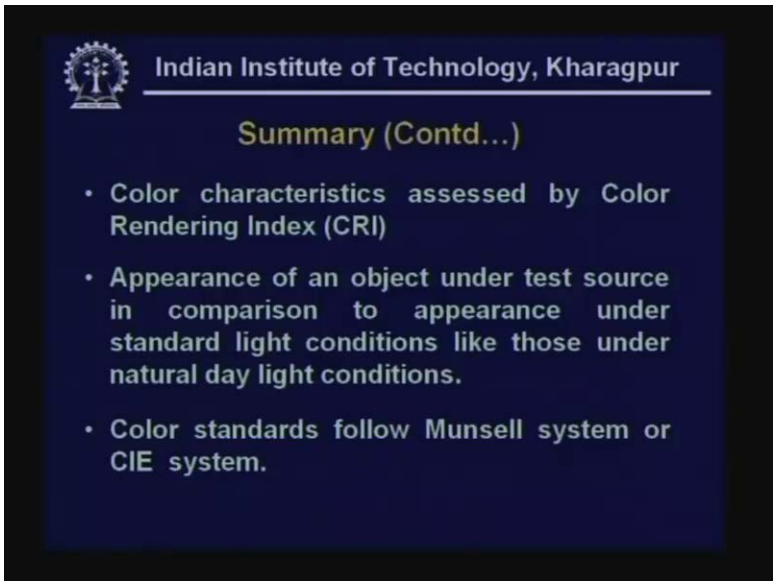

Now in order to specify this for the lamps or the sources we use an index called colour rendering index. By name or by definition it is in a index, it tells how good this source is able to retain the parent colour just as it was in reference light conditions. We have seen the most ideal reference condition would be a natural day light condition. However for accessing the CRI or Ra we have already seen depending on the class of source based on the colour temperature, one can have different types of reference sources. So, the appearance of an object under test source in comparison to appearance under standard light conditions is what we call colour rendering index. So for lamps having colour temperature greater than 5000 degree Kelvin, one could in fact have simulated day light of appropriate colour temperature in order to arrive at CRI whereas for lamps having colour temperatures below 5000, a complete radiator of nearest colour temperature is taken as reference.

I said although natural day light conditions would be preferable; it may be all right to have a radiator of this kind based on the colour temperature. In fact based on the colour temperature, the colour appearance has been classified into three categories as blue, white and red. Now the standard systems that are followed are one is a Munsell chart other is the CIE system which follows a chromaticity triangle. Munsell system is a three dimensional one where hue, value and chrome are specified and a book of colours is consisting of charts is used where there are colour chips. The value essentially talks about their level of illumination or colour intensity on a grey scale from 0 corresponding to black to 10 corresponding to white. Chrome indicates the saturation of that colour level.

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So, if this be the way to go about, what could be the tutorial questions that one may address from this lecture? The one is what are primary colours. Two, what are the various colour specification schemes? We have seen the three colour specification schemes one Munsell system, the other one is CIE system, the third is L a b space system. What are basic elements in colour specification and what is a perceived colour? Perceived colour is apparently the most important in fact when you are talking in terms of colour rendering is the perceived colour that's being talked about. What is CRI?

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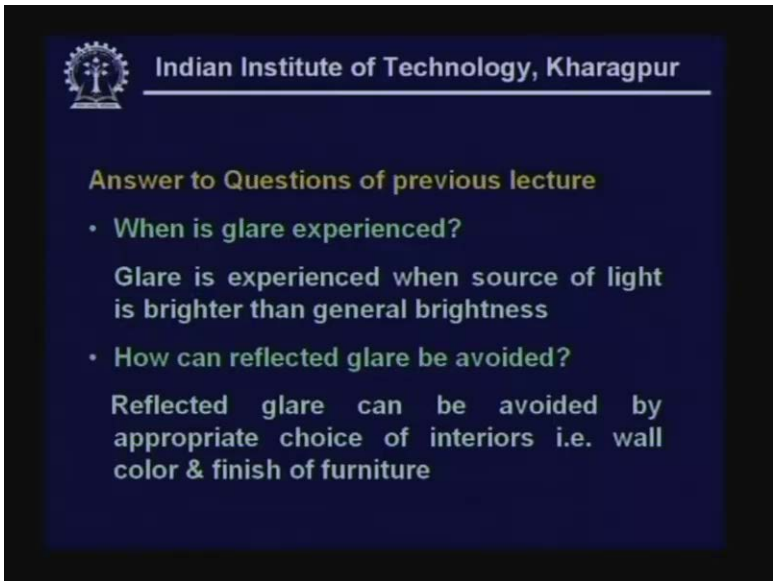

Let us take up some of the answers to questions of the earlier lecture. When is glare experienced? Glare is experienced when source of light is brighter than general brightness. So whenever a source of light is much brighter than the general brightness and is in the plane of observation then the glare is observed. How can reflected glare be avoided? The reflected glare can be avoided by appropriate choice of interiors, by appropriate choice of interiors that is wall colour and finish of furniture they, that can and by a choice of appropriate reflectance per all these sources of reflection.

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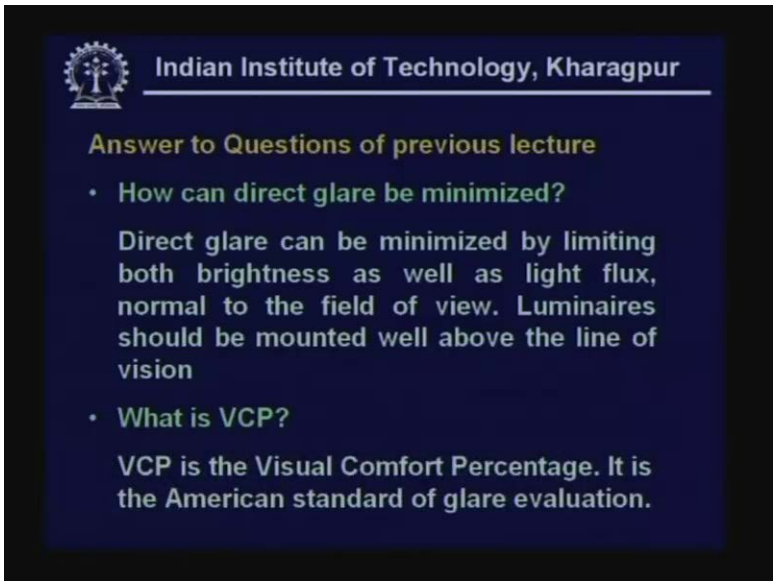

Continuing with the equations, how can direct glare be minimized? Direct glare is best minimized by limiting both brightness as well as light flux in the field of view. See the luminaries should be mounted well above the line of vision. In fact when they are mounted in the line of vision and if there is an intense source of the light that's when the glare arises. So, direct glare can be minimized by limiting both brightness as well as light flux normal to the field of view. Luminaries should be mounted well above the line of vision. What is VCP? VCP is the visual comfort percentage; it is the American standard of glare evaluation. It was discussed in the last lecture VCP stands for visual comfort percentage is the American standard glare evaluation process.

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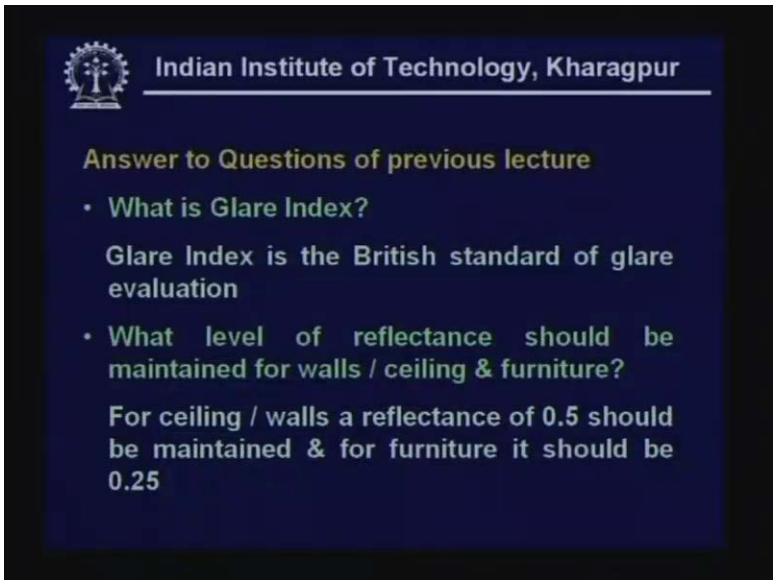

What is glare index? The glare index is the British standard of glare evaluation, we had glare index, the luminance curve system and VCP, VCP is the American reference. What level of reflection should be maintained for walls or ceiling and furniture? In fact we said in order to minimize reflected glare, the reflectance should be controlled. For ceiling or walls a reflectance of 0.5 should be maintained and for furniture it should be 0.25 that means very little of the intense light that falls on them is reflected thereby minimizing any glare in the plane of vision or work.

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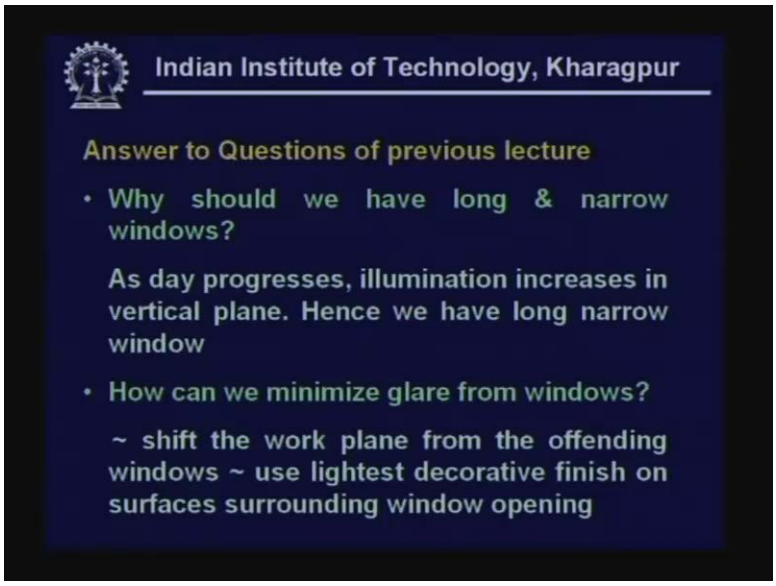

Why should we have long and narrow windows? As day progresses illumination increases in vertical plane and hence we have long narrow windows. So, we should have long and narrow windows because that again ensures that throughout the day as the sunlight moves, we do get nearly same light conditions and minimize the reflected glare. How can we minimize glare from windows? We can minimize the glare from windows by shifting the work plane from the offending windows and trying to use light decorative fittings on surfaces surrounding window openings.

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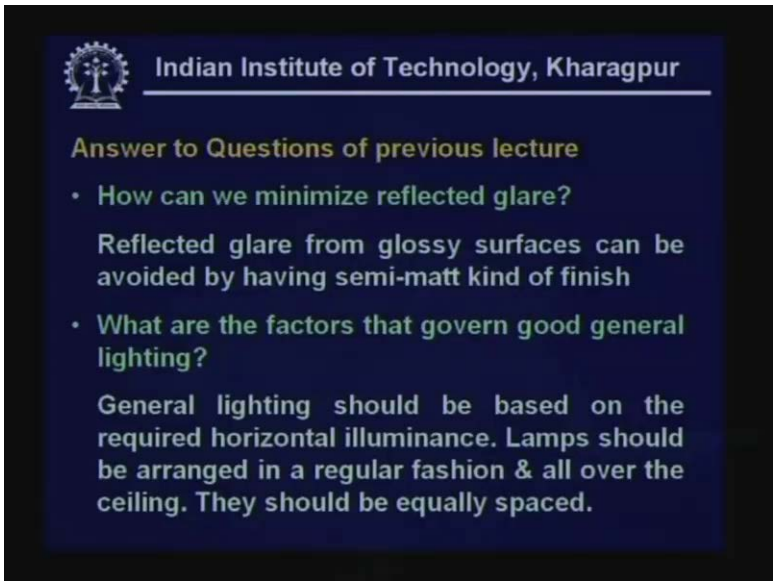

How can we minimize reflected glare? Reflected glare from glossy surfaces can be avoided by having semi matt type kind of finish. What are the factors that govern good general lighting? General lighting should be based on the required horizontal illuminance; lamps should be arranged in a regular fashion and all over the ceiling. They should be equally spaced this becomes very important because general lighting together with the local lighting enables avoiding glare to a very large extent.

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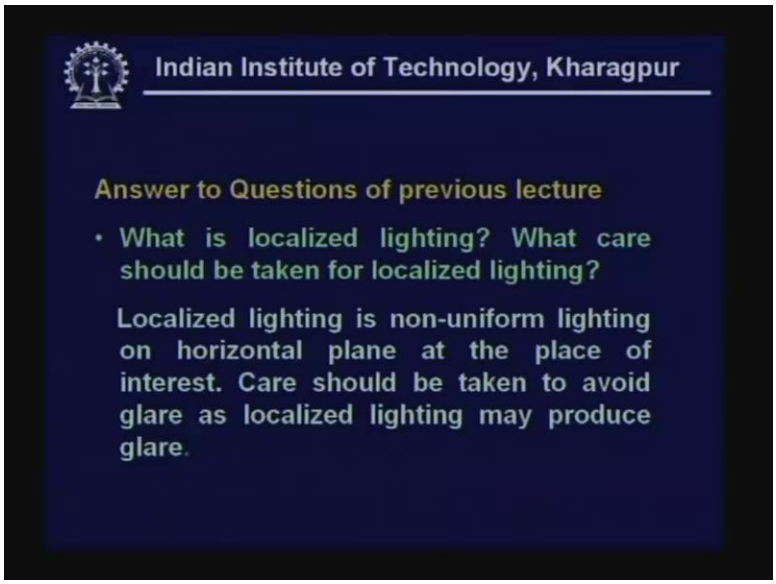

What is localized lighting, what care should be taken for localized lighting? Localized lighting is non-uniform or intense lighting on a horizontal plane at the place of interest. The care should be taken to avoid glare as localized lighting may produce some glare. Thank you.

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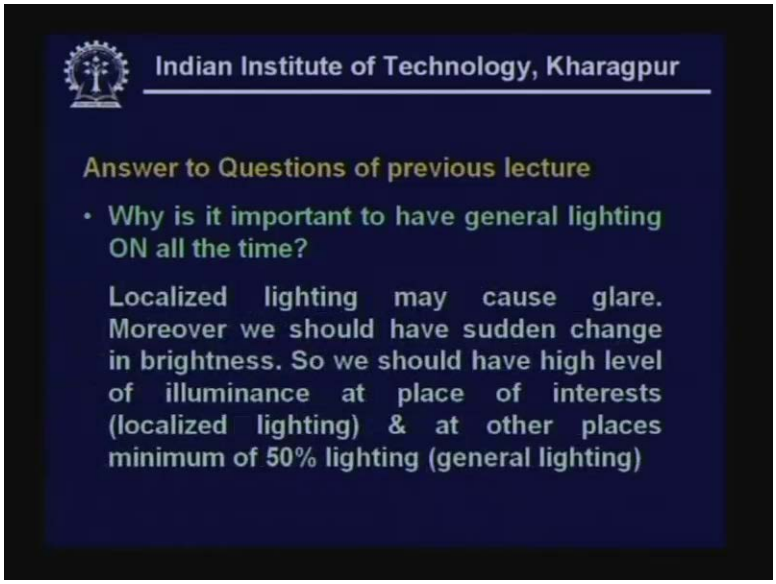

Why is it important to have general lighting on at all the time? Localized lighting may cause glare, moreover we may have sudden change in brightness. So, we should have high level of illuminance at the place of interests. The other places minimum of 50% general lighting so that there is a gradual variation and that will enable glare free observation because glare we saw can need not damage I mean at worse it damage the eye but it can cause a noise. Thank you.